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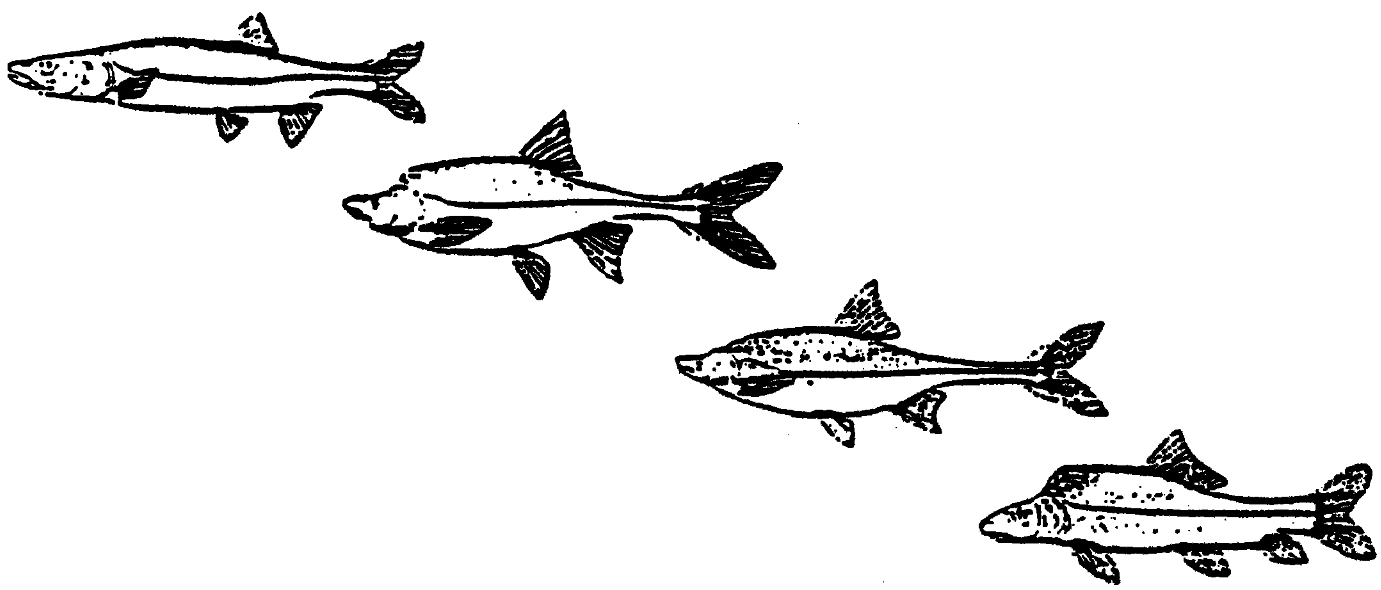
State of Colorado
Hatchery Feasibility Study
for Endangered Fishes of the
Upper Colorado River Basin

Volume II
Technical Appendices



Prepared for:

Colorado Water Conservation Board

Prepared by:

URS Consultants, Inc.
FishPro, Inc.
Bio/West, Inc.
Leonard Rice Consulting Water Engineers, Inc.

September 1993

Colorado Water Conservation Board
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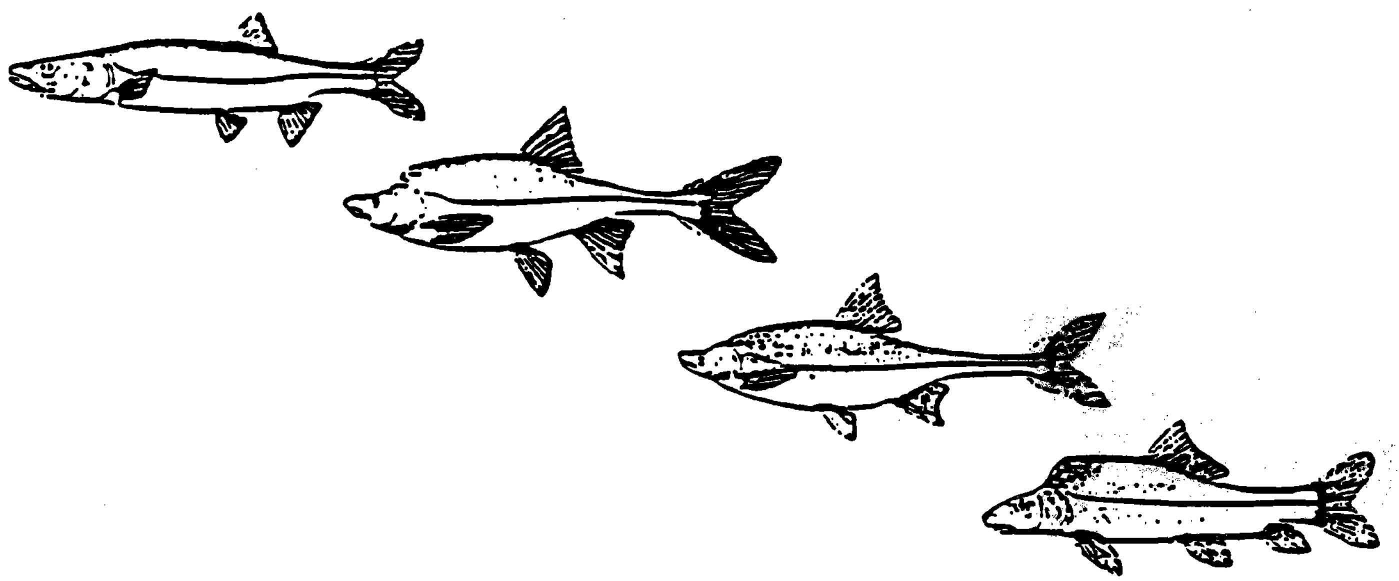

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APPENDICES

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APPENDIX A

ANNOTATED BIBLIOGRAPHY OF PERTINENT CULTURE INFORMATION ON THE COLORADO RIVER ENDANGERED FISH

REFERENCE NUMBER: 001

CITATION: Minckley, W.L., D.G. Buth, and R.L. Mayden. 1989. Origin of brood stock and allozyme variation in hatchery-reared Bonytail, an endangered North American Cyprinid Fish. Transactions of the American Fisheries Society 118(2):435-440

SPECIES AND LIFE STAGE: BT, BT_ADULT

TOPICS: Research

KEYWORDS: GENETICS, ALLOZYME VARIATION, BROOD STOCK, BONYTAIL

SUMMARY: Allozyme variation was electrophoretically examined from 45 loci in 24 F2 fish from Dexter NFH. Variation was comparable to average values recorded for other western cyprinids. No unusual morphologic abnormalities in Dexter brood stock were noted.

REFERENCE NUMBER: 002

CITATION: Ammerman, L.K., and D.C. Morizot. 1989. Biochemical genetics of endangered Colorado squawfish populations. Transactions of the American Fisheries Society 118(4):435-440.

SPECIES AND LIFE STAGE: CS, CS_ADU

TOPICS: Life history, Production, Research

KEYWORDS: GENETICS, BROOD STOCK, ELECTROPHORESIS

SUMMARY: Genetic make up of two wild populations of Colorado squawfish and two hatchery stocks were found to be very similar. One hatchery stock was derived from three females and 10 males from a group of twenty-nine wild fish collected from the upper Colorado and lower Green rivers in 1978 and 1979. The other hatchery stock was derived from one female and five males from a group of eight fish collected from the Yampa River in 1973 and 1974.

Vertical starch gel electrophoresis was conducted on muscle, liver, fin and brain-eye tissues by the Siciliano and Shaw (1976) method. At least 9 of 44 identified loci were polymorphic. Five of these 9 can be identified from fin tissue which can be taken non-lethally. Heterozygosities were high (2.6 - 5.3%), and polymorphic loci were also high (9.1 - 13.6%) as compared to a congener (Sacramento squawfish 4.2%). The Dexter stock from the Green and Colorado rivers has gained an allele not detected, but probably present in low frequencies in natural populations. Four other loci exhibited allelic variation in two or more populations. Deviation of two loci from expected Hardy-Weinberg proportions existed in the Green River population and suggest reduced gene flow between localities. "Greater divergence may be seen after several more generations of breeding in these captive populations unless such variability is preserved by carefully designed breeding programs."

REFERENCE NUMBER: 003

CITATION: Hamman, R.L. 1989. Survival of Colorado squawfish cultured in earthen ponds. Progressive Fish-Culturist 51(1):27-29.

SPECIES AND LIFE STAGE: CS, CS_LAR, CS_JUV, CS_ADU

TOPICS: Production, Culture techniques, Diet, Life History

KEYWORDS: SPAWNING, REARING, DIET, PONDS, FECUNDITY, CLAM SHRIMP

SUMMARY: Swim-up fry and fingerling Colorado squawfish were reared in earthen ponds. Ponds averaged 3 feet in depth and 0.89-0.98 acre (fry) and 0.98-1.08 acre (fingerling). Fry were stocked 105,316 - 137,438 per acre in each of three ponds. Fry at stocking averaged 95,340 -104,420 fish per pound. Fingerlings were stocked 52,978 - 55,424 per acre in each of two ponds. At stocking fingerlings ranged from 980 - 1088 fish per pound. Fry were feed commercial trout feed at an undetermined rate as a supplement to natural plankton. Fingerlings were feed #1 and #2 granules at 5.0% of body weight daily from time of stocking. Fry survival at 50 days averaged 32.8% . Fingerling survival at 88 days averaged 92.7%. Twenty-five females from the 1974 Dexter National Fish Hatchery stock were induced to spawn by injection of acetone-dried carp pituitary. Average weight was 4.7 lb, and mean fecundity was 82,576 eggs.

Ponds used for swim-up fry were fertilized 10 days prior to stocking with alfalfa pellets (300 lb/acre) and superphosphate (50 lb/acre). Rotifers and cladocerans were present in ponds. Clam shrimp *Cyzicus sp.* occurred in ponds creating excessive turbidity. This crustacean was controlled with Masoten (trichlorfon) at 0.25 ppm three days prior to stocking of fry. This affected plankton populations and contributed to low percent survival of these fish.

REFERENCE NUMBER: 004

CITATION: Hamman, R.L. 1982b. Spawning and culture of humpback chub. Progressive Fish-Culturist 44(4):213-216

SPECIES AND LIFE STAGE: HB, HB_EGG, HB_LAR, HB_ADULT

TOPICS: Production, Culture Techniques, Temperature, Life History

KEYWORDS: SPAWNING, BROOD STOCK, TEMPERATURE

SUMMARY: Humpback chub were spawned and cultured at Willow Beach National Fish Hatchery. Seventeen wild females ovulated after injection with 4 mg acetone-dried carp pituitary per kilogram of fish. Eight females were stripped manually, whereas the remaining nine injected females spawned naturally in a trout raceway. Mean fecundity of the eight females was 2,523.

Incubation periods ranged from 102 to 146 h at water temperatures of 21-22 C, 115-160 h at 19-20 C, 167-266 h at 16-17 C, and 304 to 475 h at 12-13 C. Egg survival rates were 79% at 21-22 C, 84% at 19-20 C, 62% at 16-17 C, and 12% at 12-13 C. Survival rates of swim-up fry were 99% at 21-22 C, 95% at 19-20 C, 91% at 16-17 C, and 15% at 12-13 C. The length of fry placed in raceways had doubled by 21 to 28 days, and fingerlings had attained a range of 36.9 to 47.5 mm and 586.5 to 887.4 mg by day 56 after hatching.

REFERENCE NUMBER: 005

CITATION: Hamman, R.L. 1982a. Induced spawning and culture of bonytail chub. Progressive Fish-Culturist 44(4): 201-203.

SPECIES AND LIFE STAGE: BT, BT_EGG, BT_LAR, BT_ADU

TOPICS: Life History, Disease, Production, Culture techniques, Water Quality, Temperature, Diet

KEYWORDS: ARTIFICIAL SPAWNING, EGG INCUBATION, REARING, DIET, PARASITISM, ICTHOPHTHIRUS, DISEASE TREATMENT, LARVAE SURVIVAL

SUMMARY: Brood stock were collected form Lake Mohave 1979 - 1981. Total lengths of 6 females ranged from 487 - 564 mm, weight ranged from 956 - 1,500 g. Males ranged from 454 - 480 mm TL, and 728 - 870 g in weight. Females were induced to spawn with intraperitoneal injections of 4 mg acetone-dried carp pituitary per kilogram of body weight. Five of the 6 females ovulated after 18 - 20 h. Fish were anesthetized prior to injections, and held in 20 -21°C flow-through tanks. Mean fecundity was 25,090 eggs or 21,514 eggs/kg body weight. When slight pressure expelled eggs, they were collected in plastic pans. Milt from 1 male was mixed with sperm diluent (12,000 mg/L) and added to the eggs, which were then stirred and washed for 45 min. Water hardening took place for 50 min, then eggs were placed on screen trays (1.4 mm hardware cloth) and tilted 30° to incoming water.

Eggs were maintained in flowing systems (7.5 L/min) at three temperatures. Eggs at 20 -21°C hatched after 99 -174 h with 90% survival. Eggs held at 16 - 17°C hatched after 170 - 269 h with 55% survival. Eggs held at 12 -13°C hatched after 334 - 498 h with 4% survival. Larvae in each case emerged 6.8 mm TL, and began swimming to the surface 48 -120 h after hatching. Optimum temperature for reproduction is 20 - 21°C. Eggs in cold water suffered 96% mortality.

Fry were transferred after swim-up to lightly fertilized (ammonium phosphate and trout starter) circulating raceways 30 x 2.4 x 1.2 m. Fry swam in schools and fed on zooplankton for 21 days after which they were fed commercial trout starter (0.25 - 0.5 kg/day 4 - 5 times per day). By 28 days mean TL was 18.1 mm, and after 70 days 49.5 mm, 97.5 g. Survival after 70 d was 71%.

Water temp in raceways varied from 12.8 - 24.4°C, carbon dioxide from 1.8 - 4.4 mg/L, ammonia nitrogen from 0.01 -0.81 mg/L, dissolved oxygen from 7.6 - 10.0 mg/L and pH from 7.8 to 9.0 units. On day 42 *Icthophthirus multifilis* was found on two dead fish. Three treatments on alternate days of formalin at 15 mg/L were used. Weekly prophylactic treatments were continued.

REFERENCE NUMBER: 006

CITATION: Hamman, R.L. 1981a. Spawning and culture of Colorado squawfish in raceways. Progressive Fish-Culturist. 43(4):173-177.

SPECIES AND LIFE STAGE: CS, CS_ADU, CS_EGG, CS_LAR

TOPICS: Life History, Production, Culture Techniques, Temp, Diet, Water Quality

KEYWORDS: COLORADO SQUAWFISH, BROODSTOCK, ARTIFICIAL SPAWNING, NATURAL SPAWNING, SUBSTRATE, FECUNDITY, PH, DISSOLVED OXYGEN, AMMONIA, OVERCROWDING, TEMPERATURE FLUCTUATION

SUMMARY: Brood stock consisting of 13 wild adults from the Colorado River between Grand Junction, Colorado and Moab, Utah and 14 wild adults from the Green River between Ouray and Jensen, Utah and two groups of hatchery reared fish were spawned at Dexter National Fish Hatchery by several different techniques. One group of wild fish were allowed to spawn naturally in a concrete raceway over substrate of boulders (30 - 40 cm) and cobble (4 - 10 cm) water depth ranged from 10 - 76 cm. Five wild females were injected with acetone-dried carp pituitary (40 mg) in a solution of oxytetracycline hydrochloride (10 ml) and allowed to spawn un-aided in a raceway with similar substrate. Thirty-nine hatchery reared females were injected at 4 mg/kg body weight and 39 were injected at 8 mg/kg body weight. When eggs could be expressed these fish were anesthetized and were stripped into plastic pans. Water diluted milt from four males was added to these eggs which were then stirred for 45 min and water hardened for 50 min. Eggs were poured onto 53 x 53 cm trays covered with 1.4 mm mesh hardware cloth and angled 30° to an 8 l/min flow and incubated at 20-21°C or 12-13°C.

Males began acquiring small tubercles on head, operculars and fins in late April at 15°C and had fully developed milt by June at 20°C. Females showed no spawning characteristics until June. Fecundity and survival of fry varied greatly among the treatments. Wild uninjected females averaged 25,000 eggs from which 7,500 fry were hatched. Hatching began at 96 h and took place over 48 h. Larvae were 6.5 - 7.0 mm TL. Fecundity of injected wild stock averaged 55,000 eggs from which 32,500 hatched naturally and 4,500 of 5,000 eggs incubated as described above were hatched. Hatching began in the raceway at 90 h (22 - 24°C) and was complete 40 h later, hatching in trays began at 90 h and was complete 30 h later (20 - 21°C). All larvae ranged from 6.5 - 7.5 mm TL. Hatchery females ovulated about 24 h after one injection and produced 78,540 eggs or 10,542 eggs per kilogram of body weight. Survival however was low, 2,000 eggs (3%) hatched. Eggs incubated at 20 - 21°C began hatching at 96 h and were complete 25 h later, eggs incubated at 12 - 13°C began hatching at 145 h and were complete 35 h later. No difference in egg fertility or fry survival was noted between the two water temperatures. Fry were reared in previously fertilized recirculating systems held at 23 - 24°C. Occasional temperature drops of 10°over 10 min were tolerated by the fish. Also an oxygen depletion from 9.9 mg/L down to 1.5 mg/L occurred causing only 60 mortalities.

Injection of wild fish and subsequent spawning over natural substrate in a raceway was superior in egg production and hatching success. Uninjected wild females had 30% hatching success, injected wild females had 67% success and artificially spawned hatchery females had 3% hatching success. Fish were able to endure variable culture conditions including low dissolved oxygen (1.5 mg/L), high ammonia nitrogen (2.0 mg/L), high carbon dioxide (15.0 mg/L), high pH (9.0).

REFERENCE NUMBER: 007

CITATION: Hamman, R.L. 1981b. Hybridization of three species of chub in a hatchery. Progressive Fish-Culturist 43(3):140-141.

SPECIES AND LIFE STAGE: BT, BT_ADU, BT_EGG, BT_LAR, HB, HB_ADU

TOPICS: Life History, Production, Culture Techniques, Temperature, Diet, Research

KEYWORDS: BONYTAIL, HUMPBACK CHUB, ROUNDTAIL CHUB, HYBRIDIZATION, SPAWNING, FEEDS, FECUNDITY, EGG DIAMETER, HATCHING TEMPERATURE

SUMMARY: Five bonytail females from Lake Mohave were crossed with roundtail and humpback chub males at Willow Beach National Fish Hatchery in 1980. Adults were held in concrete tanks with recirculating systems. Water was heated to 20 - 21°C by a liquid propane gas water heater (45,000 BTU/h) and pumped at 132 l/min from one tank to another, return flow was by gravity. Substrate consisting of 50 - 75 mm cobble was placed in the upper portion of the raceway. Cobble substrate was not used for natural spawning by the fish. Fish were injected with acetone-dried carp pituitary mixed with distilled water (40 mg/10 ml for bonytail x roundtail) or oxytetracycline hydrochloride (40 mg/10 ml for bonytail x humpback). Males of each species produced milt of low viscosity after two injections 24 h apart. One bonytail female was ripe when captured and was not injected, the other females all became ripe after one injection. Upon ripening, females were anesthetized with tricaine methanesulfonate (1:20,000), wiped dry, and stripped into plastic pans. Milt from three or four males was added with water and the eggs were stirred for 60 min. Some clumping occurred. Eggs were placed on screen trays covered with 1.4 mm hardware cloth angled 30° to an 8 l/min flow at either 13 or 20°C. After hatching fry were placed in cages (1x1x1m covered with 0.5 mm saran filter) in an outside recirculating raceway and fed a starter trout diet and the natural zooplankton present in the tank.

Bonytail x roundtail (three females eight males): Eggs (7216) from the uninjected bonytail were not fertile. Injected females produced 15,862 and 20,806 eggs each. Egg diameter was 1.5 - 2.0 mm and the volume was 103 eggs/ml. Eggs incubated at 13°C developed very slowly. Embryos formed by 96 h but died after 110 h. Eggs incubated at 20°C hatched by 86 h and were completed by 95 h. Larvae averaged 5.5 - 6.5 mm TL. All fry were swimming by 96 h after hatching and averaged 6.5 - 7.5 mm TL. After 16 days these bonytail x roundtail hybrids averaged 12 -13 mm TL.

Bonytail x humpback chub (two females five males): Eggs from the one bonytail female stripped were 1.5 - 2.0 mm in diameter and 103 eggs/ml in volume. Fecundity was 22,660. Fertilization was as described above. Eggs incubated at 12°C failed to hatch, embryos formed by 96 h but died after 110 h. Eggs incubated at 21°C began hatching at 101 h, and were complete by 172 h. Yolk sacs were absorbed by 96 h after hatching and all fry were swimming by 120 h. Fry averaged 6.5 -7.5 mm TL. These hybrids reached 13 - 14 mm TL in 15 days.

Progeny from each of these crosses persisted for at least seven months and were transferred to Dexter National Fish Hatchery. The combinations of bonytail and roundtail and bonytail and humpback failed to spawn naturally despite their simultaneous sexual maturity and the presence of seemingly suitable spawning substrate. Embryos in eggs from both crosses incubated at 12 - 13°C failed to survive to hatching. Death of embryos at lower temperatures suggests one cause for the decline of such endangered species -- eggs may not survive the low water temperature characteristic of the upper Colorado River basin.

REFERENCE NUMBER: 008

CITATION: Muth, R.T., T.P. Nesler, and A.F. Wasowicz. 1988. Marking cyprinid larvae with tetracycline. American Fisheries Society Symposium. 89 - 95.

SPECIES AND LIFE STAGE: CS, CS_LAR

TOPICS: Research, Life History

KEYWORDS: COLORADO SQUAWFISH, PROTOLARVAE, LARVAE, TETRACYCLINE, OTOLITH, MARKING, PRESERVATIVES, TL

SUMMARY: Four day old Colorado squawfish protolarvae were exposed to different concentrations of tetracycline hydrochloride over differing lengths of time in an attempt to identify effective marking techniques. Fish were held in 20° flowing well water troughs and fed live *Artemia* sp. nauplii and Tetra Min Fry Diet twice daily. Photoperiod was adjusted to 9-h light:15-h dark at an intensity of 100 lx. At the beginning of this investigation larvae were in swim-up stage and had 50 - 70% of their yolk sacs remaining. Total lengths were between 7.5 and 8.0 mm.

Exposure times for the different concentrations were 4, 12, and 36 h. Concentration levels were 200, 350, or 500 mg tetracycline hydrochloride (TC) per liter aerated distilled water. Distilled water was used as the diluent since TC binds to calcium. The pH for each test solution was adjusted from 3.6 to 6.8-7.o with tris buffer. Dead larvae were collected after each treatment and survival rates were calculated. Ten living larvae were sacrificed from each treatment group immediately after exposure and at weekly intervals after that. Two preservation fluids (95% ethanol and 3% formalin) were used to evaluate their effects on mark retention.

Colorado squawfish mortality at durations of 36 h was high (71-100%) for all concentration levels of TC. Exposures of this duration are not recommended. Mortalities in the 500 mg TC solution at 4 h were 16% and at 12 h, 24% . Mortalities were minimal in lower concentration of TC. Exposure to TC had no obvious effects on fish development or behavior. Pale yellow external fluorescence was visible for 15 days following any TC exposure. This was most evident in the yolk and gut regions. Fish preserved in ethanol showed this fluorescence more on the dorsoanterior tip of the preopercal bone (not apparent in formalin preserved samples). Otoliths of fish preserved in formalin either disintegrated during storage or were thin transparent crumbly disks unsuitable for microscopic examination. Otoliths from fish preserved in ethanol retained fluorescent yellow bands throughout the 77 days of the study. Overall mark intensity was higher for the 350 and 500 mg/l treatments and increased in intensity with exposure time in all concentrations. The optimal survival and mark intensity is achieved by immersing larvae in 350 mg TC/L for 4 - 12 hours. Samples should be preserved in 95% ethanol with pH 8.0 even though some body desiccation occurs. Mark intensity did not seem to decline after exposure to white light. It is assumed that these marks may remain detectable for several years (5-6 years in Kokanee in Lake Granby).

REFERENCE NUMBER: 009

CITATION: Muth, R.T., and T.P. Nesler. 1989. Marking Colorado squawfish embryos and newly hatched larvae with tetracycline. Southwestern Naturalist 34(3):432-436.

SPECIES AND LIFE STAGE: CS, CS_LARVAE

TOPICS: Culture Techniques, Research

KEYWORDS: COLORADO SQUAWFISH, MARKING, TETRACYCLINE, REARING

SUMMARY: Techniques were developed for mass marking 5-day-old larvae of Colorado squawfish by incorporation of tetracycline hydrochloride (TC) in otoliths though immersion in TC solutions. Best results were found when 5-day-old squawfish were immersed 4 to 12 h in a solution of 350 mg TC/L. TC was retained for at least 77 days after treatment.

Colorado squawfish eggs were obtained from Dexter Hatchery. Eggs were immersed in a 0.2% solution of formalin for about 20 min to treat against fungal infections. Six days after hatching larvae were fed twice daily with live <u>Artemia</u> nauplii and Tetra Min Fry diet.

REFERENCE NUMBER: 010

CITATION: Pimentel, R. and R.V. Bulkley. 1983. Concentrations of total dissolved solids preferred or avoided by endangered Colorado River fishes. Transactions of the American Fisheries Society 112(5):595-600.

SPECIES AND LIFE STAGE: HB, HB_JUV, BT, BT_JUV, CS, CS_JUV

TOPICS: Water Quality, Research

KEYWORDS: COLORADO SQUAWFISH, HUMPBACK CHUB, BONYTAIL, TOTAL DISSOLVED SOLIDS

SUMMARY: Juvenile (age 0-1) Colorado squawfish, humpback chub and bonytail chub were subjected to a gradient of total dissolved solid (TDS) to determine the concentrations they preferred and avoided.

SPECIES	TDS (mg/l) Preferred	TDS (mg/l) Avoided
C. Squawfish	560-1150	4400
Humpback Ch.	1000-2500	5100
Bonytail Ch.	4100-4700	<560 and >6600

REFERENCE NUMBER: 011

CITATION: Bulkley, R.V., and R. Pimentel. 1983. Temperature preference and avoidance by razorback suckers. Transactions of the American Fisheries Society 112(5):601-607.

SPECIES AND LIFE STAGE: RZ, RZ_ADULT

TOPICS: Temperature, Research

KEYWORDS: RAZORBACK SUCKER, TEMPERATURE PREFERENCE, TEMPERATURE AVOIDANCE

SUMMARY: Final thermal preferendum and estimates of upper and lower avoidance temperatures were estimated for razorback suckers using an electronic shuttlebox. Final thermal preferendum ranged from 22.9 to 24.8 °C. Estimates of upper and lower avoidance temperature ranged from 27.4 to 31.6 °C and from 8.0 to 14.7 °C respectively.

REFERENCE NUMBER: 012

CITATION: Hamman, R.L. 1987. Survival of razorback suckers cultured in earthen ponds. Progressive Fish-Culturist. 49(2):138-140.

SPECIES AND LIFE STAGE: RZ, RZ_LAR

TOPICS: Production, Culture Techniques, Diet, Temperature

KEYWORDS: RAZORBACK SUCKER, FEEDS, EARTHEN PONDS, FERTILIZER, STOCKING RATE, FOOD CONVERSION RATE, SWIM-UP FRY, TOTAL LENGTH

SUMMARY: Razorback sucker swim-up fry, sub-fingerlings, and fingerlings were successfully reared in earthen ponds at Dexter National Fish Hatchery in 1985. Swim-up fry were stocked in 0.34 - 1.08 acre ponds at densities of 101,000 - 109,000 fry/acre. Fry averaged 71,000 per lb. Seven days prior to stocking fry, ponds were treated with alfalfa pellets at 300 lb/acre and superphosphate at 50 lb/acre. After initial treatment two ponds received 5 weekly fertilizations of alfalfa pellets at 100 lb/acre and the two larger ponds received 3 weekly fertilizations of alfalfa pellets at 100 lb/acre and superphosphate at 25 lb/acre. Fry were reared 69 - 78 d in 9 - 22°C water. Survival ranged from 87.8 - 98.6%, and size varied from 724 to 508 per pound.

Sub-fingerlings were stocked in ponds 3-4 ft deep and 0.86 - 0.98 acre at densities of 51,000 - 58,000/acre. Fish ranged from 724 to 549 per pound. Prior to stocking, ponds were given a single treatment of alfalfa pellets at 100 lb/acre. Fish were fed number 1 and 2 granules of commercial trout diet at a rate of 5.5%/lb body weight. Survival of fish reared 51 - 70 d at temperatures of 16 - 22°C ranged from 92.7 - 95.8%. Size of sub-fingerlings varied from 141 - 159 per pound. The pond with a single treatment of alfalfa pellets had the highest survival rate but also the highest food conversion (2.67) of the test ponds.

Fingerlings were stocked in ponds 0.98 acre and 3 ft in depth at densities of 26,000 - 27,000/acre. Fish averaged 158 per pound and were fed number 2 and 3 granules of commercial trout dies at a rate of 5.0 - 3.5% per pound of body weight. Survival of fish reared 50 - 55 d at temperatures of 19 - 24°C was 96.2%. Size of fish varied from 61.5 to 75.0 per pound. Food conversion averaged 2.38.

Razorback sucker culture techniques have consistently improved since the transfer of the program to Dexter National Fish Hatchery in 1981. Survival has gone from 10.8% in 1981 to 91.8% overall in 1985. This improvement has been contributed to management practices such as fertilization rate and stocking rate refinement of pond culture.

REFERENCE NUMBER: 013

CITATION: Colorado State University. 1989. Research hatchery squawfish propagation report. June, 1989. Unpublished report. Colorado State University Research Hatchery. Fort Collins, Colorado. 3 pp.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_LAR

TOPICS: Production, Culture Techniques, Temperature, Diet

KEYWORDS: COLORADO SQUAWFISH, EGGS, INCUBATION TEMPERATURES, FEEDS, BIOKYOWA, ZEIGLER LARVA

SUMMARY: Colorado squawfish fry were subjected to different rearing treatments to determine dietary performance of three feeds. Fourteen hour old eggs from Dexter National Fish Hatchery were separated into incubation trays. Water was circulated through these trays at 22.7 l/min at temperatures of 21°C and 11.4°C. Hatching began in the 21°C trays after 80 h and was complete after 96 h. Since eggs were so small 3,600/ounce, no exact percentage of hatching success could be obtained. The eggs in the 11.4°C trays "disappeared" after 12 days. Surviving fry were confined within troughs to small pans (15" x 12" x 5") with mesh tops and an airstone in each to maintain high oxygen levels. These airstones also kept food particles suspended longer. Fish were offered feed two days after hatching. Brine shrimp were fed to control groups at three temperatures (11.4, 15.5, and 20°C), Biokyowa was fed to three temperature groups and Zeigler (larva) and Rangen Trout diets were fed to two temperature groups (15.5, 20°C). Initially all treatment groups were fed brine shrimp twice daily and the test diet once daily. Fish other than control groups were then gradually switched to the test feed three times daily.

Observations in this report are given prior to final completion. Fry held at 11.4°C became very lethargic after five days, quit feeding and suffered increased mortality rates. The remaining fish were condensed into one tray and the water temperature was increased to 15.5°C. After three days fish began eating again. Twelve days later water temperatures were lowered again and fish were still actively feeding and seemed healthy.

It was determined that squawfish eggs cannot successfully be incubated at 11.4°C, and swim-up fry cannot be started on feed at that temperature. But after two weeks of initial feeding at a warmer temperature, fry can be switched to colder water and cultured effectively. Fish held at warmer temperatures (15.5°C) were more active on Biokyowa diet. At 20°C all performance of fry on all feeds seemed equal.

REFERENCE NUMBER: 014

CITATION: Jensen, B.L. 1984. Annual narrative report, calendar year 1984. Dexter National Fish Hatchery, U.S. Fish and Wildlife Service. Dexter, New Mexico.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE, RZ_ADULT, CS, CS_LARVAE, CS_ADULT, BT, BT_LARVAE, BT_ADULT

TOPICS: Production, Disease

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, BONYTAIL, FECUNDITY, SWIM-UP FRY, LERNAEA, ASIAN TAPEWORM

SUMMARY: Razorback suckers, Colorado squawfish and bonytails were spawned at Dexter National Fish Hatchery.

SPECIES	n	MEAN FECUNDITY	SWIM-UP FRY % of TOTAL
Razorback (Wild)	25	123,110	51.7
Razorback (Domestic)	70	63,674	39.8
Colorado Sq. (Domestic)	9	66,185	19.8
Bonytail	11	16,464	37.7

Lernaea problems remained in the bonytail, but razorback sucker and Colorado squawfish have been cleared of this parasite. Asian Tapeworms were found in Colorado squawfish. Adult squawfish were given oral treatments of Di-N-Butyl-Tin-Oxide (DNBTO) in gelatin capsules and three-year-old fish were given DNBTO on feed in an attempt to eliminate this parasite. Extent of control was unknown at the time (December 6, 1984).

REFERENCE NUMBER: 015

CITATION: Papoulias, D. 1986. Food availability and mortality for larval razorback sucker, Xyrauchen texanus. Proceedings of the Desert Fishes Council 18:210 (abstract).

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE

TOPICS: Diet, Research

KEYWORDS: RAZORBACK SUCKER, DIET, STARVATION

SUMMARY: Laboratory experiments were performed at the United States Fish and Wildlife Service, Dexter, New Mexico facility at water temperatures of 18°C. To determine when larval razorback sucker must encounter food or die, larvae were started on food at 4-day intervals. Those larvae fed beginning 25 and 29 days post-hatch had significantly higher mortalities than those larvae fed 5, 9, 13, and 17 days after hatching. The effect of varying food density on mortality was investigated. Fish receiving 10 nauplii per liter per 8-hour period had greater than 70% mortality. Fish which received no food throughout the experiment, as well as those fed at varying time periods of prey densities, experienced peak mortalities between 20 and 30 days post-hatch. The point of irreversible starvation was determined to be between 17 and 21 days post-hatch, and the critical period between 7 and 17 days post-hatch.

REFERENCE NUMBER: 016

CITATION: Jensen, B.L. 1989. Dexter National Fish Hatchery (description). Dexter National Fish Hatchery, U.S. Fish and Wildlife Service. Dexter, New Mexico.

SPECIES AND LIFE STAGE: BT,CS,RZ

TOPICS: Production, Water_quality

KEYWORDS: DEXTER, WATER QUALITY

SUMMARY: Dexter National Fish Hatchery is located in the Pecos River Valley of southeastern New Mexico. Elevation is 3,500 ft, average annual rainfall is 12 inches. Water is supplied by three shallow wells with a pH ranging from 7.2 to 7.5. Temperature in a constant 64°F. Total harness averages 2,100 ppm and total dissolved solids average 3,500 ppm.

REFERENCE NUMBER: 017

CITATION: Valdez, R.A. 1985. A review of the hatchery program for threatened and endangered fishes of the Colorado River. Colorado Water Congress Special Project on Threatened and Endangered Species. 29 pp.

SPECIES AND LIFE STAGE: HB, BT, CS, RZ

TOPICS: Research, Production

KEYWORDS: HATCHERY FACILITIES, HATCHERY CAPABILITIES

SUMMARY: The background and current status of the hatchery program for endangered Colorado River fishes was reviewed and recommendations were made regarding future hatchery construction. A new facility was estimated to cost $8,570,000 , plus and additional $333,000 to $588,000 per year for operation and maintenance (U.S. Fish and Wildlife Service 1983). An alternative to constructing a new hatchery was to utilize existing hatchery facilities. The following eleven sites were evaluated; Willow Beach NFH, Dexter NFH, Hotchkiss NFH, Logan FES, Ouray NWR, Fish Springs NWR, Smithfield Well, Big Spring, Rifle Falls SFH, Page Springs SFH and Browns Park NWR.

REFERENCE NUMBER: 018

CITATION: Inslee, T.D. 1981. Spawning of razorback suckers. Pages 145-157 In W.H. Miller, J.J. Valentine, and D.L. Archer. (eds.) Colorado River Fishery Project Final Report: Part 3, Contract Reports. U.S. Fish and Wildlife Service, Bureau of Reclamation., Salt Lake City, Utah.

SPECIES AND LIFE STAGE: RZ, RZ_EGG, RZ_LARVAE, RZ_ADULT

TOPICS: Production, Culture Techniques, Diet

KEYWORDS: RAZORBACK SUCKER, SPAWNING, HORMONE INJECTION, HATCHING, FUNGUS, FEEDING

SUMMARY: Razorback suckers (136) were transferred from Lake Mohave to Dexter National Fish Hatchery. Four spawning methods were tried: pond spawning, spawning in flow through ponds, circular tank spawning, and holding house tank spawning. Best results were found using 6-foot circular tanks. The bottoms of the tanks were lined with 1/2 to 3 inch rocks and filled to a depth of 22 inches. Well water, averaging 62°F, was pumped at 10 L/min and aimed at a 45° angle to produce a circular flow.

Hormone injections of 500 IU chorionic gonadotropin and 2 mg/lb carp pituitary were tried on female fish. Injections of 2 mg carp pituitary per pound of female brood fish were most successful.

Eggs were incubated utilizing five methods: Mcdonald jars; in the circular tank on rocks after natural spawning; in a circular tank after stripping; on a fine-mesh net suspended in holding house tank; and a Heath incubator. Hatching results were best in the Heath incubators.

Egg fungus was treated with formalin solution. It was found that viable eggs can be treated with a solution as strong as 1:75 for 10 minutes. Fungi can be killed or retarded with 1:200 formalin for 10 min. Recommended treatment is a constant flow concentration of 1:100 for 10 minutes on the 2nd and early on the forth day after hatching.

Fry were offered a diet of trout starter four times daily for the first 17 days. The fish were then moved to a 0.1 acre rearing pond that had developed a zooplankton bloom. The plankton bloom was started by addition of 100 pounds of manure and 80 pounds of 18-46-0 fertilizer to the bottom of the pond before filling.

REFERENCE NUMBER: 019

CITATION: Beleau, M.H., and J.A. Bartosz. 1982. Acute toxicity of selected chemicals: data base. Pages 243-254 In W.H. Miller, J.J. Valentine, and D.L. Archer. (eds.) Colorado River Fishery Project Final Report: Part 3, Contract Reports. U.S. Fish and Wildlife Service, Bureau of Reclamation., Salt Lake City, Utah.

SPECIES AND LIFE STAGE: CS, CS_LARVAE, CS_JUV, CS_ADULT, HB, HB_LARVAE, HB_JUV

TOPICS: Water Quality

KEYWORDS: COLORADO SQUAWFISH, HUMPBACK CHUB, TOXICANTS, STATIC ACUTE TOXICITY

SUMMARY: Static toxicity tests were performed on Colorado squawfish (post-larval, juvenile, and sub-adult) and humpback chub (post-larval and juvenile). Bioassays were used to find the 96 hour LC_{50} for the following toxicants: arsenic, cadmium, Chlordane, chlorine, chromium, copper, cyanide, DDT, Dieldrin, Endrin, iron, lead, manganese, mercury, nickel, Parathion, selenium, Squoxin, Toxaphene, zinc.

REFERENCE NUMBER: 020

CITATION: Flagg, R. 1981. Disease survey of the Colorado River fishes. Pages 177-184 In W.H. Miller, J.J. Valentine, and D.L. Archer. (eds.) Colorado River Fishery Project Final Report: Part 3, Contract Reports. U.S. Fish and Wildlife Service, Bureau of Reclamation., Salt Lake City, Utah.

SPECIES AND LIFE STAGE: HB, HB_ADULT, BT, BT_ADULT, CS, CS_ADULT, RZ, RZ_ADULT

TOPICS: Disease

KEYWORDS: HUMPBACK CHUB, BONYTAIL, COLORADO SQUAWFISH, RAZORBACK PATHOGENS

SUMMARY: The endangered fishes of the Colorado River were examined and a list of recovered pathogens created. The endemic fishes were found relatively healthy; no detectable virus was found. The most likely threat to culture of endangered fishes was thought to be the motile aeromonads (Aeromonas hydrophila) and pseudomonads (Pseudomonas sp.) frequently related to mortalities in present cultural systems. Saprolegnia was stated to be the probable limiting factor in the rearing and propagation of endangered fish.

REFERENCE NUMBER: 021

CITATION: Bulkley, R.V., C.R. Berry, R. Pimental, and T. Black. 1981. Tolerance and preferences of Colorado River endangered fishes to selected habitat parameters. Pages 185-241 In W.H. Miller, J.J. Valentine, and D.L. Archer. (eds.) Colorado River Fishery Project Final Report: Part 3, Contract Reports. U.S. Fish and Wildlife Service, Bureau of Reclamation., Salt Lake City, Utah.

SPECIES AND LIFE STAGE: HB, HB_JUV, BT, BT_LAR, CS, CS_LAR, CS_ADULT, RZ, RZ_JUV

TOPICS: Water Quality, Transport, Temperature

KEYWORDS: HUMPBACK CHUB, BONYTAIL, COLORADO SQUAWFISH, RAZORBACK SUCKER, TEMPERATURE PREFERENDUM, EGG TEMPERATURE TOLERANCE, TRANSPORT STRESS

SUMMARY: Four endangered Colorado River fishes were studied to: determine temperature and total dissolved solid preferences; determine baseline hematological parameters; determine swimming stamina at various water velocities and temperatures; determine effects of swimming and transport stress on certain blood parameters.

Final temperature preferendum are as follows: humpback chub 24°C, bonytail chub 24.2°C, razorback sucker 24.9°C, Colorado squawfish (juvenile) 24.6°C and Colorado squawfish (adult) 25.4°C.

Egg temperature tolerance was tested for Colorado squawfish, bonytail and humpback chub. Results (temperature °C / percent hatched/ incubation time) are as follows:

Colorado squawfish 5°/0%/- , 10°/0%/- , 14°/0%/- , 20°/60%/10 days

Bonytail chub 5°/0%/- , 10°/0%/- , 14°/60%/10 days, 20°/70%/6 days, 26°/80%/3 days, 31°/0%/-, 37°/0%/-

Humpback chub 5°/0%/- , 10°/30%/19 days, 14°/50%/ 16 days, 20°/100%/4 days, 26°/95%/3 days

Blood glucose levels in 40 razorback suckers increased from 54 mg/100 ml to 144 mg/100 ml after 15 hours of transport. No significant change in blood chloride was noted. Salt was suggested as a way of reducing osmoregulatory stress during transport.

REFERENCE NUMBER: 022

CITATION: Meffe, G.K. 1986. Conservation genetics and the management of endangered fishes. Fisheries 11(1):14-23.

SPECIES AND LIFE STAGE:

TOPICS: Culture Techniques

KEYWORDS: GENETICS, INBREEDING

SUMMARY: Recommendations are made for the maximization of genetic variance in hatchery stocks of endangered fishes. Inbreeding in small populations of endangered brood stock is thought to depress fecundity, fertility, age at maturity, growth and survivorship. For short-term survival a genetically effective minimum population size of 50 is recommended.

REFERENCE NUMBER: 023

CITATION: Toney, D.P. 1974. Observations on the propagation and rearing of two endangered fish species in a hatchery environment. Proceedings of the Annual Conference of the Western Association of State Fish and Game Commissioners 54:252-239.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_ADULT, RZ, RZ_EGG, RZ_LARVAE, RZ_JUV, RZ_ADULT

TOPICS: Disease, Production, Culture Techniques, Temperature, Diet

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, BROODSTOCK, HOLDING FACILITIES, DIET, GROWTH, DISEASE, SPAWNING, HATCHING

SUMMARY: Colorado squawfish and razorback suckers were reared at the Willow Beach National Fish Hatchery. Eggs from the suckers were hand stripped from wild (Lake Mohave) stock. Squawfish eggs were collected from natural spawning in a hatchery raceway.

Seven squawfish from the Yampa River were placed in a concrete raceway (100' X 8' X 30"). Gravel was placed in the first 30' of the holding raceway and water was pumped into the raceway at 200 gal/min. The squawfish were fed live trout three to four times daily. Combined weight of the fish increased from 22.7 pounds in August 21, 1973 to 24.1 pounds on May 30, 1974. Ninety pounds of trout were fed the squawfish over this nine month period for a total conversion of 1.4 pounds. The only disease organisms found were Myxobolus, Lernaea and Ichthyophthirius. Formalin (25 mg/l) and malachite green (.05 mg/l) were used for three weeks as control. Three females were induced to spawn by injection of 900 units/lb of chronic gonadotrophin. Eggs were discovered in the gravel one week later.

Forty razorback suckers were collected from Lake Mohave. Eggs were hand stripped and placed in hatchery tank (3' x 15'). Water in the tank was 2 feet deep and averaged 60°F. After hatching the fry were fed small amounts of baby food, strained beef liver, four or five times daily. After three weeks the fry were moved outside and fed on zooplankton found in the hatchery raceways. Ichtyophthirius were observed on the fry and treated with formalin and malachite green. Myxosoma spores were found on the adult razorbacks.

REFERENCE NUMBER: 024

CITATION: Marsh, P.C. 1985a. Effect of incubation temperature on survival of embryos of native Colorado River fishes. The Southwestern Naturalist 30(1):129 - 140.

SPECIES AND LIFE STAGE: BT, CS, HB, RZ, RZ_EGG, RZ_LAR, HB_EGG, HB_LAR, BT_EGG, BT_LAR, CS_EGG, CS_LAR

TOPICS: Temperature, Life History, Water Quality, Culture, Research

KEYWORDS: COLORADO SQUAWFISH, BONYTAIL, HUMPBACK CHUB, RAZORBACK SUCKER, INCUBATION TEMPERATURE, EGGS, ABNORMALITIES, TL, INCUBATION APPARATUS

SUMMARY: Eggs of Colorado squawfish, Razorback sucker, Humpback chub, and bonytail were held at 5, 10, 15, 20, 25, and 30° to determine effects of incubation temperature upon hatching and survival.

Six 22 liter glass aquaria were maintained at experimental temperatures with a combination of cold water inflow and thermostatically-controlled immersion-type heaters. The 30° tank had no flow and the other 5 tanks had a 1.0 liter/h inflow. Incubation chambers were made of 76 mm ID PVC pipe fitted on the bottom with 0.5 mm-mesh nylon netting. Six to eight chambers were suspended in each aquaria. The water was obtained from the wells at Dexter National Fish Hatchery (DNFH), NM, and was characterized by relatively high salts especially sulfate 1900-1930 mg/L, nitrate 11.1-12.0 mg/L, and conductivity 3830 - 4500 umhos, 25°C. A full report of water quality of DNFH wells can be reviewed in the body of this paper.

Broodstocks were obtained from wild populations in Lake Mohave and the Little Colorado River, or as hatchery-bred fish from Willow Beach National Fish Hatchery, AZ, and held at Dexter NFH. As sexual readiness approached, 1-2 females and 5-20 males of each species respectively were brought from ponds to indoor tanks at 17.5 - 18°C. Adults were injected with one or both human chorionic gonadotropin or acetone-dried carp pituitary. Eggs were stripped, fertilized and water hardened for 1 - 2.5 h at 17.5-18°C. After hardening eggs were siphoned into incubation chambers. Eggs of Razorback sucker were treated daily with 1.0% formaldehyde for 10 min until embryo motility was observed within the chorion.

Razorback sucker -- All embryos incubated at 5, 10, and 30°C died. Greatest success was achieved at 20 and 25°C with significantly lower success at 15°C. Time to hatch was 216 h at 15°C and 84 h at 25°C. Prolarvae were 6.5 - 8.6 mm TL, active and squirming on the bottom. Swim-up was attained at 103 - 312 h depending on temperature. Swim-up fry were 8.4 - 8.6 mm TL and stunting and deformities were significantly lower at 20°C (8.1%) than either 15 or 25°C (38%).

Bonytail -- No hatch occurred at 5, 10, or 30°C (0.5% hatch at 25°C). Hatching success was not significantly different for 15, 20°C. Time to hatch varied from 204 h at 15°C to 103 h at 20°C. Prolarvae averaged 6.0 - 6.3 mm TL. Prolarvae remained quiescent on the bottom unless disturbed. Many larvae adhered to sides of incubation chambers with the anteroventral portion of their head. Swim-up occurred at 148 - 396 h increasing towards lower temperatures. Swim-up length was 8.1 - 8.6 mm TL. Incidence of abnormalities ranged from 0 - 4% not related to temperature.

Humpback chub -- No hatch occurred at 5, 10, or 30°C (0.8% hatch occurred at 15°C, and 2% at 25°C). Greatest success was at 20°C. Time to hatch ranged from 156 h at 15°C to 72 h at 25°C. New prolarvae were longest at 15° (6.3 mm TL) compared with 5.5 and 5.7 mm TL at 20 and 25°C respectively. Swim-up occurred at 372 h at 15°C and at 166 h at 25°C. Swim-up fry were 8.2 - 8.5 mm TL. Incidence of abnormality was greatest at 15° (33%, 13 and 17% at 20 and 25°C respectively).

Colorado squawfish -- Two attempts at experimental incubation of squawfish eggs were pooled due to suspicious outcomes. Percentage hatch of squawfish was 27% at 20°C in trial I and 2% in trial II. All ova died at 5, 10, 15, 25, and 30°C in trial I, and at 5, 10, 15, and 30°C in trial II. Peak hatch occurred at 78 - 108 h at 20°C compared with 63 h at 25° C in trial II. Prolarvae averaged 5.5 mm TL at 20°C and 5.6 mm TL at 25°C. Prolarvae were helpless at hatching, moving feebly on the bottom. Embryos responded with increased frantic swimming activity in the presence of bright light. Abnormal fry made up 26% of the hatch at 25°, and 11% at 20°.

REFERENCE NUMBER: 025

CITATION: Tyus, H.M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah, 1979 - 1986. Transactions of the American Fisheries Society 116(1):111-116.

SPECIES AND LIFE STAGE: RZ, RZ_ADU, RZ_LAR

TOPICS: Life History, Temperature

KEYWORDS: RAZORBACK SUCKER, LARVAE, TOTAL LENGTH, SPAWNING, SUBSTRATE, TEMPERATURE, TIMING

SUMMARY: Adult razorback suckers were collected from flat-water sections of the mainstem Green River and lower portions of the Yampa River. In the Green River the area of highest concentration was from the mouth of the Duchesne upstream to the mouth of the Yampa River. Six fish were collected from the lower sections of the Green River also. Total lengths of 323 fish ranged from 426 - 608 mm TL. Ripe males averaged 503 mm and ripe females averaged 544 mm TL male to female ratio for all years combined was 1.61:1 . Ripe females were significantly longer and heavier than males. Razorback suckers were more vulnerable to capture during spawning from May through June.

Razorback sucker larvae were collected downstream of suspected spawning areas. Larvae 10.6 - 13.6 mm TL were identified by the Larval Fish Lab. of Colorado State Univ. 31% of 42 samples contained larval razorback suckers.

Ripe razorback suckers were collected over coarse sand substrate, but some were collected near gravel and cobble bars. It is not known whether staging occurs in one area and spawning in another, or if spawning occurs over both areas. Water temperatures ranged from 10.5° in May to 18° in June. Average temperatures where ripe fish were captured were 15° for males and 16° for females.

REFERENCE NUMBER: 026

CITATION: Buth, D.G., R.W. Murphy, and L. Ulmer. 1987. Population differentiation and introgressive hybridization of the flannelmouth sucker and of hatchery and native stocks of the razorback sucker. Transactions of the American Fisheries Society. 116(1):103-110.

SPECIES AND LIFE STAGE: RZ, RZ_ADU, RZ_JUV

TOPICS: Research

KEYWORDS: RAZORBACK SUCKER, GENETICS, INTROGRESSIVE HYBRIDIZATION, FLANNELMOUTH SUCKER, ELECTROPHORESIS

SUMMARY: A problem regarding the management of any fish species that is artificially mass-produced concerns the maintenance of the natural gene pool. Sampling error results in the enhancement of the frequencies of some alleles and the reduction of others in the necessarily small subsample of the wild population. This inherent characteristic of hatchery propagation coupled with the razorback's tendency to hybridize naturally with other catostomids is cause for concern when considering hatchery augmentation of natural populations.

Flannelmouth specimens for this study were obtained from the Virgin River in Arizona, the mouth of the Paria River in AZ, the Little Colorado river drainage, AZ, Upper Colorado River near Grand Junction, CO. Razorback specimens were obtained from Lake Mohave, AZ, Senator Wash Reservoir, CA, and form Dexter national Fish Hatchery, NM. Brain, liver, heart, and skeletal muscle tissues were used for electrophoresis. Gene products compared included acid phosphatase, alcohol dehydrogenase, creatine kinase, glycerol-3-phosphate dehydrogenase and several others.

Flannelmouth sucker were polymorphic in 9 of 21 loci in at least one of the geographic locations. Within each of these locations, genotype arrays were within Hardy-Weinberg expectations of genetic variability. Between the different geographic locations, statistically significant structuring of gene flow patterns exist. Indicating geographic limitations of certain polymorphism, though no complete allelic difference. Razorback sucker were polymorphic in 11 out of 21 loci in at least one of the geographic locations. Within each of these sample populations genotype arrays were within Hardy-Weinberg expectations except for the Dexter National Fish Hatchery population which showed excessive gene restriction in one loci. Between the different geographic locations no structuring of gene flow patterns was noted. Four loci were identified that were species-specific and could be used as marker loci. Two of these four loci have allelic distributions suggesting some gene flow between the two species. Both alleles are present in both species and the predominant allele in each species is present in low frequency in the other species. Gene flow is proceeding both from flannelmouth to razorback sucker and from razorback to flannelmouth sucker. There is the possibility that both alleles at both loci were present in a common ancestor of the catostomids. Evidence of introgression in flannelmouth sucker is found in the Virgin River sample and the upper Colorado River sample. Introgression is apparently rare enough for the species to maintain integrity of their respective gene pools in the wild. The current hatchery stock at Dexter has not been appreciably affected by sampling error in favor of introgressed genes form flannelmouth suckers, and has fewer introgressed genes than parental stock from Lake Mohave. As long as breeding stock continues to be obtained form natural populations, the breeding program for razorback suckers at Dexter can be quite successful. Programs that select subsequent breeding stock from their own reared stock are ill advised for the razorback.

REFERENCE NUMBER: 027

CITATION: Hamman, R.L. 1986. Induced spawning of hatchery-reared Colorado squawfish. The Progressive Fish-Culturist 48(1):72 - 74.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_LAR

TOPICS: Culture, Production, Temperature, Research

KEYWORDS: COLORADO SQUAWFISH, INDUCED SPAWNING, EGGS, INCUBATION TEMPERATURE, INCUBATION APPARATUS, DEXTER NATIONAL FISH HATCHERY, PITUITARY, FECUNDITY

SUMMARY: Hatchery-reared squawfish were successfully induced to spawn during 1983 - 1984 at Dexter National Fish Hatchery, NM.

The brood stock during 1983 and 1984 consisted of 24, 9-year old females and nine 10-year old females, respectively. These fish were 1974 year-class progeny from wild adults collected from the Yampa River and spawned at Willow Beach Hatchery.

Ovulation was induced with injections of acetone-dried carp pituitary at the rate of 4 mg/kg body weight at 24-h intervals. Fish were anesthetized before the intraperitoneal injection, and then placed in a 2.75 x 0.75 x 0.75 m holding tank and held until they were stripped. Cool water at 17 -18 C flowed through the tank at 90 - 130 l/min.

When eggs could be expelled with slight pressure, a female was anesthetized and rinsed, and the eggs were stripped into a pan containing water and diluent. Milt from two or three hatchery-reared males was added, and the eggs were gently stirred with a feather. A bentonite clay solution was then added to counteract egg adhesiveness. Eggs were then washed and placed in a 31 x 31 x 18 -cm floating basket and allowed to water harden for approximately 30 min.

Eggs were placed in either Heath incubators or hatching jars for incubation (20 - 22 C at 4 - 11 L/min). After hatching, fry were transferred to 2.75 x 0.75 x 0.75 - m tanks (20 - 22 C at 15 - 23 L/min) and held until swim-up occurred.

In 1983, all 24 females ovulated 18 - 20 h after receiving one carp pituitary injection. Fecundity averaged 77,400; average number of eggs per kilogram body weight was 55,533. Eggs commenced hatching at 100 h and were completely hatched by 144 h. Numbers of fry following swim-up in Heath and jar incubators were 283,017 and 34,855, respectively.

In 1984, all nine females ovulated 20 - 24 h after receiving two hormonal injections. Fecundity averaged 66,185; average number of eggs per kilogram body weight was 45,451. All eggs were incubated in hatching jars. Hatching began at 96 h and ended by 144 h. Actual numbers of swim-up fry were 118,157.

REFERENCE NUMBER: 028

CITATION: Black, T., and R.V. Bulkley. 1985a. Growth rate of yearling Colorado squawfish at different water temperatures. Southwestern Naturalist 30(2):253-257.

SPECIES AND LIFE STAGE: CS, CS_JUV

TOPICS: Temperature

KEYWORDS: COLORADO SQUAWFISH, TEMPERATURE, GROWTH RATES

SUMMARY: Growth rate of yearling Colorado squawfish, over a 12-week period, was determined for fish held at 15, 20, 25 and 30°C with excess food. The effect of temperature on growth was highly significant; fastest growth occurred at 25°C. Fish gained about 0.3 gram at 15°C, 0.9 gram at 20 and 30°C, and 1.7 grams at 25°C during the 12-week period. Test fish had a mean weight of 0.45 g (SD = 0.11 g)

REFERENCE NUMBER: 029

CITATION: Hamman, R.L. 1981c. Transporting endangered fish species in plastic bags. Progressive Fish Culturist 43(4):212-213.

SPECIES AND LIFE STAGE: HB, HB_LARVAE, HB_JUV, CS, CS_LARVAE, CS_JUV, CS_ADULT

TOPICS: Transportation

KEYWORDS: TRANSPORTATION

SUMMARY: Transportation of endangered fish species on commercial airlines using plastic bags was tested at Willow Beach Hatchery. Fry were shipped at a density of 31-625 fish/l or 1-85 g/l, fingerlings at 60-120 fish/l or 60-120 g/l and adults at 1 fish/l or 250 g/l. Bags were inflated with oxygen, sealed and placed in Styrofoam containers. Water temperature was 12-13°C.

REFERENCE NUMBER: 030

CITATION: Black, T., and R.V. Bulkley. 1985b. Preferred temperature of yearling Colorado squawfish. Southwestern Naturalist 30(1):95-100.

SPECIES AND LIFE STAGE: CS, CS_JUV

TOPICS: Temperature

KEYWORDS: COLORADO SQUAWFISH, TEMPERATURE, FINAL PREFERENDUM

SUMMARY: Temperature preferences for Colorado squawfish was determined in a horizontal gradient trough. Fish were acclimated to 14, 20, and 26°C, and twenty fish were tested from each acclimation temperature. Acute preferenda were 21.9, 27.6, and 23.7°C for 14, 20, and 26°C acclimated fish, respectively. Final preferendum was estimated as 25°C.

REFERENCE NUMBER: 031

CITATION: Hamman, R.L. 1985a. Induced spawning of hatchery-reared razorback sucker. Progressive Fish Culturist 47(3):187-189.

SPECIES AND LIFE STAGE: RZ, RZ_EGG, RZ_LARVAE, RZ_ADULT

TOPICS: Production, Culture Techniques, Temperature

KEYWORDS: RAZORBACK SUCKER, BROOD STOCK, INDUCED SPAWNING, HATCHING, TEMPERATURE

SUMMARY: Seventy hatchery-reared, 3-year-old female razorback suckers were induced to spawn at Dexter Hatchery. Ovulation was induced by intramuscular injections of 220 units chorionic gonadotropin per kg of body weight at 24-hour intervals. Eggs were manually stripped (mean fecundity = 63,645), combined with the milt of two to three males and allowed to water harden. Eggs were then placed in Heath incubators and hatching jars for incubation. Heated water (20-22°C) flowed through the jars and incubators at 4-11 l/min. Percent swim-up fry for the Heath incubators and hatching jars was 38.1 and 54.7% respectively.

REFERENCE NUMBER: 032

CITATION: Hamman, R.L. 1985b. Induced spawning of hatchery-reared bonytail. Progressive Fish Culturist 47(4):239-241.

SPECIES AND LIFE STAGE: BT, BT_EGG, BT_LARVAE

TOPICS: Production, Culture Techniques, Temperature

KEYWORDS: BONYTAIL CHUB, BROOD STOCK, INDUCED SPAWNING, HATCHING, TEMPERATURE

SUMMARY: Hatchery-reared bonytail chub were induced to spawn at Dexter Hatchery. Brood stock during 1983 and 1984 consisted of 24 females (two-year-old) and 11 females (three-year-old), respectively. Ovulation was induced by intraperitoneal injections of 4 mg/kg acetone-dried carp pituitary at 24-hr intervals. Eggs were manually stripped, combined with the milt of two to three males and allowed to water harden. Eggs were placed in Heath incubators for hatching. Heated water (20-22°C) flowed through the incubators at the rate of 11 l/minute. After hatching fry were transferred to holding tanks (9 x 2.5 x 2.5 ft). Warm water (20-22°C) flowed though the tanks at 15 to 22 l/min.

In 1983, all 24 females ovulated 18 to 20 hours after receiving one injection of carp pituitary. With Fecundity averaging 4,990 and percent swim-up fry 17.1%. In 1984, all 20 females ovulated 20 hours after receiving one hormonal injection. With fecundity averaging 16,464 and percent swim-up fry 37.7%.

REFERENCE NUMBER: 033

CITATION: Berry, C.R. 1988. Effects of cold shock on Colorado squawfish larvae. Southwestern Naturalist 33(2):193-197.

SPECIES AND LIFE STAGE: CS, CS_LARVAE

TOPICS: Temperature

KEYWORDS: COLORADO SQUAWFISH, COLD SHOCK

SUMMARY: Colorado squawfish larvae, acclimated to 22°C, were subjected to water temperature decreases of 5, 10, or 15°C within 240 to 300 min. Most mortality, due to shock, occurred in the first 48 h. The 15°C shock in 5 min caused an average of 65% mortality in 14-day-old larvae. Abrupt cold shock did not affect 40-day-old larvae. In addition to causing this direct mortality, shocks of 10 to 15°C in 5 min caused behavioral changes in 14-day-olds that could result in. indirect mortality of live fish

REFERENCE NUMBER: 034

CITATION: Berry, C.R. 1984. Hematology of four rare Colorado River fishes. Copeia 1984(3):790-793.

SPECIES AND LIFE STAGE: HB, HB_JUV, BT, BT_JUV, CS, CS_JUV, CS_ADULT, RZ, RZ_ADULT

TOPICS: Transport, Research

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, HEMATOLOGY, TRANSPORT STRESS

SUMMARY: Hematological characteristics of four rare Colorado River fishes were determined. Characteristics included; hematocrit, hemoglobin, total protein, number of erythrocytes, number of leukocytes, lymphocytes, thrombocytes and granulocytes.

Blood was collected from 40 razorback suckers before and 17-21 h after transport to evaluate the effects of hauling. Blood glucose increased from 52 mg/100 ml to 141 mg/100 ml. Blood chloride decreased significantly from 108 milliequivalents/l to 99 milliequivalents/l after hauling.

REFERENCE NUMBER: 035

CITATION: Mueller, G. 1989. Observations of spawning razorback sucker (Xyrauchen texanus) utilizing riverine habitat in the lower Colorado River, Arizona-Nevada. Southwestern Naturalist 34(1):147:149.

SPECIES AND LIFE STAGE: RZ, RZ_ADULT

TOPICS: Life History

KEYWORDS: RAZORBACK SUCKER, SPAWNING

SUMMARY: Razorback suckers were observed spawning 4.8 km downstream of Hoover Dam. Spawning activities appeared to be restricted to a 300 m^2 area of scoured sand and gravel in the mouth of a dry wash. Eighteen depressions measuring 0.25 to 1 m^2 were identified and occurred at depths of 1.2 to 2.0 m. Mean water velocities ranged from 0.00 to 0.37 m/s. Nose velocities (10 cm from substrate) at five specific sites where spawning was observed averaged 0.15 m/s. Samples taken directly from spawning depressions yielded 10.5 to 16.7 eggs/m^2.

REFERENCE NUMBER: 036

CITATION: Marsh, P.C., and J.E. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. Southwestern Naturalist 34(2):188-189.

SPECIES AND LIFE STAGE: RZ, RZ_JUV

TOPICS: Research

KEYWORDS: RAZORBACK SUCKER, PREDATION, STOCKING

SUMMARY: Juvenile razorback suckers, 45 to 168 mm standard length, reintroduced into the Gila River, suffered intensive predation by channel catfish and flathead catfish. Estimated losses un the 2.5 km study reach over a 2 day post-stocking period were up to 900 individuals/km in autumn. Predation in autumn was lower when average size of stocked fish was increased from 68 to 113 mm standard length. Extrapolated total loss to predation in winter, when channel catfish did not feed actively, was about one-sixth that in autumn. Cold weather planting of larger razorback suckers, in the range of 300 mm, was recommended as one way to enhance post-stocking survival.

REFERENCE NUMBER: 037

CITATION: Minckley, W.L., and E.S. Gustafson. 1982. Early development of the razorback sucker Xyrauchen texanus (Abbot). Great Basin Naturalist 42(4):553-561.

SPECIES AND LIFE STAGE: RZ, RZ_EGG, RZ_LARVAE

TOPICS: Life History, Research

KEYWORDS: RAZORBACK SUCKER, DEVELOPMENT

SUMMARY: Fertilized ova of razorback sucker held at 14°C were adhesive for 3 to 4 hours after fertilization. Cleavage was completed at 24 hours, gastrulation occurred at 34 hours, and blood circulation was established at 117 hours. Hatching occurred from 5.3 to 5.5 days after fertilization. Larvae were from 6.8 to 7.3 mm TL at hatching. Yolk was assimilated at 13 days (10 mm TL). all fins were formed and had ossified rays at 64 days (27 mm TL). The unique nuchal keel appeared about 200 days after fertilization. All larvae were held in 15°C water.

REFERENCE NUMBER: 038

CITATION: Kaeding, L.R., and D.B. Osmundson. 1988. Interaction of slow growth and increased early-life mortality: an hypothesis on the decline of Colorado squawfish in the upstream regions of its historic range. Environmental Biology of Fishes 22(4):287-298.

SPECIES AND LIFE STAGE: CS, CS_LARVAE, CS_JUV

TOPICS: Life History, Temperature

KEYWORDS: COLORADO SQUAWFISH, GROWTH, MORTALITY, TEMPERATURE

SUMMARY: A growth-rate versus temperature relation for Colorado squawfish was computed to compare temperature regimes of historic and present habitats. A strong positive relation was found between temperature-regime suitability and first-year growth of squawfish in the upper basin. Unusually small size of the age-0 fish going into the winter might be an important factor affecting recruitment to the adult stock. Simulations showed how the effect of increased early-life mortality can be especially significant on populations of slow growing fish.

REFERENCE NUMBER: 039

CITATION: Marsh, P.C., and D.R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. Environmental Biology of Fishes 21(1):59-67.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE

TOPICS: Life History, Diet

KEYWORDS: RAZORBACK SUCKER, DIET, LARVAL MORTALITY

SUMMARY: Razorback sucker larvae and zooplankton were collected from Davis Reservoir and an adjacent, isolated backwater in which larvae were naturally produced. Food availability and primary dietary constituents were similar in both habitats. Reservoir larvae selected Bosmina spp. (Cladocera) and apparently avoided Copepoda, while larvae from the backwater selected Bosmina, but avoided Rotifera.

Nutritional factors such as type, number, or size of available foods do not explain disappearance of larval razorback suckers from Lake Mohave, since larvae survive to far greater ages and size in the backwater. Predation by introduced fishes appears a significant cause of larval mortality.

REFERENCE NUMBER: 040

CITATION: Johnson, J.E. 1983. Reintroducing the natives: razorback sucker. Proceedings of the Desert Fishes Council XIII:73-79.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE, RZ_JUV

TOPICS: Research

KEYWORDS: RAZORBACK SUCKER, REINTRODUCTION

SUMMARY: Over 15,000 young razorback suckers were reintroduced into historic localities within the Gila River basin in Arizona in 1981. Fish were stocked in a joint State (Arizona)/Service (FWS) project to recover the razorback in lieu of listing it under the Endangered Species Act. Localities of the stockings, criteria for site selection and size of the stocked fish are discussed.

REFERENCE NUMBER: 041

CITATION: Berry, C., R. Bulkley, D. Osmundson, and V. Rosen. 1985. Survival of stocked Colorado squawfish with reference to largemouth bass predation. Annual Report, Utah Cooperative Fishery Research Unit. Utah State University, Logan. 42 pp.

SPECIES AND LIFE STAGE: CS, CS_JUV

TOPICS: Production, Culture Techniques

KEYWORDS: STOCKING MORTALITY, STOCKING TIME

SUMMARY: The impacts of largemouth bass predation on Colorado squawfish was studied by stocking juvenile squawfish in ponds containing bass. Bass stomach content analysis showed that diets of bass switched almost entirely to squawfish immediately after stocking. Loss of squawfish, by predation from bass, was estimated in one pond to be as much as 79 percent in the first day.

Using survival and growth data it was determined there was little advantage to stocking squawfish in fall rather than spring. Winter stress was found to exact a heavy toll on squawfish numbers and no growth occurred during the winter.

REFERENCE NUMBER: 042

CITATION: Inslee, T.D. 1983. Spawning and hatching of the Colorado squawfish (Ptychocheilus lucius). Dexter NFH, U.S. Fish and Wildlife Service, Dexter, New Mexico. 17 pp.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_LARVAE, CS_ADULT

TOPICS: Culture Techniques, Production, Disease

KEYWORDS: COLORADO SQUAWFISH, SPAWNING, HORMONE INJECTIONS, FECUNDITY, INCUBATION, FUNGUS

SUMMARY: Colorado squawfish were spawned at the Dexter Hatchery. Squawfish were spawned in circular tanks, in 0.1 acre ponds and by stripping. Eggs were incubated on gravel beds in ponds, on gravel beds in tanks, in Heath incubators and in a McDonald jar.

Strip spawning using hormone injections was most successful. The hormone and dosage rate that proved to be most effective for females were injections of carp pituitary at 2 mg/lb of body weight. Fish that carried mature eggs would ovulate from 12 to 20 hours after injection. Daily injections of chorionic gonadotropin at 300 units/lb for 2 to 7 days brought males to high fluidity.

Fecundity per pound of stripped females ranged from 18,372 to 43,137 resulting in a mean of 31,094. Egg diameter was from .0861 to .0670 inches with a mean diameter of .0730 inches (1.86 mm).

Best hatching success was found when eggs were incubated in Heath incubator trays or McDonald jars. The McDonald jar gave almost the same hatching success as the clayed eggs in Heath trays, 41.4 and 40.8 percent respectively.

Bioassays showed that all age squawfish eggs can be treated with 1:100 formalin for 10 minutes to control fungus. Treatments at 1:150 on 2, 3 and 4 day old eggs also proved satisfactory in controlling fungal growths in Heath trays.

REFERENCE NUMBER: 043

CITATION: Vanicek, C.D., and R.H. Kramer. 1969. Life history of the Colorado squawfish, Ptychocheilus lucius, and the Colorado chub, Gila robusta, in the Green River in Dinosaur National Monument, 1964-1966. Transactions of the American Fisheries Society 98(2):193-208.

SPECIES AND LIFE STAGE: CS, CS_LARVAE, CS_JUV, CS_ADULT, BT, BT_LARVAE, BT_JUV, BT_ADULT

TOPICS: Life History, Diet

KEYWORDS: COLORADO SQUAWFISH, BONYTAIL CHUB, GROWTH RATES, DIET, SPAWNING TIME

SUMMARY: Investigations of the ecology and life history of the Colorado squawfish and the Colorado chub (roundtail, bonytail) were conducted on the Green River in Dinosaur National Monument.

Mean calculated total lengths for 658 squawfish from the upper Green River showed that young squawfish grew about 50 mm per year until year 3, when annual increments increased for a couple of years and then decreased as fish became larger.

Cladocerans, copepods, and chironomid larvae were important food items for squawfish up to 50 mm total length. Utilization of insects increased up to a total length of 100 mm after which fish became the major food item. Fish were the only food item found in stomachs of squawfish over 200 mm long. Chironomidae larvae and Ephemeroptera nymphs were the most abundant food items found in smaller chubs. Principal food items of chubs over 200 mm were terrestrial insects.

Squawfish were found to spawn approximately one month after water temperature had reached 65°F. Chubs were observed to spawn when the water temperature reached approximately 65°F.

REFERENCE NUMBER: 044

CITATION: Jensen, B.L. 1983b. Culture techniques for selected Colorado River imperiled fishes. Dexter National Fish Hatchery, U.S. Fish and Wildlife Service. Dexter, New Mexico. 7 pp.

SPECIES AND LIFE STAGE: BT, BT_EGG, BT_LARVAE, BT_ADULT, CS, CS_EGG, CS_LARVAE, CS_ADULT, RZ, RZ_EGG, RZ_LARVAE, RZ_ADULT

TOPICS: Production, Culture Techniques, Temperature

KEYWORDS: RAZORBACK SUCKER, COLORADO SQUAWFISH, BONYTAIL CHUB, SEXUAL MATURATION, INDUCED SPAWNING, STRIPPING, HATCHING

SUMMARY: Techniques for the culture of razorbacks, squawfish and bonytails were developed at Dexter Hatchery.

Razorback sucker: Sexually mature females at Dexter averaged 15.6 inches, 1.6 pounds and three years of age. Mature males averaged 16.2 inches, 1.9 pounds and two years of age. Females become gravid as water temperature approaches 50°F and are usually ready to spawn when temperatures reach 55°F. Female razorbacks are injected with human chorionic gonadotropin (HCG) at 100 IU per pound of body weight to finalize maturation and to stimulate ovulation of maturated eggs. Females receive HCG injections every 24 hours until all eggs have been ovulated. Male razorbacks are injected with HCG at 300 IU per pound of body weight daily for two to three days.

Utilizing the wet method, eggs from ripe females are hand-stripped into pans and mixed with the milt of two or more males. Razorback eggs are "clayed" with bentonite to reduce adhesiveness and allowed to water harden for 30 minutes. Eggs then placed in Heath incubators at 70°F with a flow of three gpm. At 70°F razorback eggs begin hatching at about 96 hours and continue through 144 hours.

Colorado squawfish: Hatchery reared Colorado squawfish became sexually mature in their sixth year. Secondary sexual characteristics become apparent as water temperatures approach 65°F, usually early in May. Female squawfish are injected with carp pituitary (CP) at two mg/lb to stimulate ovulation of maturated eggs. Male squawfish normally stay ripe and fluid but receive injections of HCG at 150 iu/lb if fluidity decreases.

Stripping and hatching of Colorado squawfish is done in the same manner as described for razorback sucker. Squawfish eggs also hatch between 96 and 144 hours after fertilization.

Bonytail Chub: Two-year-old hatchery reared bonytails were spawned in May utilizing CP to stimulate egg ovulation. Spawning and hatching techniques were the same as those reported for razorback sucker and Colorado squawfish.

REFERENCE NUMBER: 045

CITATION: Jensen, B.L. 1982. Operation of Dexter National Fish Hatchery, an endangered fishes facility. Dexter National Fish Hatchery, U.S. Fish and Wildlife Service. Dexter, New Mexico. 15 pp.

SPECIES AND LIFE STAGE: BT, CS, RZ

TOPICS: Production

KEYWORDS: BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, DEXTER HATCHERY

SUMMARY: The primary goal of Dexter Hatchery is to prevent the extinction of endangered southwestern fishes. Species are taken to Dexter for one, or all, of the following criteria: 1) to provide a refuge for those fish threatened with extinction, 2) to study their biological requirements and develop methods of spawning and rearing them, and 3) to produce selected species for reintroduction into their historic habitats.

REFERENCE NUMBER: 046

CITATION: Valdez, R.A., and G.H. Clemmer. 1981. Life history and prospects for recovery of the humpback and bonytail chub. Pages 109-119 In W.M. Miller, H.M. Tyus and C.A. Carlson (eds.). Fishes of the Upper Colorado River system: Present and Future. American Fisheries Society, Bethesda, Maryland.

SPECIES AND LIFE STAGE: HB, HB_ADULT, BT, BT_ADULT

TOPICS: Life History

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, SPAWNING, INTRODUCTIONS

SUMMARY: Humpback and bonytail chub were studied in Black Rocks, Colorado. In 1980 Spawning of humpbacks in Black Rocks occurred from approximately June 2 to 15 at water temperatures of 11.5-16.0°C and flows of 21,500-26,000 cfs. In 1981 spawning occurred from about May 15-27 at water temperatures of 16.0-16.6°C and flows of 3,000-5,000 cfs.

Recommendations were made for the possible introduction of bonytail in Cataract Canyon on the Colorado River and either Grey or Desolation Canyon on the Green River. However it was warned that these introductions may be detrimental to the existing wild stocks by increasing competition for limited habitat, introducing gene pools from a different part of the system, and enhancing the possibility of hybridization of bonytail with humpback and roundtail chub. Introductions of hatchery-reared humpback chub were advised only in Cataract Canyon.

REFERENCE NUMBER: 047

CITATION: Holden, P.B., E.J. Wick. 1982. Life history and prospects for recovery of Colorado squawfish. Pages 98-108 In W.M. Miller, H.M. Tyus and C.A. Carlson (eds.). Fishes of the Upper Colorado River system: Present and Future. American Fisheries Society, Bethesda, Maryland.

SPECIES AND LIFE STAGE: CS, CS_ADULT

TOPICS: Life History

KEYWORDS: COLORADO SQUAWFISH, SPAWNING

SUMMARY: Basic life history information in summarized for the Colorado squawfish in the Colorado and Green River drainages. Spawning is thought to occur when river temperatures are about 20°C, usually in July and August, in the Upper Colorado Basin.

REFERENCE NUMBER: 048

CITATION: Wick, E.J., C.W. McAda, and R.V. Bulkley. 1981. Life history and prospects for recovery of the razorback sucker. Pages 120-126 In W. Miller, H.M. Tyus and C.A. Carlson (eds.). Fishes of the Upper Colorado River system: Present and Future. American Fisheries Society, Bethesda, Maryland.

SPECIES AND LIFE STAGE: RZ, RZ_ADULT

TOPICS: Life History

KEYWORDS: RAZORBACK SUCKER, SPAWNING

SUMMARY: Hybridization, reproduction, food, growth, habitat, and movements of the razorback sucker are summarized. Razorback suckers were observed to spawn in the spring when water levels are rising and water temperatures are increasing.

REFERENCE NUMBER: 049

CITATION: McAda, C.M., and R.S. Wydoski. 1980. The razorback sucker, Xyrauchen texanus, in the Upper Colorado River Basin, 1974-76. Technical Paper 99, U.S. Fish and Wildlife Service, Washington, D.C. 15 pp.

SPECIES AND LIFE STAGE: RZ, RZ_ADULT

TOPICS: Life History, Production

KEYWORDS: RAZORBACK SUCKERS, SPAWNING, FECUNDITY

SUMMARY: Razorback suckers were observed to spawn in April and May, when water temperatures were 6 to 15°C. Estimated fecundity ranged from 24,490 eggs for a fish 529 mm in total length to 76,576 for a fish 485 mm long. Estimated ages based on scale examinations indicated that the razorback suckers collected had completed from 4 to 9 growing seasons, all were mature.

REFERENCE NUMBER: 050

CITATION: Johnson, J.E. 1985. Reintroducing the natives: Colorado squawfish and woundfin. Proceedings of the Desert Fishes Council XVII:118-124.

SPECIES AND LIFE STAGE: CS, CS_JUV, CS_ADULT

TOPICS: Research

KEYWORDS: COLORADO SQUAWFISH, REINTRODUCTION

SUMMARY: After the 1985 relistment of the Colorado squawfish as "experimental nonessential", under the 1982 reauthorization of the Endangered Species Act, over 117,000 squawfish were stocked into the Salt and Verde rivers in Arizona.

REFERENCE NUMBER: 051

CITATION: Inslee, T.D. 1982. Spawning and hatching of the razorback sucker. Proceedings of the Western Association of Fish and Wildlife Agencies 62:431-432.

SPECIES AND LIFE STAGE: RZ, RZ_EGG, RZ_LARVAE, RZ_ADULT

TOPICS: Culture Techniques, Production

KEYWORDS: RAZORBACK SUCKER, SPAWNING, FUNGUS, EGG ENUMERATION, FRY ENUMERATION

SUMMARY: Razorback sucker broodstock were obtained from Lake Mohave and spawned at Dexter Hatchery. The most successful spawning method was daily injections of human chronic gonadotrophin in the muscle at 100 iu/lb of female weight. Egg viability was increased from 27.7% to 61.1% by stripping at 12 hour intervals after the start of egg ovulation, then enumerating eggs and moving to incubator trays as soon as eggs had water hardened. The Heath incubator was the superior method for egg incubation. Fungus was controlled on incubating eggs with a ten minute dip of 1:100 formalin in the Heath tray.

The gravimetric method of egg enumeration was believed most accurate. Sample counts from 100 trays resulted in a mean of 130 eggs per gram. Fry enumeration after hatching utilizing the water displacement method on 67 samples was found to be 233 fry/ml.

REFERENCE NUMBER: 052

CITATION: Haynes, C.M., R.T. Muth, and T.P. Nesler. 1985. Identification of habitat requirements and limiting factors for Colorado squawfish and humpback chub. Job Final Report SE-3-4, federal aid in fish and wildlife restoration. Colorado Division of Wildlife. 42 pp.

SPECIES AND LIFE STAGE: CS

TOPICS: Life History

KEYWORDS: COLORADO SQUAWFISH, SPAWNING

SUMMARY: It was suggested that Colorado squawfish reproduction is generally enhanced by "high" late spring flow accompanied by rapid heat accumulation in the river. These conditions provide high quantity/quality spawning areas and satisfactory incubation and/or growth conditions for squawfish eggs and larvae.

REFERENCE NUMBER: 053

CITATION: Jensen, B.L. 1983a. Annual narrative report, calendar year 1983. Dexter National Fish Hatchery, U.S. Fish and Wildlife Service. Dexter, New Mexico. 9 pp.

SPECIES AND LIFE STAGE: BT, BT_EGG, BT_LARVAE, BT_ADULT, CS, CS_EGG, CS_LARVAE, CS_ADULT, RZ, RZ_EGG, RZ_LARVAE, RZ_ADULT

TOPICS: Culture Techniques, Production

KEYWORDS: BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, BROOD STOCK, SPAWNING, FECUNDITY, HATCHING

SUMMARY: Bonytail chub, Colorado squawfish and razorback sucker were spawned and reared at Dexter Hatchery in 1983.

Razorback sucker: A total of 55 wild razorback females were spawned utilizing chorionic gonadotrophin to induce egg ovulation; 46 of them (83.6%) spawned successfully. The 46 fish produced 5,728,025 eggs for an average fecundity of 124,522. At 70°C razorback eggs begin hatching at about 96 hours and continue through 144 hours. Egg viability at 72 hours averaged 75.1% with an expected hatch of 4,300,265 fry. Actual swim-up fry numbered 2,915,761 for 68.1% of expected fry and 50.9% of eggs produced.

Colorado squawfish: A total of 26 hatchery reared squawfish females were spawned utilizing carp pituitary to induce egg ovulation. Fecundity of the broodfish ranged from 57,766 to 113,341 with a mean of 77,436. Eggs were hatched in both Heath incubators and jars. Egg viability averaged 59% in the Heaths and 66% in the jars. Expected number of fry was 1,274,753. Actual number of swim-up fry was 354,000 for 27.7% of expected fry and 16.9% of eggs produced.

Bonytail chub: A total of 24 two-year-old bonytail females were spawned. Fecundity ranged from 1,015 to 10,384 with a mean of 4,677. A total of 119,764 eggs were taken with a mean viability of 67.5%. Expected number of fry was 80,840.

REFERENCE NUMBER: 054

CITATION: Lanigan, S.T., and H.M. Tyus,. 1987. Abundance, status, and rearing of razorback sucker (Xyrauchen texanus) in the Green River basin of Utah, USA. Proceedings of the Desert Fishes Council XIX:136-148.

SPECIES AND LIFE STAGE: RZ, RZ_EGG

TOPICS: Production, Culture Techniques

KEYWORDS: RAZORBACK SUCKER, SPAWNING, REARING FACILITIES

SUMMARY: An experimental razorback sucker rearing facility was established in 1986 at the Ouray National Wildlife Refuge. The facility consists of three 0.10 acre ponds, a building which houses incubators and rearing tanks, and a well.

Adult fish were collected from a razorback sucker spawning site in the Green River, on April-May 1987. Three female razorback suckers were stripped and eggs fertilized on the spawning ground with the milt from one to three males. Twenty four other adult razorback suckers (13 females, 11 males) were taken to the Ouray facility for hormone induced spawning. Five attempts at spawning eleven females with 2 - 7 males each resulted in about 15,000 fertilized eggs. However fungus in the incubator (at low water temperature of about 11°C) wiped out all but a few hundred eggs. Five females were subsequently spawned with 1 - 3 males resulting in 4500 fertilized eggs. These eggs were treated with malachite green and moved to warmer ponds (16-21°C), where a good hatch occurred.

REFERENCE NUMBER: 055

CITATION: Vanicek, C.D. 1967. Ecological studies of native Green River fishes below Flaming Gorge Dam, 1964 - 1966. PhD Dissertation Utah State University. Logan, Utah. 121 pp.

SPECIES AND LIFE STAGE: CS, BT, CS_ADU, CS_JUV, BT_JUV

TOPICS: Life History

KEYWORDS: COLORADO SQUAWFISH, COLORADO CHUB, BONYTAIL, ROUNDTAIL CHUB, HUMPBACK SUCKER, DIET, DISTRIBUTION, FLAMING GORGE DAM, TEMPERATURE, SPAWNING, GROWTH

SUMMARY: This post-impoundment study found native Green River fishes almost eliminated for the first 7 miles below Flaming Gorge Dam, and a reduction in native species as far downstream as the mouth of the Yampa. No reproduction of native species occurred above the mouth of the Yampa in 1964 and 1966 probably due to reduced water temperatures and altered flow patterns. Reduced flow in the summer of 1965 allowed reproduction of several native species including chub sp. in the Green River above Echo Park. Colorado squawfish and "Colorado chubs" (*Gila robusta* and *Gila elegans*) grew more slowly after closure of the dam (1963-1965) than before dam closure (1955 - 1962). Bonytail grew faster than roundtail chub, and distinct differences in body weight to length relationships exist between the two. Dietary differences were also noted between roundtail chub and bonytail. Roundtail chub were piscivorous (8% of stomachs) and insectivorous while bonytail diets were limited to terrestrial insects (adult beetles, grasshoppers, and ants which were commonly found floating on the surface), plant debris, and algae. Young chubs ate mostly aquatic insects (chironomid larvae and ephemeropteran nymphs). Colorado squawfish up to 50 mm TL ate cladocerans, copepods, and chironomid larvae. Larger fish (100 mm TL) had increased proportions of insects in their stomachs. Fish over 200 mm TL ate almost exclusively other fish with redside shiners being most often identified. Humpback sucker stomachs were found to be packed with mud, containing chironomid larvae and plant stems and leaves. No seasonal or geographic changes in diet were noted for any of these species. Although young fish were found consistently after collection of ripe adults, no spawning locations or exact timing is noted for any of the above species.

REFERENCE NUMBER: 056

CITATION: Marsh, P.C., and M.S. Pisano. 1985. Influence of temperature on development and hatching success of native Colorado River fishes. Proceedings of the Annual Conference of the Western Association of Fish and Game Agencies 62:434 (abstract).

SPECIES AND LIFE STAGE: HB, HB_EGG, HB_LARVAE, BT, BT_EGG, BT_LARVAE, CS, CS_EGG, CS_LARVAE, RZ, RZ_EGG, RZ_LARVAE

TOPICS: Culture Techniques, Temperature

KEYWORDS: RAZORBACK SUCKER, HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, HATCHING TEMPERATURE, DEVELOPMENT

SUMMARY: Razorback sucker, bonytail chub, humpback chub, and Colorado squawfish eggs were spawned and fertilized at 17°C, and ova then incubated at 5, 10, 15, 20, 25, and 30°C. Total mortality of all ova occurred in 12-96 hours at 5, 10, and 30°C; and in 48-60 hours for squawfish only. Survival and percentage hatch was highest at 15-20°C (bonytail) or 20°C (all others). Hatched prolarvae were 0.2-1.3 mm TL longer at 20°C than at 15 or 25°C. Spinal or other anomalies were more frequent at 15 and 25°C than at 20°C. Development rates were similar for all species, 4.4-6.1 (15°C), 8.4-9.9 (20°C), and 12.4-18.8 (25°C). Development rate (V): temperature (T) relationships, defined as $V = mT + b$, were similar for all species, all were highly significant ($r^2 = 0.77$-0.99), and indicated a "zero development" temperature range of 8.6°C (bonytail) to 12.2°C (squawfish). Because of lower survival and significantly higher incidence of anomalies at 15 and 25°C, the optimal temperature for development and hatching of these species is probably near 20°C.

REFERENCE NUMBER: 057

CITATION: Burdick, B.D., and L.R. Kaeding. 1985. Reproductive ecology of the humpback chub and the roundtail chub in the Upper Colorado River. Proceedings of the Annual Conference of the Western Association of Fish and Game Agencies 65:163 (abstract).

SPECIES AND LIFE STAGE: HB, HB_ADULT

TOPICS: Life History, Research

KEYWORDS: HUMPBACK CHUB, SPAWNING TIME

SUMMARY: Research was conducted at Black Rocks on the Colorado River in Western Colorado in 1983 and 1984 to obtain information about the spatial and temporal spawning relationship of humpback and roundtail chub. Spawning of humpback and roundtail chubs temporally overlapped in both 1983 and 1984. Gonadosomatic indices and mean ovum diameter were the most definitive data available to estimate spawning time. Roundtail chubs spawned between the first of June and mid-July 1983 whereas humpback chubs spawned near the end of June. Spawning time for both fishes occurred later in 1984. Roundtail chubs spawned between mid-June and mid-July; humpback chubs spawned near the end of July. Occurrence of nuptial tubercles, expressible milt and relative body condition generally had limited application as a definitive indication of spawning time.

REFERENCE NUMBER: 058

CITATION: Kaeding, L.R., and M.A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado Rivers of the Grand Canyon. Transactions of the American Fisheries Society 112(5):577-594

SPECIES AND LIFE STAGE: HB, HB_ADULT

TOPICS: Life History, Diet

KEYWORDS: HUMPBACK CHUB, GROWTH, SPAWNING, HABITAT, DIET

SUMMARY: Humpback chubs in the Little Colorado River, a warm tributary to the Colorado River, grew rapidly to about 250-300 mm total length at 3 years of age, the onset of reproductive maturity for female fish. Fish spawned in April of May; annual reproductive success was greatest when spawning coincided with seasonal river runoff. Use of habitat by age-0 and juvenile humpback chubs was affected by light intensity; shallow littoral areas were used during darkness, but during daylight only when the water was turbid. Stomach contents from humpback chubs were dominated numerically by immature Chironomidae and Simuliidae. Lernaea cyprinacea was the most conspicuous metazoan parasite of humpback chubs in the Little Colorado River but was rarely found on fish in the Colorado River.

REFERENCE NUMBER: 059

CITATION: Marsh, P.C. 1985b. Razorback sucker management in Arizona. Proceedings of the Desert Fishes Council. XVII:181 (abstract).

SPECIES AND LIFE STAGE: RZ, RZ_JUV, RZ_ADULT

TOPICS: Culture Techniques, Research

KEYWORDS: RAZORBACK SUCKER, MANAGEMENT HISTORY, STOCKING, PREDATION

SUMMARY: Razorback sucker management in Arizona began in 1981 with a 10 year memorandum of understanding between Arizona Game and Fish Department (GFD) and U.S. Fish and Wildlife Service. Production is at Dexter National Fish Hatchery, New Mexico, with grow-out to larger sizes both there and at GFD Page Springs Hatchery. By 1985, more than 10 million juveniles, fingerlings, and fry have been stocked at 28 sites on the Gila, Salt, and Verde rivers and their tributaries. Stocking sites and downstream riverine reaches have been monitored annually, and reservoirs on each system were sampled in 1985. Few have been recaptured more than a few weeks after introduction. Post-stocking studies to evaluate dispersal and predation were carried out in 1984 and 1985. Fish 62-213 mm TL move downstream at night. Predation by introduced catfishes has potential to remove significant percentages of stocked fish. It is recommended that razorback be stocked at upstream localities where predator populations are absent or small, in winter when predation may be reduced, or when predators have been removed or at least depleted. Introductions should be of a few individuals over a wide time span rather than abruptly in large groups.

REFERENCE NUMBER: 060

CITATION: Jensen, B.L. 1986. The role of fish culture in endangered fishes recovery. The Proceedings of the Bonneville Chapter of the American Fisheries Society, 1986:31 - 41.

SPECIES AND LIFE STAGE: CS, BT, HB, RZ, CS_EGG, BT_EGG, RZ_EGG, CS_LAR, BT_LAR, RZ_LAR, CS_JUV, BT_JUV, RZ_JUV

TOPICS: Disease, Production, Culture, Temperature, Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, BONYTAIL, HUMPBACK CHUB, DEXTER NATIONAL FISH HATCHERY, EGGS, TL, INDUCED SPAWNING, GENETIC DIVERSITY, REINTRODUCTION, PARASITES

SUMMARY: In 1974, Dexter National Fish Hatchery began working with endangered southwestern fishes to determine if they could be held and reared in captivity. Up to 20 species of imperiled fishes have been held at one time and presently 14 species are being held at Dexter with three additional introductions planned for 1986.

Genetic diversity is an important aspect of the Dexter program. In order to maintain the genetic diversity of domestic fish, broodstock are often fish captured in the wild and additional wild fish are brought in periodically to mix with equal numbers of hatchery fish. In 1985, 625 larval razorback suckers were collected from Lake Mohave to be utilized as broodstock in 1987. A new lot of squawfish is also being reared to replace the existing brood. Attempts to collect bonytails from Lake Mohave in order to incorporate greater diversity into the broodstock have failed.

Most efforts in developing culture techniques have been concentrated on four Colorado fishes: razorback sucker, Colorado squawfish, bonytail, and humpback chub. The "wet" method is typically employed in spawning out these fish; eggs are hand-stripped into pans, milt is added from two or more males and eggs are stirred gently with a feather to ensure adequate mixing. Slurried bentonite is added following fertilization and the "clayed" eggs are poured into floating egg baskets, gently washed to remove the bentonite, allowed to water harden, enumerated gravimetrically, and placed in Heath trays and in jars. Incubator water is heated to 70 F and flow is regulated at three gpm. Female razorback suckers become gravid and spawn when water temperature approaches 55 F. Both male and female fish receive injections of chorionic gonadotropin (CG). A total of 134 three and four-year old domestic razorback sucker averaging 3.2 pounds were spawned in 1985. These fish gave a total of 8,714,114 eggs for a mean egg take of 65,030 and 19,887 eggs per pound of body weight. In 1985, 18 female Colorado squawfish averaging 3.6 pounds produced 1,490,006 eggs for a mean egg take of 82,778 (22,921 eggs/pound body weight). Overwinter mortality of the squawfish fingerlings, however, was less than one percent. Eleven female bonytails spawned naturally in holding ponds, producing 12,618 fingerlings.

The ultimate goal in the recovery effort is to restore depleted or extirpated members of the native ichthyofauna to viable, self-sustaining populations within their historic range. More than 8.7 million fry, 790,000 fingerling, and 280 adult razorback sucker have been released into Arizona waters since 1981. Monitoring surveys determined mortality of planted fish, especially fry, to be very high. Predation by ictalurids and centrarchids is the main reason for low survival.

REFERENCE NUMBER: 061

CITATION: Valentine, J. 1981. Hatchery and laboratory phase of the Colorado River Endangered Fishes Study. Proceedings of the Bonneville Chapter of the American Fisheries Society, 1981:111 - 117.

SPECIES AND LIFE STAGE: CS, BT, HB, RZ, CS_EGG, CS_LAR, CS_JUV, BT_EGG, BT_LAR, BT_JUV, HB_EGG, HB_LAR, HB_JUV, RZ_JUV

TOPICS: Temperature, Life History, Diet, Research, Water Quality, Culture, Production

KEYWORDS: COLORADO RIVER ENDANGERED FISHES STUDY, COLORADO SQUAWFISH, HUMPBACK CHUB, BONYTAIL CHUB, RAZORBACK SUCKER, TEMPERATURE, TL, SWIMMING, HABITAT, COMPETITION, INDUCED SPAWNING, HYBRID, BIOASSAY

SUMMARY: The purpose of the Colorado River Fishery Project was to gather biological information on the fishes of the Colorado River, particularly those that were listed by the Fish and Wildlife Service as endangered or threatened. The objectives of the hatchery-laboratory project are to learn how to propagate and to produce Colorado squawfish, humpback chub, and bonytail chub for laboratory studies; to determine how temperature and total dissolved solids affect these fish; to determine the toxicity of trace chemicals to them; to determine their habitat requirements and competition with other species under laboratory conditions; and, to measure their swimming ability.

Hatcheries -- Wild Colorado squawfish successfully spawned in 100 x 8 x 4 ft raceways. Several tons of gravel were placed in the upper 1/3 of the raceways to provide depths of 0 - 75 cm spawning habitat. The water was unfiltered, unsterilized river water. Maturation occurred about a month after the water temperature reached 68 to 70 F. Injections of carp pituitary were used to successfully induce spawning in both wild and domestic broodstock. Up to 95% of the wild eggs from natural spawning hatched successfully, but only about 2% of the eggs hatched of those taken from domestic broodstock. Squawfish fry were successfully converted to trout feed but grew very slowly, taking about 100 days to grow from 7 to 50 mm.

Wild humpback chubs did not spawn naturally in the gravel raceways, and few eggs were collected following inducement of spawning with carp pituitary. Fry growth was faster than the squawfish and some grew 1 mm per day.

Eggs from wild bonytail chubs were fertilized with sperm from roundtails and humpbacks. Hatching success was 75% for roundtail and 62% for humpback crosses. Growth of humpback x bonytail fry was excellent, reaching 125 mm in 6 months. Roundtail hybrids, however, grew only 75 mm and some had deformed backbones.

Laboratories -- Temperature preference is being determined under laboratory conditions for young-of-the-year, juveniles, and subadults of the razorback suckers, Colorado squawfish, humpback chub, and bonytail chub hybrids. The fish are tested individually in either an electronic shuttle box or a horizontal temperature gradient. Razorback suckers (150 - 300 mm) acclimated to temperatures of 20 and 26 C both preferred temperatures from 22 - 23 C. Colorado squawfish (100 mm) acclimated at 14, 20, and 26 C preferred water temperatures of

20.3, 28.5, and 22.8 C, respectively. A stamina tunnel is being used to test swimming performance of individual fish at three acclimation temperatures. Razorback suckers tested at water current velocities of 0.5 to 2.0 ft/sec were able to swim for 1 hour at velocities less than 1,25 ft/sec, and less than 2 minutes at velocities of 2 ft/sec or greater. No differences were detectable between temperatures.

Bioassays -- Eight inorganic and eight organic compounds are being tested in 96-hour static bioassays on Northern and Colorado squawfish. For each chemical, LD50s are determined at 12, 17, and 22 C, with total dissolved solids levels of 730, 175, and 32 mg/l. Some tests have been made which showed Colorado squawfish faring better than the Northern squawfish.

Culture -- Fiberglass tanks and aquaria were set up to hold and culture large numbers of fish various stages of development for bioassay and behavior studies. Juvenile Colorado squawfish and humpbacks are under intense culture at various temperatures and fed a commercial diet of trout feed.

Life History -- Currently, Colorado and Northern squawfish are being studied in the field and laboratory for information on spawning biology, early life history, food habits, habitat preferences, length-weight, and age-growth.

REFERENCE NUMBER: 062

CITATION: Johnson, J.E., and B.L. Jensen. 1989. History and operation of endangered species hatcheries. U.S. Fish and Wildlife Service, Dexter National Fish Hatchery, Dexter, New Mexico.

SPECIES AND LIFE STAGE: CS, CS_ADULT, BT, BT_ADULT

TOPICS: Production, Culture Techniques

KEYWORDS: COLORADO SQUAWFISH, BONYTAIL CHUB, HISTORY, BROODSTOCK, STOCKING

SUMMARY: W.L. Minckley first attempted to rear razorback suckers at the Phoenix Zoo in Arizona in 1968, but was unable to keep fish alive for more than one year. Starting in the 1970's, three long-term projects designed specifically to protect southwestern fishes were initiated. In Nevada, the U.S. Bureau of Reclamation established Devil's Hole Pupfish Refuge below Hoover Dam. In 1974, Texas Department of Parks and Wildlife constructed the Comanche Springs Pupfish Canal at Balmorhea State Recreation Area. The third facility, Dexter National Fish Hatchery, operated by the U.S. Fish and Wildlife Service, began working with native fishes in 1974. Since that time, propagation of native southwestern fishes in artificial environments has centered around the program at Dexter Hatchery.

Colorado Squawfish: The first Colorado squawfish were brought into captive propagation at Willow Beach NFH in Arizona and later transferred to Dexter NFH. A total of 122 squawfish have been taken from the wild for broodstock since 1973, but 60 of those fish were juveniles that failed to survive transfer from rearing ponds at Ouray National Wildlife Refuge. The present (1989) broodstock, maintained at Dexter, consists of 14 wild fish and two cohorts of F1 fish from wild broodstock; 185 fish from the 1974 year-class and 243 fish from the 1981 year-class. Reintroduction of Colorado squawfish began in Arizona in 1985 on the Salt and Verde rivers, as one part of the recovery of this species. Success will be evaluated in 1994 when the stocking effort is complete.

Bonytail Chub: Eighteen adult bonytail were collected from Lake Mohave between 1976-1983 as broodstock for the propagation program at Dexter NFH. Four fish failed to survive capture and transportation trauma and others have not produced gametes. Only six female and five male wild bonytail parented the existing broodfish. The present (1989) broodstock consists of 1,780 fish of the 1981 year-class; all wild fish are now dead. Approximately 110,000 bonytail chub have been stocked back into Lake Mohave between 1981-1987.

REFERENCE NUMBER: 063

CITATION: Loudermilk, W.E. 1981. Aspects of razorback sucker (Xyrauchen texanus, Abbott) life history which help explain their decline. Proceedings of the Desert Fishes Council XIII:67-72.

SPECIES AND LIFE STAGE: RZ, RZ_ADU, RZ_EGG, RZ_LAR

TOPICS: Life History, Temperature

KEYWORDS: EGG DIAMETER, FECUNDITY, TEMPERATURE PREFERENCE, SPAWNING TEMPERATURE, SPAWNING DEPTH, HYBRIDIZATION, REINTRODUCTION

SUMMARY: *Fecundity, temperature preferenda, and other biological criteria listed in this manuscript are rather dated when compared to more recent publications contained in the CWCB library. We have included this work as historical background.*

During the Period 1909 - 1938 seven dams were built on the lower Colorado River which has resulted in colder, but more uniform water temperatures extending longer into the spring, and the warming trend into the summer is slower. These condition changes have contributed to the peril of the razorback sucker. Only in the Yampa River, CO is channel substrate and temperature near natural conditions. Spawning generally occurs at temperatures of 12 - 18°C (January - April) at depths of 0.5 - 3.0 m. Substrates where spawning has been observed is made up of cleaned gravel-sand areas. Maturity occurs between 5 - 7 years of age. Relative fecundity was estimated (from Lake Mohave fish) at 27,000 - 144,000 eggs per female. Eggs are mildly adhesive to substrate and range in size from 1.8 - 3.2 mm in diameter. Time to hatching decreases as temperatures increase, with egg survival best between 16 - 25°C. Sub-adult fish had a temperature preference of 25.4°C. about 2-3 days after swim-up, larvae in aquaria used the upper 1/3 of the water column and displayed little tendency to seek shelter, a mild current would have displaced them downstream. After this period they moved to the bottom and began feeding on or near the substrate and used vegetation and rock as cover when disturbed. They rarely entered the upper half of the water column beyond 15 days after hatching. Hybridization may also be a threat to the continued presence of razorback suckers. Hybrids of razorback and many other catostomids have been reported (*Catostomus latipinnis, C. commersoni, C. discobolus, C. insignis*). Reintroduction without defining and satisfying egg and larval survival requirements and not considering habitat maintenance will not result in natural recruitment. Considering the apparent need for relatively warm egg incubation temperatures, somewhere along the lower Colorado River will be the most feasible location to attempt recovery on the mainstream. The lack of spawning substrate may be solved through modification of proposed projects.

REFERENCE NUMBER: 064

CITATION: Ulmer, L. 1980. Movement and reproduction of the razorback sucker (Xyrauchen texanus) inhabiting Senator Wash Reservoir, Imperial county California. Proceedings of the Desert fishes Council XII:106 (abstract)

SPECIES AND LIFE STAGE: RZ, RZ_ADULT

TOPICS: Life History

KEYWORDS: RAZORBACK SUCKER, SPAWNING

SUMMARY: The movements of five razorback suckers within a reservoir of the Colorado River were monitored through two spawning periods from January to April, 1980 and 1981, using ultrasonic transmitters. Telemetry data indicated that razorback suckers congregated and spawned over two gravel areas in the littoral zone of the reservoir in 2-18 feet of water. Substrate samples analyzed from spawning sites at Senator Wash Reservoir and a third location on the Colorado River revealed similar geological and petrological composition.

REFERENCE NUMBER: 065

CITATION: Osmundson, D.B. 1987. Growth and survival of Colorado squawfish (Ptychocheilus lucius) stocked in riverside ponds, with reference to largemouth bass)Micropterus salmoides) predation. M.S. Thesis, Utah State University, Logan, Utah. 191 pp.

SPECIES AND LIFE STAGE: CS, CS_JUV

TOPICS: Research

KEYWORDS: PREDATION, COLORADO SQUAWFISH, SIZE SELECTIVITY, RIVERSIDE POND REARING, GRAVEL-PIT PONDS, ANNUAL GROWTH, STOCKING

SUMMARY: Hatchery-reared Colorado squawfish 45 - 145 mm TL were stocked into five riverside ponds near Grand Junction in fall 1983 and summer 1984. Ponds were 0.85 - 3.16 hectares, and fish were stocked at 3,090 per hectare. All ponds were formed from gravel removal operations, and had been flooded by ground water. Winter low temperatures were -9.32°C, summer high temperatures were 34.44°C. Predation, parasitism and winter stress all effected survival which was generally low. Annual growth of fingerling squawfish in one warm water pond, however, was more than twice that reported from natural river conditions or hatchery ponds. With predator control, growth of spring stocked fingerlings could reach 230 - 250 mm TL by fall.

Laboratory experiments were conducted with largemouth bass to determine forage type and size preferences. In the lab, bass preferred squawfish over green sunfish and red shiners but selected fathead minnows and squawfish equally. Bass ate significantly more small than large squawfish. In pond conditions, bass switched their diet from customary food items to squawfish after squawfish were stocked. The presence of fathead minnows (equally preferred in the lab) failed to buffer predation on squawfish, indicating that stocked squawfish were more vulnerable. Survival in ponds was 0-52% thirty weeks after stocking in the fall of 1983, 0 - 46% ten weeks after stocking in summer of 1984, and 0.0 -0.3% twenty-eight weeds after stocking in the fall of 1984. Stomach contents of bass indicated that intense predation was largely responsible for the complete loss of squawfish from one pond which had a high bass density.

REFERENCE NUMBER: 066

CITATION: Seethaler, K. 1978. Life history and ecology of the Colorado squawfish (Ptychocheilus lucius) in the Upper Colorado River Basin. M.S. Thesis, Utah State University, Logan, Utah. 144 pp.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_LARVAE, CS_JUV, CS_ADULT

TOPICS: Life History, Disease

KEYWORDS: COLORADO SQUAWFISH, LIFE HISTORY, PARASITES

SUMMARY: Field observations on the life history of the Colorado squawfish were made during 1974-76 in Dinosaur National Monument and adjacent areas of the upper Green and Yampa rivers, and at Grand Junction on the Colorado mainstem. Although squawfish were captured at two widely separated localities in the Green and Colorado rivers, the species was thought to consist of a single population.

A series of 15 detailed drawings was made to document the development of young Colorado squawfish from egg, various larval stages, and juveniles. Morphometrics and meristics were tabulated for each stage. Squawfish were observed to mature when individuals reached a size of 428-503 mm TL and an age of 6-8 years. The most common parasite of the Colorado squawfish was found to be the copepoda, Lernea sp. Other parasites and diseases included the fungus, Ichthyophthirius sp., the tapeworm Proteocephalus amblopiites, and the protozoa Myxosoma sp. and Myxobolus sp.

REFERENCE NUMBER: 067

CITATION: Hendrickson, D.A. and L.H. Simons. 1988. Native fish-the long hard swim. Arizona Wildlife Views 31(2):4-7.

SPECIES AND LIFE STAGE: CS, BT

TOPICS: Life History

KEYWORDS: COLORADO SQUAWFISH, BONYTAIL CHUB, GENERAL HISTORY

SUMMARY: This is a general article dealing with the plight of southwestern fishes. A brief, general account of recent (1988) reintroductions of razorback and squawfish are given.

REFERENCE NUMBER: 068

CITATION: Rinne, J., Johnson, B. Jensen, A. Ruger, and R. Sorenson. 1986. The role of hatcheries in the management and recovery of threatened and endangered fishes. Pages 271-285 in R. Stroud, (ed.). Fish culture in fisheries management. American Fisheries Society, Bethesda, M.D.

SPECIES AND LIFE STAGE: HB,BT,CS,RZ

TOPICS: Culture Techniques, Production

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, MANAGEMENT, HATCHERIES

SUMMARY: Site suitability criteria for endangered fishes facilities were developed in the planning process for Dexter NFH. These included many standard needs; location, water quality and quantity, space, access, security, and climate. Two of the principal criteria for locating an endangered fishes facility are unique. First, isolation of the facility from natural surface waters is essential. Second, it is essential to isolate culture ponds from one another, because many of the fish species involved are phylogenetically similar and could produce fertile hybrids.

REFERENCE NUMBER: 069

CITATION: Jensen, B.L. 1987. Annual narrative report, calendar year 1987. Dexter National Fish Hatchery, U.S. Fish and Wildlife Service. Dexter, New Mexico. 23 pp.

SPECIES AND LIFE STAGE: CS, CS_JUV, RZ, RZ_JUV

TOPICS: Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, CONDITIONING, STOCKING SURVIVAL, STOCKING SIZE

SUMMARY: The effects of conditioning of hatchery-reared fish was studied to test the hypothesis that conditioning would increase survival in the wild. Prior to the 1986 stocking, squawfish and razorbacks were separated into equal groups, marked, and placed either in a raceway with no measurable current or with 5 cm/sec current.

Results of the conditioning study on razorback suckers indicated that conditioning did not appear to enhance the retention of hatchery-reared razorback sucker. All fish moved downstream, and exhibited a crepuscular pattern. Thus, prior conditioning to current has no apparent positive effects on the dispersal of razorback sucker. Only four squawfish from the 1986 stockings were recaptured causing results on the effect of conditioning inconclusive.

REFERENCE NUMBER: 070

CITATION: Valentine, J. J. 1983. Colorado River endangered fish hatchery feasibility study. U.S. Fish and Wildlife Service, Colorado River Fishery Project, Salt Lake City, Utah. 47 pp.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_LAR, CS_JUV, HB, HB_EGG, HB_LAR, HB_JUV, BT, BT_EGG, BT_LAR, BT_JUV

TOPICS: Life History, Production, Culture Techniques, Water Quality, Temperature

KEYWORDS: SITE SELECTION CRITERIA, PONDS, RACEWAYS, COLORADO SQUAWFISH, HUMPBACK CHUB, BONYTAIL CHUB, PRODUCTION NUMBERS, BROODSTOCK, PH, AMMONIA, TEMPERATURE, HEAVY METALS, D.O.

SUMMARY: This work quantifies the need for hatchery-reared Colorado River fishes in the Upper Colorado River Basin (UCRB) based upon the draft Conservation Plan (1983), and in the Lower Colorado River Basin based on Recovery Plans for Colorado River fishes. Needs for hatchery-reared fish are identified in the Conservation Plan for research/management studies, for stocking to increase upper basin stocks, and for development of a sport fishery for Colorado squawfish in a small reservoir.

Some life history information such as percentage of hatch, survival of fry, and artificial spawning techniques is presented in this paper. However, this information is quite dated.

Broodstock in hatcheries have diminished since 1981 due to theft and attrition. In order to maintain genetic variability and avoid inbreeding, geneticists advise keeping at least 50 adults for breeding, with equal numbers of males and females. Hatchery-raised Colorado squawfish can survive in the wild but their ability to reproduce is unknown. About 1500, 8-15 inch Colorado squawfish from Willow Beach NFH were tagged and stocked in the Upper Colorado River in 1980. Fifteen of these have been recaptured in association with wild fish. About 7300 humpback chubs from Willow Beach NFH were released into the Upper Colorado River in Cataract Canyon in 1981. In 1982, 42,000 hatchery-reared bonytail were released into Lake Mohave.

Several types of hatchery and laboratory facilities have been used to culture Colorado River endangered fishes. At Willow Beach NFH, water was held in raceways and aerated mechanically and circulated to achieve a water temperature of 70°C for spawning and growth. Ammonia and other waste products built-up in these raceways, so periodically water was replaced and raceways were cleaned. At the Univ. of Idaho at Moscow, 40,000 Colorado squawfish and humpback chub from Willow Beach NFH were reared for several months in a closed system with a biofilter. Flow-through systems have been used at Utah State University and the USFWS Field Research Laboratory at Jackson, Wyoming. Warm water ponds have been used for rearing at Dexter NFH, Hotchkiss NFH, Page Springs State Fish Hatchery, Arizona, and at Niland State Fish Hatchery in California. Facility designs and site evaluations are based on the projected need to produce 500,000 fingerlings per year (Colorado squawfish, humpback chub and bonytail).

Selection criteria follow:
<u>WATER</u> -- Water rights for 5-10 cfs should exist or be for sale, this must be an all season

source, must be able to refill 3 one acre ponds in 48 hrs and all ponds in 2 weeks. Water quality must meet basic requirements, be between 20-30°C, have ap least 7 ppm O_2, and pH 7-9. Water should be free of contaminants, H_2S, Mn, heavy metals, silt sand, fish and disease organisms. Gravity supply is preferred to pumping. More than a single source of water is preferred.

LAND -- Should be in federal or state ownership or be attainable, present use should not conflict with its use for a fish hatchery. At least 50 acres should be available. Should be near level but facilitate draining of ponds. Raceways should have 18 inches of fall. Site must be amenable to construction for ponds.

LOCATION -- Site should be located centrally in the Upper Colorado River Basin within the historical range of the Colorado River endangered fishes, preferably where they still occur. Housing should be available in the community.

ECONOMICS -- Construction, operation and maintenance costs should be the most economical. Life span of facilities should be considered, and operating and maintenance costs determined.

STRUCTURAL NEEDS (MINIMUM) -- 25 one acre earthen ponds, 10 0.2-0.5 acre earthen ponds and 6 raceways for pond culture; or, 10 6'x60' and 5 8'x80' raceways and 10 0.2-0.5 acre earthen ponds. Holding house with 16 tanks, and laboratory. Administration building, office, crew room, visitor's center. Three stall garage and shop. Residences, and roadways and drives.

Sites evaluated were Willow Beach NFH, Dexter NFH, Hotchkiss NFH, Logan FES, Page Springs SFH, Rifle Falls SFH, Ouray NWR, Brown's Park NWR, Big Spring, Fish Springs NWR, and Smithfield Well.

Dexter NFH may not be able to expand production due to limited water rights and leaking ponds. Proximity to the Upper Basin is less than optimal. One hatchery for holding all the reserve populations of Colorado River endangered fishes in not adequate. The Ouray Utah site has many advantages and is recommended for further analysis by this study. As an alternate site, Fish springs possess the ideal temperature for warm water fish culture. They have adequate water for raceway culture and should be suitable for ponds. This site would accelerate growth of Colorado squawfish and chubs by year-round culture in raceways. It is however remote.

REFERENCE NUMBER: 071

CITATION: Echelle, A.A. 1988. Review of genic diversity and conservation genetics in fishes of U.S. Fish and Wildlife Service Region II, with a suggested program of conservation genetics. Dept. of Zoology, Oklahoma State Univ. Stillwater, Oklahoma. 42 pp.

SPECIES AND LIFE STAGE: RZ, CS, BT

TOPICS: Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, BONYTAIL CHUB, GENETICS, REINTRODUCTION, GENIC DIVERSITY, ELECTROPHORESIS, ALLELE FREQUENCY

SUMMARY: Human activities are causing losses of genetic diversity in two primary ways: by causing attrition in population size and extinction of local populations and whole taxa, and, perhaps not so obviously, by encouraging hybridization (primarily through introductions of non-native forms). Once a taxon or geographic subdivision of a taxon has been targeted for conservation efforts, management needs and priorities depend primarily on knowledge of the geographic pattern of genetic variation. The best strategy for preserving flexibility of a taxon is to maintain as many populations as possible while retaining natural patterns of genetic diversity within and between populations. Protein electrophoresis can provide sensitive indexes of these patterns of diversity, though they should not be used to the exclusion of morphology and life-history information.

Two types of human activities contribute to loss of native populations by encouraging hybridization: 1) habitat alterations, and 2) introductions of fishes into areas outside their natural areas of occurrence. Habitat changes can heighten hybridization by allowing contact between previously separate populations, by altering environmental features important in reproductive isolation, or by reducing the abundance of a species until contact with individuals of another species becomes more likely than contact with conspecifics. When a taxon is rare, hybridization enhanced by habitat alterations may threaten the genetic integrity of the entire taxon. The introduction of non-native forms can cause catastrophic genetic introgression after only minimal introductions.

Intensive management of little understood fishes (Colorado squawfish, razorback sucker, and bonytail chub) is already underway. Ideally these activities should be based on patterns of genetic variation. One of the first priorities in plans for the recovery of any species should be to obtain geographic surveys of genetic variation. The extinctions of alleles essentially are irrevocable losses, while changes in frequencies of available alleles are not. The primary purposes of artificial propagation efforts are 1) to protect genetic resources against catastrophic loss of natural populations, 2) to allow research on needs of threatened fishes, and 3) to provide stocks for reintroduction into historic ranges of occurrence. If a species is extremely rare the goals might shift to merely preservation of as much as possible of the remaining genetic diversity. Care should be used in the choice of populations for captive propagation, sites for founding stock should show the highest heterozygosity. The primary problem to be avoided in preserving genetic integrity of captive populations are loss of genetic variability due to genetic drift, genetic changes due to selection, and contamination with foreign genes. In artificially spawned species, the initial founding population size should have an "absolute minimum" of 25 females and 25 males; succeeding generations in captivity should be maintained at no fewer than 100 females and 100 males; and effort should be made to

equalize the reproduction of all individuals in the founding population.

Contained as a secondary portion to this document is a well thought out program of conservation genetics to be applied to Western North American fishes. It is quite detailed and reviews all priorities for preservation of viable natural fish populations.

REFERENCE NUMBER: 072

CITATION: Brooks, J.E. 1986a. Annual reintroduction and monitoring report for the razorback sucker Xyrauchen texanus, in the Gila River Basin, Arizona, 1985. Arizona Game and Fish Department, Albuquerque, New Mexico. 23 pp.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE, RZ_JUV

TOPICS: Production, Research

KEYWORDS: RAZORBACK SUCKER, STOCKING, GROWTH, SURVIVAL

SUMMARY: Three million razorback suckers were stocked by USFWS and AGFD at fifteen localities in the Gila River drainage, Arizona in 1985. Most (86.5%) were fry transplanted in the Salt River drainage. Monitoring surveys conducted in 1985 showed that stocked razorback sucker growth was evident; with subfingerlings more than doubling in size and fingerlings in Bonita Creek about 25% larger at time of capture. Stocked suckers were found to grow best in backwaters where other catostomids were absent. Mainstem river sampling failed to collect any razorback sucker. In 1985 post-stocking dispersal studies on 25,875 razorback suckers (90 mm TL) showed dispersal of stocked razorbacks was downstream, with only one fish taken 0.5 km above.

Data indicate that the presence of introduced predators is a primary factor affecting success of recovery. It was also thought possible that conventional pond rearing may adversely affect a razorback's ability to adapt rapidly to the lotic environment when stocked. Nearly all fry (87%) of razorbacks stocked in 1985, were susceptible to essentially all sizes of predators. It was recommended that size of stocked razorback should be no less than 250 mm TL.

REFERENCE NUMBER: 073

CITATION: Brooks, J.E. 1986b. Reintroduction and monitoring of Colorado Squawfish (Ptychocheilus lucius) in Arizona, 1985. Arizona Game and Fish Department, Albuquerque, New Mexico. 15 pp.

SPECIES AND LIFE STAGE: CS

TOPICS: Production, Research

KEYWORDS: COLORADO SQUAWFISH, STOCKING, SURVIVAL

SUMMARY: Colorado squawfish were stocked into six locations of the Salt and Verde Rivers. More than 96,000 fingerling and 442 larger (355-405 mm TL) squawfish were stocked August through October 1985. Initial monitoring consisted of over-night trammel netting at one site on the Verde River in September of 1985. From this site seven Colorado squawfish from the 26 August 1985 stocking were collected. Seining in September and a later trip by Arizona State University personnel in November failed to collect any additional squawfish.

It was recommended that squawfish be stocked in upstream tributaries to avoid stranding of fish in irrigation diversions and to reduce predation by non-natives. Also recommended was the stocking of larger fish

REFERENCE NUMBER: 074

CITATION: Muth, R.T. 1990. Predator-prey interactions between selected non-native fishes of the Colorado River and larval Colorado squawfish and razorback sucker (Progress Report). Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado. 55 pp.

SPECIES AND LIFE STAGE: CS, CS_LARVAE, RZ, RZ_LARVAE

TOPICS: Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, PREDATION, RED SHINER, CHANNEL CATFISH, GREEN SUNFISH

SUMMARY: This study examined predator-prey interactions between three potential predators (adult red shiner, young channel catfish and green sunfish) and larval Colorado squawfish and razorback sucker under laboratory conditions.

Before addition of predators larval razorback were distributed fairly evenly throughout the aquarium. After addition of predators, larvae tended to stay in the upper 1/2 of the aquaria (light and dark periods). During light periods predators tended to stay on bottom 1/2 of aquaria; however green sunfish would actively swim to the surface to chase/capture a larvae. During dark periods catfish and shiners were observed actively swimming throughout the aquaria.

Before addition of predators larval squawfish were distributed throughout aquaria (most in bottom half) then, with addition of predators, they moved to the upper half. Behavior of predators was similar to that described in the razorback trials: sunfish actively pursuing prey in light hours, catfish and shiners more active in dark hours.

REFERENCE NUMBER: 075

CITATION: Mpoame, M. and E.J. Landers. 1981. Ophiotaenia critica (Cestoda: Proteocephalidae), a parasite of the Colorado River squawfish. Great Basin Naturalist 41(4):445-448.

SPECIES AND LIFE STAGE: CS, CS_ADU

TOPICS: Research

KEYWORDS: PARASITES, COLORADO SQUAWFISH, ANTIHELMINTHICS

SUMMARY: Nineteen tapeworms of an apparently new species were recovered from adult Colorado squawfish maintained at Willow Beach National Fish Hatchery. Treated fish were held in isolated portions of the raceways over a three day period. Voided worms were collected hourly. During October 1980 fish were treated with the antihelminthic Di-N-butyl Tin Oxide in graded dosages of 480 mg, and 1120 mg per fish per day. Another treatment was conducted in April. Fish were treated once with oxytetracycline HCl (Terramycin) at a rate of 25 mg/pound of fish body weight, with no antihelminthic drug used. Parasites were stained with Grenacher's alcoholic borax carmine, Semichon's acetic carmine, and Harris's hematoxylin using procedures of Meyer and Olsen (1975). Schmidt's (1970) identification key was used to determine the genus Ohpiotaenia. Most species in this genus have been reported from amphibian and reptilian hosts with two exceptions from piscine hosts, one from Channel Catfish and one from a siluroid fish, Synodontis schall. The specific name is derived from the latin criticus, meaning critical, or decisive, and is used in reference to the endangered status of the host species, the Colorado squawfish.

REFERENCE NUMBER: 076

CITATION: Douglas, P.A. 1952. Notes on spawning of the humpback sucker, Xyrauchen texanus (Abbot). California Fish and Game 38:149-155.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE, RZ_ADULT

TOPICS: Life History

KEYWORDS: RAZORBACK SUCKER, SPAWNING

SUMMARY: In March 1950, razorback sucker were observed spawning in the littoral areas of Lake Havasu. Two suckers, both ripe males exuding milt, were seined. Their lengths were 21.2 and 21.3 in and their weights 4.8 and 5.5 lbs, respectively. Nine other ripe males were sampled with gill nets. No females were captured. Spawning groups as large as 48 were noted. One larval sucker was found in a plankton tow. Temperatures averaged 62°F over the 15 day observation period (March 2 to 17)

REFERENCE NUMBER: 077

CITATION: Berry, C.R., and R. Pimentel. 1985. Swimming performances of three rare Colorado River fishes. Transactions of the American Fisheries Society 114(3):397-402.

SPECIES AND LIFE STAGE: HB, HB_JUV, BT, BT_JUV, CS, CS_JUV, CS_ADULT

TOPICS: Research

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, SWIMMING PERFORMANCE, FATIGUE VELOCITY, FV50

SUMMARY: A stamina tunnel was used to determine the prolonged swimming performance of age-0 humpback chub, bonytail chub, Colorado squawfish, and subadult squawfish. The fatigue velocity in body lengths per second at which 50% of the test fish were fatigued (FV50) was determined at 14, 20, and 26°C. The ranges of FV50 values for the three fishes (average total length in parentheses) were: humpback chub (95 mm), 4.4-5.7; bonytail chub (99 mm), 4.7-5.8; small Colorado squawfish (104 mm), 4.0-4.5; large Colorado squawfish (432 mm), 2.0-2.3. Absolute speed of large Colorado squawfish was about 2.4 times that of small squawfish. Swimming ability of subyearlings increased with increased water temperature. Swimming abilities were found to be similar to other fish species.

REFERENCE NUMBER: 078

CITATION: Haynes, C.M., T.A. Lytle, E.J. Wick, and R.T. Muth. 1984. Larval Colorado squawfish (Ptychochielus lucius Girard) in the Upper Colorado River Basin, Colorado, 1979-1981. Southwestern Naturalist 29(1):21-33.

SPECIES AND LIFE STAGE: CS, CS_LARVAE

TOPICS: Life History

KEYWORDS: COLORADO SQUAWFISH, LARVAL DISTRIBUTION, COLORADO RIVER, YAMPA RIVER

SUMMARY: A survey of the Colorado River drainage in Colorado was made during the summer-fall of 1979-1981 to determine the distribution of larval Colorado squawfish and relate their occurrence to hydrological regime. Squawfish larvae were collected in the lowermost 31 km of the mainstem Colorado River in 1979-81 and in the lowermost 29 km of the Yampa River in 1980-81. Larval squawfish were not found in collections from either the Gunnison or White Rivers. Estimates of spawning periods for the Colorado River range from as early as 18 June in 1981 to as late as 26 August in 1980. In the Yampa it was estimated that spawning occurred as early as 16 June in 1980 and as late as 3 August in 1981. Observations indicated that reproductive success was related to both flow and temperature regimes.

REFERENCE NUMBER: 079

CITATION: Osmundson, D.B., and L.R. Kaeding. 1989. Colorado squawfish and razorback sucker grow-out pond studies as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. U.S. Fish and Wildlife Service, Colorado River Fishery Project. Grand Junction, Colorado. 57 pp.

SPECIES AND LIFE STAGE: CS, CS_JUV, CS_ADULT, RZ, RZ_JUV, RZ_ADULT

TOPICS: Production, Culture Techniques, Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER

SUMMARY: Results of this study, and of earlier investigations by Osmundson (1987), indicate that riverside gravel-pit ponds can provide good rearing habitat for Colorado squawfish. Growth rates varied considerably among ponds. Growth rate was found to be tied to stocking density and the availability of forage. Survival rates also vary, but are generally low (as low as 1.5%). Starvation, susceptibility to common pathogens due to inadequate forage, and possible asphyxiation from hydrogen sulfide were offered as possible explanations for the low survival rates.

Growth rate and survival was extremely high for the 430 razorbacks stocked in the riverside gravel-pit ponds. Mean length was 462 mm, mean weight was 1088 g, and all fish apparently had reached sexual maturity by the end of the third growing season. Rapid growth was attributed to the pond's high productivity and low numbers of razorback stocked.

REFERENCE NUMBER: 080

CITATION: Arizona Game and Fish Department. 1988. Bubbling Pond Hatchery 1988 Annual Hatchery Report 89-15. Phoenix, Arizona.pp 44-48.

SPECIES AND LIFE STAGE: CS, CS_JUV, CS_ADULT, RZ, RZ_JUV, RZ_ADULT
TOPICS: Production, Culture Techniques, Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, HORMONE INJECTION, FECUNDITY, DIET

SUMMARY: Colorado squawfish from Pond 31 were captured and examined for ripeness on June 2, 1988. Ripeness was determined by presence of tubercles, and for the females by the softness of the abdomen and the color and shape of the genital papilae. Thirty females and 60 males were transferred to raceways. Females were injected with 2 mg acetone dried carp pituitary (CP)/lb body weight intraperitoneally. Fish were stripped 24 hours later. Eggs were stripped into pans containing sperm diluent and bentonite clay. Eggs were transferred to baskets to water harden for 1/2 hour.

A total of 712,897 eggs were taken from 26 females with a mean number of 29,946 eggs/female. Eggs began hatching in 48 hours and completed hatching in 72 hours at incubation temperatures of 68°F. Approximately 50% hatched. Sac-fry were transferred to hatchery tanks until swim-up, and then transferred to rearing ponds.

Pond 1 was filled and fertilized with 50 lbs of 16-20-0. One gallon of Diquat and 28 pounds of copper sulfate were used for vegetation control. The pond was stocked with 100,000 squawfish fry on June 15. The fish were fed 2-5 lbs trout food daily. In October, 8,000 fish were harvested at a mean size of 2.1". Fish survival was a poor 8% because of poor vegetation control and cannabalism.

Pond 5 was filled and fertilized with 50 lbs of 16-20-0. After filling, it was treated with 23 lbs copper sulfate and 1 qt Sonar during the rearing period for vegetation control. On June 15, 100,000 squawfish fry were stocked and fed 2-5 lb trout food daily. During October, 22,400 fish were harvested at a mean size of 2.1". Fish survivival was 22.4% and vegetation control was excellent.

Razorback sucker fry (300,000) were received March 14, 1988, from Dexter NFH. Fry were placed in each of four ponds at a density of 75,000. Survival was 60.0%, 63.7%, 72.0%, and unevaluated from March to October when the fish were 3.0 to 3.2" long.

Pond 2 was filled and fertilized with 50 lb of 16-20-0. After filling, it was fertilized with an additional 270 lb of 16-20-0 and 2 gal liquid fertilizer. It was treated with 10 lb Karmex, 1 gal liquid Karmex, 10 lb copper sulfate, and 3/4 quart Sonar for vegetation control. The 75,000 fry were stocked March 14 and fed trout food daily at a rate of 5-15 lb. Survival was 60% with no vegetation problems.

Pond 4 was filled and fertilized with 50 lb of 16-20-0. After filling, it was fertilized with an additional 200 lb of 16-20-0 and 2 gal liquid fertilizer. It was treated with 10 lb Karmex, 1 gal liquid Karmex, 10 lb copper sulfate, and 3/4 quart Sonar for vegetation control. The 75,000 fry were stocked March 14 and fed trout food daily at a rate of 5-15 lb. Survival was 64% with no vegetation problems.

Pond 28 was filled and fertilized with 50 lb of 16-20-0. After filling, it was fertilized with an additional 200 lb of 16-20-0 and 2 gal liquid fertilizer. It was treated with 8 lb Karmex, 2.5 gal Cutrine-Plus, 1/2 gal Diquat for vegetation control. The 75,000 fry were stocked March 14 and fed trout food daily at a rate of 5-15 lb. Survival was 72% with but weed control was poor.

Pond 28 was filled and fertilized with 50 lb of 16-20-0. After filling, it was fertilized with an additional 175 lb of 16-20-0 and 2 gal liquid fertilizer. It was treated with 8 lb Karmex, 2.5 gal Cutrine-Plus, 1/2 gal Diquat for vegetation control. The 75,000 fry were stocked March 14 and fed trout food daily at a rate of 3-10 lb. Survival was not evaluated and weed control was poor.

REFERENCE NUMBER: 081

CITATION: Arizona Game and Fish Department. 1989. Bubbling Pond Hatchery 1989 Annual Report 90-2. Phoenix, Arizona. pp 55-58.

SPECIES AND LIFE STAGE: CS, CS_JUV, CS_ADULT, RZ, RZ_JUV, RZ_ADULT

TOPICS: Production, Culture Techniques, Research

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, HORMONE INJECTION, FECUNDITY, DIET

SUMMARY: Colorado squawfish from Pond 31 were captured and examined for ripeness during the first week of June. Ripeness was determined by presence of tubercles and free-flowing milt, and for the females by the softness of the abdomen and the color and shape of the genital papilae. Thirty females and 60 males were transferred to raceways. Females were injected with 2 mg acetone-dried carp pituitary (CP)/lb body weight. Fish were stripped 24 hours later. Eggs were stripped into pans containing sperm diluent and bentonite clay. Eggs were transferred to baskets to water harden for 1/2 hour.

A total of 712,897 eggs were taken from 26 females with a mean number of 29,946 eggs/female. All eggs were hatched in 72 hours at incubation temperatures of 68°F. Approximately 50% hatched. Sac-fry were transferred to hatchery tanks until swim-up, and then transferred to rearing ponds.

Pond 23 was filled and fertilized with 80 lbs alfalfa pellets and 50 lb cottonseed meal. After filling an additional 120 lb alfalfa pellets, 75 lbs cottonseed meal, 55 lb of 18-46-0 and 11 gal liquid fertilizer were added. Sonar at 1.2 qt/acre, Diquat at 1 gal/acre-ft and cutrine at 2 gal/acre-ft was added for vegetation control. On June 9, 20,000 squawfish fry were stocked but no fish were harvested on September 22. Seventeen smallmouth bass 8" long were found in the pond.

Pond 24 was filled and fertilized with 80 lbs alfalfa pellets and 50 lb cottonseed meal. After filling an additional 120 lb alfalfa pellets, 65 lbs cottonseed meal, 30 lb of 18-46-0 and 11 gal liquid fertilizer were added. Sonar at 1.2 qt/acre, Diquat at 1 gal/acre-ft and cutrine at 2 gal/acre-ft was added for vegetation control. Granual cutrine-plus at 90 lb/acre was also added. On June 9, 50,000 squawfish fry were stocked and 2,625 were harvested on September 21 at a mean size of 2.7".

Pond 26 was filled and fertilized with 40 lbs alfalfa pellets and 50 lb cottonseed meal. After filling an additional 20 lb of 18-46-0 and 11 gal liquid fertilizer were added. Sonar at 1.2 qt/acre and cutrine at 2 gal/acre-ft was added for vegetation control. Granual cutrine-plus at 90 lb/acre was also added. On June 9, 50,000 squawfish fry were stocked and 392 were harvested on September 20 at a mean size of 2.9".

Razorback sucker fry and fingerlings were reared under similar conditions with a survival of 85%, 15.9%, 19.2%, and 7.8% survival. Growth from March to September was 3", 11", 9.2", and 11.5".

REFERENCE NUMBER: 082

CITATION: U.S. Fish and Wildlife Service. 1987. Recovery implementation program for endangered fish species in the Upper Colorado River Basin. U.S. Fish and Wildlife Service Region 6, Denver, Colorado.

SPECIES AND LIFE STAGE: CS, CS_JUV, CS_ADULT, RZ, RZ_JUV, RZ_ADULT

TOPICS: Life History

KEYWORDS: COLORADO SQUAWFISH, RAZORBACK SUCKER, STOCKING, GENETIC DIVERSITY

SUMMARY: "Stocking of native fish species" is identified as one of the five principal recovery elements for the endangered fishes of the upper Colorado River basin. Colorado squawfish and humpback chub are reproducing in the upper basin, but their long-term reproductive success is unknown. The bonytail chub appears in imminent danger of extinction since it has been found in insufficient numbers to effectively support a viable population; only five have been captured in the upper basin in the past few years. Recent data indicate the razorback sucker is very rare and its population is limited to a small number of very old adults; successful recruitment in the wild has never been documented.

Procedures for producing the rare species in hatcheries for the research program will be developed by the Service, and will include: (1) Maintenance of genetic diversity, (2) Collection of gametes from the wild, (3) Procedures for spawning at the hatchery, (4) Location of fish stocks, (5) Details on research projects, and (6) Method of transport and release to the wild.

REFERENCE NUMBER: 083

CITATION: U.S. Fish and Wildlife Service. 1989. Three year propagation/genetics management work plan.

SPECIES AND LIFE STAGE: HB,BT,CS,RZ

TOPICS: Life History, Research

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, BROODSTOCK, STOCKING, GENETICS, PROPAGATION

SUMMARY: Addresses the following objectives and tasks:

Objective 1: Develop ad hoc propagation work group

Task 1: Establish ad hoc propagation work group

Task 2: Hire full-time fish culture expert

Task 3: Expand & update 3-yr propagation/genetics plan

Objective 2: Short Term Fish Needs

Task 1: Identify all principal investigators and request updated information on fish needs

Task 2: Summarize findings

Task 3: Requests to Dexter/Willow Beach NFH

Objective 3: Review, refine, and update long-term fish needs in five year increments

Task 1: Establish fish needs for broodstock development, refugium stocks, research needs, augmentation.

Objective 4: Genetics Management Plan

Task 1: Develop a work plan draft

Task 2: Hire genetics expertise to develop plan

Task 3 and 4: Develop and implent plan, establish necessary schedules and protocols for implementation

Task 6: Develop genetics data base

Objective 5: Colorado River endangered fish hatchery and research center

Task 1: Identify short and long-term needs and review and recommend new technologies

Task 2: Determine requirements and limiting factors in nature and under fish culture conditions.

Task 3: Establish site/facility criteria

Task 4: Site evaluations

Task 5-8: Engineering assessment and design

Objective 6: Refugia or Gene Banks

Task 1: Develop criteria and necessary protocols for operating and managing Colorado River endangered fish refugia

Task 2: Develop plan for initiating refugia with implementation schedule

Objective 7: Integrated Recovery Management Plan

Task 1: Develop in collaboration with other Service branches recommendations for an integrated recovery management plan

REFERENCE NUMBER: 084

CITATION: Williams, J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras-Balderas, J.D. Williams, M. Navarro-Mendoza, D.E. McAllister, and J.E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14(6):2-20.

SPECIES AND LIFE STAGE: HB,BT,CS,RZ

TOPICS: Life History

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, ENDANGERED SPECIES ACT

SUMMARY: The American Fisheries Society herein provides an update of their 1979 list of rare North American fishes. The 1989 list adds 139 new taxa to the 1979 list of 251 fishes and removes 26 for a total of 364 fishes in Canada, United States, and Mexico that warrant protection because of their rarity. Not a single fish warranted removal from the list because of successful recovery efforts. In addition, 49 fishes have changed in status but remain on the list: 7 have improved in status, 24 have declined, and 18 have been reclassified.

REFERENCE NUMBER: 085

CITATION: Miller, R.R. et al. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22-38.

SPECIES AND LIFE STAGE: HB,BT,CS,RZ

TOPICS: Life History

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, ENDANGERED SPECIES ACT

SUMMARY: Extinctions of 3 genera, 27 species, and 13 subspecies of fishes from North America are documented during the past 100 years. Extinctions are recorded from all ares except northern Canada and Alaska. Regions suffering the greatest loss are the Great Lakes, Great Basin, Rio Grande, Valley of Mexico, and Parras Valley Mexico. Physical habitat alteration was the most frequently cited causal factor (73%) contributing to extinction.

REFERENCE NUMBER: 086

CITATION: Colorado River Fishes Recovery Team. 1984. Humpback chub (Gila cypha) recovery plan (agency review draft). 40 pp.

SPECIES AND LIFE STAGE: HB, HB_EGG, HB_LARVAE, HB_JUV, HB_ADULT

TOPICS: Culture Techniques, Life History

KEYWORDS: HUMPBACK CHUB, BROODSTOCK, STOCKING, GENETICS, REINTRODUCTION

SUMMARY: Item 6 of the stepdown plan is as follows:

Assess potential reintroduction or augmentation sites and implement stocking when deemed necessary and feasible.

6.1 Establish and maintain production facilities

6.1.1 Select and support appropriate production facilities

6.1.2 Select broodstocks

6.1.3 Maintain genetic variability and integrity in broodstocks

6.1.4 Develop/refine rearing and handling techniques

6.1.5 Establish production goals in terms of numbers and sizes that are needed for reintroduction or augmentation

6.2 Implement and evaluate reintroductions and augmentations

6.2.1 Identify areas for reintroduction

6.2.2 Restore and prepare stocking sites as needed for reintroduction or augmentation

6.2.3 Develop and implement a plan for stocking and monitoring activities

6.2.3.1 Determine optimum size and time for stocking

6.2.3.2 Determine stocking rates and duration needed to reestablish humpback chub populations

6.2.3.3 Establish a monitoring program to evaluate the success of reintroductions

REFERENCE NUMBER: 087

CITATION: Colorado River Fishes Recovery Team. 1984. Bonytail chub (Gila elegans) recovery plan (technical review draft). 40 pp.

SPECIES AND LIFE STAGE: BT, BT_EGG, BT_LARVAE, BT_JUV, BT_ADULT

TOPICS: Culture Techniques, Life History

KEYWORDS: BONYTAIL CHUB, BROODSTOCK, STOCKING, GENETICS, REINTRODUCTION

SUMMARY: Item 1.3 of the stepdown plan is as follows:

1.3 Reintroduce bonytail chub into the wild with hatchery-reared fish.

- 1.3.1 Develop an artificial propagation and rearing plan
- 1.3.2 Propagate bonytail chub
  - 1.3.2.1 Refine propagation techniques
  - 1.3.2.2 Spawn bonytail chub using the best available broodstocks
- 1.3.3 Rear bonytail for stocking to a size that provides good survival
- 1.3.4 Conduct experimental stocking of bonytail chub and identify priority recovery areas
- 1.3.5 Stock reared bonytail in priority recovery sites

REFERENCE NUMBER: 088

CITATION: Colorado River Fishes Recovery Team. 1978. Colorado Squawfish (Ptychocheilus lucius) revised recovery plan, (original approval: March 16, 1978). 52 pp.

SPECIES AND LIFE STAGE: CS, CS_EGG, CS_LARVAE, CS_JUV, CS_ADULT

TOPICS: Culture Techniques, Life History

KEYWORDS: COLORADO SQUAWFISH, BROODSTOCK, STOCKING, GENETICS, REINTRODUCTION

SUMMARY: Item 3.0 of the stepdown plan is as follows:

3.0 Reintroduce Colorado squawfish into their historic range.

3.1 Develop capabilities to produce adequate numbers of Colorado squawfish for research and mangement

3.1.1 Develop or improve propagation, holding, and rearing techniques to optimize production

3.1.2 Maintain a diversified gene pool

3.2 Conduct reintroduction/augmentation programs

3.2.1 Identify areas for reintroduction/augmentation

3.2.2 Restore or prepare stocking sites as needed

3.2.3 Stock and monitor reintroduced/stocked populations

REFERENCE NUMBER: 089

CITATION: U.S. Fish and Wildlife Service. 1988. Plan for the propagation of threatened and endangered fishes of the upper colorado river basin.

SPECIES AND LIFE STAGE: HB,BT,BS,RZ

TOPICS: Culture Techniques, Life History

KEYWORDS: HUMPBACK CHUB, BONYTAIL CHUB, COLORADO SQUAWFISH, RAZORBACK SUCKER, CULTURE, GENETICS

SUMMARY: Document emphasizes need to develop a comprehensive plan and strategy for propagation to effectively meet recovery goals. Requirements are identified as: (1) constant full-time involvement of trained technical staff to develop, manage, and execute, (2) commitment by agencies, (3) sound, reasoned, professional approach to address technical aspects of fish culture, (4) in-depth genetic evaluation and plan, (5) detailed site and engineering assessments. Objectives and tasks outlined are similar to those presented by the Three-Year Propagation/Genetics Management Work Plan (USFWS 1989).

REFERENCE NUMBER: 090

CITATION: Bestgen, K.R. 1990. Status review of the razorback sucker, Xyrauchen texanus (draft). Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado. 93 pp.

SPECIES AND LIFE STAGE: RZ, RZ_EGG, RZ_LARVAE, RZ_JUV, RZ_ADULT

TOPICS: Culture Techniques, Life History

KEYWORDS: RAZORBACK SUCKER

SUMMARY: Document presents a thorough search of the literature pertinent to the razorback sucker. Status review was developed for this species in lieu of a Recovery Plan since the razorback sucker is not a listed species. A petition was filed to propose for listing on May 22, 1990.

REFERENCE NUMBER: 091

CITATION: Tyus, H.M., and S.H. Severson. 1990. Growth and survival of larval razorback suckers Xyrauchen texanus fed five formulated diets. Progressive Fish Culturist 52(3): In Press. 9 pp.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE

TOPICS: Production, Culture Techniques, Diet

KEYWORDS: RAZORBACK SUCKER, SURVIVAL, COMMERCIAL FRY DIETS, DIET

SUMMARY: Razorback sucker sac fry were reared 45 d on five commercial fry diets as first foods. The five diets were AP-100 (Zeigler Bros., Inc., Gardners, PA), LIV (Farm and Wildlife Products, Inc., Omaha, NE), 4200 (Bio-Marine, Hawthorne, CA) and A-250 and B-250 (BioKyowa, Inc., St. Louis, MO). Fish fed diets of LIV and B-250 had 78% survival, and diets AP-100, 4200, and B-250 had fish survival of 59%, 32%, and 20%, respectively. Fish total length at study completion ranged from 12.3 to 26.3 mm, and average fish weight ranged from 0.026 to 0.092 g. Growth of fish fed a limited ration (1-5% body weight per day) was comparable to other laboratory experiments using live foods. The authors recommend the use of foods producing highest survival (LIV or B-250) as first foods for razorback sucker.

REFERENCE NUMBER: 092

CITATION: Severson, S.H., C.A. Karp, H.M. Tyus, and G.B. Haines. 1990. Rearing of razorback suckers at Ouray, Utah. Proceedings of the Bonneville Chapter of the American Fisheries Society 1990: In Press. 4 pp.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE, RZ_JUV

TOPICS: Production, Culture Techniques, Diet

KEYWORDS: RAZORBACK SUCKER, SURVIVAL, STREAMSIDE FERTILIZATION, DIET, STOCKING

SUMMARY: The U.S. Fish and Wildlife Service established an experimental endangered fish hatchery at the Ouray National Wildlife Refuge, Ouray, Utah in 1987 to develop techniques for rearing and propagation of the razorback sucker. Efforts were concentrated on refining streamside fertilization techniques, intensive culture of larvae, establishment of brood stock from fry of wild-fish parentage, and stocking of young fish. Adult razorback were captured in the Jensen area of the Green River from 1987 to 1989, sex products were stripped in the field, and fertilized eggs were transported to the hatchery for incubation and rearing.

These progeny were used in studies evaluating growth and survivorship of fish in ponds, and in fish fed one of five commercial diets in tanks. The use of commercial foods has aided the establishment of seven lots of prospective brood stock representing progeny of seven females from two different spawning areas. These and future lots may be used in intensive population augmentation effort to aid the recovery of the razorback sucker in the Upper Colorado River basin. Preliminary information from stocked fish (N = 1,879, 40-271 mm TL) indicated that they moved from shoreline habitats in which they had been stocked to other habitats.

REFERENCE NUMBER: 093

CITATION: Knott, K. 1990. Intensive culture of Colorado squawfish to enhance growth and survival of fry. Colorado State University, Fort Collins, Colorado. 15 pp.

SPECIES AND LIFE STAGE: CS, CS_LARVAE

TOPICS: Production, Culture Techniques, Diet

KEYWORDS: COLORADO SQUAWFISH, SURVIVAL, COMMERCIAL FRY DIETS, DIET, GROWTH

SUMMARY: During intensive culture at the Bellvue Research Hatchery, Bellvue, Colorado, Silver Cup and Biokowa diets were compared to find out which diet enhanced survival and growth rates of Colorado Squawfish. Survival rates ranged from 90-99.8%. Fry that were being fed the Silver Cup diet measured an average of 0.58 inches TL after 60 days of feeding. Fry that were being fed the Biokyowa diet averaged 0.70 inches total length after the same period. After 44 days of feeding, fry that were fed the Silver Cup diet began to swim erratically and were later diagnosed as having scoliosis, which can arise from dietary deficiencies. Monthly temperature units (MTU) were generated for comparison of growth among fry held in troughs at different water temperatures. Fry reared at 69-71 °F required 69.82-77.00 MTU's to achieve an inch of growth, fry held at 65 °F required 118.57 MTU's to achieve an inch of growth.

REFERENCE NUMBER: 094

CITATION: Black, T. 1982. Preferred temperature of Colorado squawfish (Ptychocheilus lucius) and its relations with age and growth rate. M.S. Thesis, Utah State University, Logan, Utah. 47 pp.

SPECIES AND LIFE STAGE: CS, CS_JUV, CS_ADULT

TOPICS: Temperature

KEYWORDS: COLORADO SQUAWFISH, TEMPERATURE PREFERENDUM, GROWTH RATE, DIET

SUMMARY: Temperature preference of Colorado squawfish was determined for both juvenile and adult fish in a horizontal gradient trough. Fish were acclimated to 14, 20, and 26 °C, and twenty juveniles and ten adults were tested from each acclimation temperature. Acute preferenda (mean of individual modes) were plotted against acclimation temperature to estimate final preferendum. Acute preferenda of juveniles were 21.9, 27.6, and 23.7 °C for 14, 20, and 26 °C acclimated fish respectively. Acute preferenda of adults were 21.5, 22.5, and 25.7 °C for 14, 20, and 26 °C acclimated fish, respectively. Adult and juvenile squawfish appear to have the same final thermal preferendum, approximately 25 °C.

Growth rate of juvenile Colorado squawfish was determined over a 12-week period at four different temperatures (15, 20, 25, and 30 °C) and two different rations (satiation and 50% satiation). The effect of ration on growth rate was significant; but both rations appeared to be in excess, and growth was actually better at the 50% satiation feeding level for fish held at 15, 20, and 25 °C, with maximal growth occurring at 25 °C. Fish gained approximately 0.3 g at 15 °C, 0.9 g at 20 and 30 °C, and 1.7 g at 25 °C over the 12-week period.

REFERENCE NUMBER: 095

CITATION: Keading, L.R., D.B. Osmundson, and C.R. Berry. 1985. Temperature as a resource limiting Colorado squawfish in the upper Colorado River Basin. U.S. Fish and Wildlife Service, Colorado River Fishery Project. Grand Junction, Colorado. 16 pp.

SPECIES AND LIFE STAGE: CS, CS_LARVAE, CS_JUV, CS_ADULT

TOPICS: Temperature

KEYWORDS: COLORADO SQUAWFISH, TEMPERATURE, LIMITING FACTORS, GROWTH

SUMMARY: The authors argue that the short growing season of the upper basin results in slow growth and late age of reproduction of Colorado Squawfish. The consequence of these life-history characteristics is a greatly reduced potential for growth. Temperature, as it affects length of growing season, should therefore be considered a limiting resource.

REFERENCE NUMBER: 096

CITATION:

Thompson, J.M. 1989. The role of size, condition, and lipid content in the overwinter survival of age-0 Colorado squawfish. M.S. Thesis, Colorado State University, Fort Collins, Colorado. 87 pp.

SPECIES AND LIFE STAGE: CS, CS_LARVAE

TOPICS: Research

KEYWORDS: COLORADO SQUAWFISH, OVERWINTER SURVIVAL, LIPID CONTENT

SUMMARY: Three size classes (small = 30 mm, medium = 36 mm, and large = 44 mm) of hatchery-reared age-0 Colorado squawfish were held at simulated winter temperatures (3-4 °C) in aquaria for 210 days to assess the role of size, condition factor, and lipid content on overwinter survival. Fish of each size class were divided among six aquaria and furnished one of three feeding regimes: dry-pellet-fed, starved, and brine-shrimp fed. Fish in all size classes fed at winter temperatures, and feeding activity was inversely related to fish size. On each of days 70 and 140 of the simulated winter period, one- fourth of the surviving fish in each aquarium were removed and measured to determine length and condition factor.

The fish grew little, and condition declined as length of exposure to winter conditions increased. Condition declined more rapidly in starved than in fed fish in all size classes. Lipid content of fish was inversely related to winter duration for all size classes and feeding regimes. Percent survival was significantly lower in starved small and medium-sized fish than in fed fish of these sizes. Laboratory results were used to construct several curves that depict the range of length-overwinter survival scenarios that may be occurring in wild populations of age-0 Colorado squawfish.

REFERENCE NUMBER: 097

CITATION: Hubbs, C.L., and R.R. Miller. 1953. Hybridization in nature between the fish genera Catostomas and Xyrauchen. Michigan Academy of Science, Arts and Letters XXXVIII (1952):207-233.

SPECIES AND LIFE STAGE: RZ, RZ_ADULT

TOPICS: Research

KEYWORDS: RAZORBACK SUCKER, HYBRIDIZATION

SUMMARY: Hybrids of Casostomus and Xyrauchen were evaluated for morphometic and meristic features. Hybrids were found to have features commonly intermediate between the razorback and flannelmouth suckers. One of the most diagnostic characters was a reduced keel similar to those found in razorbacks. In hybrids the keel is distinctly formed, though it is much less strikingly developed that in razorback suckers.

REFERENCE NUMBER: 098

CITATION: Harris, L., T. Mandis, and P. Schler. 1990. Fish hatchery Bellvue, Colorado squawfish report 1989-90. 14 pp.

SPECIES AND LIFE STAGE: CS, CS_LARVAE, CS_JUV

TOPICS: Culture Techniques, Temperature, Diet

KEYWORDS: COLORADO SQUAWFISH, CULTURE TECHNIQUES, TEMPERATURE, DIET

SUMMARY: This experiment found that for productive growth of Colorado squawfish a minimum water temperature of 64 °F is needed. Fish were observed to accept a diet at lower temperatures (52.6 and 60 °F) but growth was marginal and eventually most fish died. The 64 and 68 °F water produced aggressively feeding fish.

Biokyowa was the preferred dry diet to start fry on. Fish fed diets of Biokyowa did not develope scoliosis, where as all lots of fish fed commercial trout diets did. Some fry had problems with trout diets being too large and impacting in their gills, thereby causing a fungus problem. Biokyowa fed fish were not found to experience this problem because of the smaller feed size (<250 um). After fry are started on Biokyowa switching to a semi-moist or trout diet seems acceptable.

REFERENCE NUMBER: 099

CITATION: Papoulias, D. 1988. Survival and growth of larval razorback sucker, Xyrauchen texanus. M.S. Thesis, Arizona State University, Tempe, Arizona. 83 pp.

SPECIES AND LIFE STAGE: RZ, RZ_LARVAE

TOPICS: Research, Diet

KEYWORDS: RAZORBACK SUCKER, SURVIVAL, DIET

SUMMARY: Effects of absence, delayed presentation, and variable quantities of food on razorback sucker larvae were demonstrated through laboratory and pond experimentation. In laboratory experiment, the majority of larvae died between 20 and 30 d post-hatching when no food was presented. Larvae experienced low (<30%) mortality if abundant food was presented at least 19 d post-hatching. Razorback suckers fed from 7 d after hatching, but at variable food concentrations, experienced mortality of less than 20% at 50 to 1000 Artemia salina nauplii/l. Larvae fed rations of 5 and 50 nauplii/l exhibited significantly greater mortality (>70%); 30 to 60 nauplii/larva/d may be a minimum necessary in the early life stage of razorback sucker.

Larvae which did not receive food during the first 31 d after hatching were smallest (15.8 mm TL) and similar in size to larvae fed from 7 d after hatching at concentrations of 5 to 50 nauplii/l. Larvae first presented with sufficient food up to 15 d after hatching grew largest (21.7 - 23.2 mm TL), and comparable to those larvae first fed from day 7 at concentrations of 500 and 1000 nauplii/l.

Ponds fertilized at three levels resulted in variable mean invertebrate densities of 43.3, 23.7 and 12.5 organisms/l, but survival of razorback sucker larvae did not differ among treatments. Total larval biomass and growth were however, greater at the two higher invertebrate densities.

REFERENCE NUMBER: 100

CITATION: Valdez, R.A., and A.. Valdez-Gonzales 1991. Field Spawning of endangered humpback chub (Gila cypha). Technical report, BIO/WEST, Inc. 2pp.

SPECIES AND LIFE STAGE: HB,HB_ADU

TOPICS: Culture Techniques

KEYWORDS: HUMPBACK CHUB, FIELD SPAWNING, STRIPPING

SUMMARY: Three female humpback chub (Gila cypha) were stripped of eggs at Black Rocks, Colorado River, Colorado in June 1980. This was the first successful effort to procure eggs from this endangered species in a field situation. The females were injected intraperitoneally with acetone-dried carp pituitary daily for three days before ovulation occurred. Totals of 4000, 4000, and 10,000 eggs were obtained from the three fish. The eggs were placed in styrofoam hatching trays and transferred to Willow Beach National Fish Hatchery.

APPENDIX B

FILE OF PERSONAL COMMUNICATIONS WITH KEY FISH CULTURISTS

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Francisco Abarca   PHONE NO. 602-942-3000

AFFILIATION: Arizona Fish and Game - Non Game Division
MISC. COMMENTS: (Y/N): N

DATE: 10-19-90   TIME: 10:45

CALLER'S NAME: Richard Valdez
==

QUESTIONS

1). Is additional literature available?

a. None produced recently
b. Working more recently on monitoring a release of RZ into the Verde, Salt, and Gila rivers. These fish were raised at Dexter. Dean Hendrickson is still working on the release information as an agency report - also working with Dennis Kubley. This report will be available through Francisco's office. They have found few recaptures of released RZ.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Dean Hendrickson will be producing reports on monitoring of RZ in Verde, Salt, and Gila rivers.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Personally involved in monitoring of RZ, but main person is Robert Clarkson on monitoring. Francisco is mainly in charge of small fishes (pup fishes, top minnows)

4). Are there any researchers that you feel we should contact in addition to those on our list?

Robert Clarkson - Native Fish Research Biologist
Francisco Abarca - Native Fish Biologist
Buddy Jensen
Bubbling Pond - Have RZ and CS.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Don Archer PHONE NO. 801-538-4700

AFFILIATION: Utah Division of Wildlife
MISC. COMMENTS: (Y/N): Y

DATE: 10-10-90 TIME: 1:10

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

None that we don't already have.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

He fears maintaining these species only in a hatchery or by hatchery production. There is a need for a small modestly priced facility to supplement stocks and extend or repopulate ranges, but not at the expense of other worthwhile endeavors. There was a problem with the proposed experimental hatchery; lack of monetary commitment to a short term facility. Agencies were not willing to commit monetary support to a program in effect for just a few (10) years. If the project were scaled down there would be less resistance. Purpose of facility should be well defined.

What is your opinion of the location ?

Any additional comments ?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. Eric Bergeson PHONE NO. 303-494-6942

AFFILIATION: U.S. Fish and Wildlife Service Co-op Unit
MISC. COMMENTS: (Y/N): N

DATE: 9-26-90 TIME: 10:00

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

He has sent the literature that he could think of.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

No.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. Ted Bjorn PHONE NO. 408-885-7617

AFFILIATION: Idaho Cooperative USFWS fish Research Unit, U. of ID, Moscow
MISC. COMMENTS: (Y/N): N

DATE: 09-21-90 TIME: --

CALLER'S NAME: FishPro

==

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Dr. Bjorn will send some old reports that he has on Colorado squawfish "surrogate rearing".

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Did work with Colorado squawfish.

4). Are there any researchers that you feel we should contact in addition to those on our list?

No other contacts noted.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Jim Brooks PHONE NO. 505-734-5910

AFFILIATION: Dexter National Fish Hatchery
MISC. COMMENTS: (Y/N): Y

DATE: 10-05-90 TIME: 10:00

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

He has sent copies of literature to us.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

==

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

He feels too much reliance is being placed on hatcheries as mitigative measures.

What is your opinion of the location ?

Any additional comments ?

Any culture of Colorado squawfish should include long term homing research.

Some reports are available from Dean Hendrickson or the new AZFG non-game manager Francisco Abarca.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Bob Caskey PHONE NO. 303-248-7175

AFFILIATION: Colorado Division of Wildlife
MISC. COMMENTS: (Y/N): Y

DATE: 3-05-91 TIME: 10:20am

CALLER'S NAME: Richard Valdez

QUESTIONS

1). Is additional literature available?

No.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

No.

4). Are there any researchers that you feel we should contact in addition to those on our list?

1. Pat Martinez
2. Lower Basin biologists.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

==

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

1. Should be labeled an "augmentation facility" - a genetic refugium.
2. We will need a major facility from which to augment - not the same as "stocking".
3. A single site is not advantageous - we need a major augmentation facility where we need to maintain genetic stock and refugia - a minimum of three.
4. Diversify genetic material so we can recover from disasters.
5. Colorado should maintain genetic stock of all native fishes.
6. Once species are listed, management options are limited.
7. Permanent use of this facility for use of all fish in the future.
8. There is pragmatic macroresearch that needs to be done to fish.
9. Definitely a need for research, but needs to be kept pragmatic.
10. Also need to look at health of system first. Probably shouldn't augment healthy system - i.e. Yampa River.
11. Facilities:
    - a minimum of one genetic refugium in system for stock - "satellite refugium";
    - also need an umbrella facility to conduct research - "umbrella augmentation facility" - with a multitude of facilities and expertise with available services;
    - Grand Valley is excellent location;
    - also good opportunity to educate the public on these fish - - need to tie in I & E with augmentation facility;
    - also should be placed within range of fish.
12. It is critical that one priority should be to obtain genetic material from the wild.
13. Recovery can be accomplished if we balance microresearch vs. macropragmatic approach.
14. No one is looking at hybrid vigor - possibly habitat changes have prevented genetic exchange to prevent vigor.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Tom Chart PHONE NO. 801-637-3310

AFFILIATION: Utah Division of Wildlife
MISC. COMMENTS: (Y/N): N

DATE: 9-26-90 TIME: 8:55

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

Tom has in draft some ecology of bonytail chub in Dexter National Fish Hatchery, Transportation and behavior information. He will send it when he gets back from the Cataract field work. Lauren Lucas has information on vitamin C injections etc.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Has report in draft, coming soon.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

Contact Lauren Lucas, 307-721-5819.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. James Deacon   PHONE NO. (702) 739-3399

AFFILIATION: University of Nevada - Reno
MISC. COMMENTS: (Y/N): Y

DATE: October 16, 1990 TIME: 10:00 am

CALLER'S NAME: Richard Valdez

==

QUESTIONS

1). Is additional literature available?

Not beyond the list.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

No; not other than hold some in aquarium.

4). Are there any researchers that you feel we should contact in addition to those on our list?

1. Jim St. Amant.
2. Linda Ulmer.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

==

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

1. Uncertain about need for a facility.
2. Clearly, requirement is to maintain habitat.
3. Traditional management solution to plant more fish is unlikely to be a long-term sustainable solution.
4. But hatchery facility may be appropriate for rehabilitated habitat.
5. Not reasonable to maintain endangered species with hatchery project.

What is your opinion of the location ?

Not aware of any specifically.

Any additional comments ?

1. Not maintaining a species, but maintaining a zoo.
2. The idea should be to maintain habitat!
3. May need hatchery facility to carry over during stochastic problems with system.
4. Some possibilities in lower basin, i.e., Gila, Verde, Salt.
5. Multi-level release structures for maintenance are possible.
6. Genetics can be examined fairly simply.
7. If CS population can expand, it will (any species has the capacity to outdo its habitat!) . . . hatchery facility may be a waste of money.
8. May be a role, but <u>only</u> for specific problems - rather than general; e.g., assisting in continued periods of drought, reintroducing into suitable areas.
9. If facility is to perform <u>special</u> purposes, then facility needs to gear to special needs.
10. More about what is needed in habitat management for them to survive.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Larry Dunsmoor PHONE NO. 503-783-2905

AFFILIATION: Klammath Indian Tribe, Chiloquin, Oregon
MISC. COMMENTS: (Y/N): 09-24-90

DATE: - TIME: N

CALLER'S NAME: Fish Pro

==

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

None noted.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Working with Klammath Lake suckers.

Several years of experience but still in experimental phase. Hatchery is an old lumber mill - earthen ponds, hatchery building. Cold well-water supply 50°F, they heat water to temperatures the suckers like. Has had excellent success with upwelling incubators, one female per unit (several hundred to 15K eggs).

PROBLEMS:

- Suckers die off in late larval stages when cultured in smaller tanks and on artificial feed
- Larvae eat like crazy but have chronic die off at 2-3 weeks past hatch (metalarval stage)
- Cannot figure out problem, micronutrient missing from diet? Water supply?
- Varied temps to match lake but with no success
- Tried brine shrimp diet, at first all ate will but then died
- Recommends use of zooplankton culture to develop "natural food" for larvae
- Static water culture works best for Klammath Lake suckers
- Success with juvenile growth in earthen ponds and doughboy pools
- Let water get eutrophic "dirty" and aerate with mechanical aerator
- Hard to see fish for monitoring
- Currently use earthen ponds 6-70 ft x 100-120 feet
- Recently HDPE lined two ponds; no results yet
- Has had outbreaks of Learnaea

DESIGN IDEAS:

- Use circular units with crowder screens and structures
- Avoid draining (lose food source)
- Add grow lights above tanks to stimulate productivity
- Larry is committed to figuring this out to allow culture of his species in smaller lots on artificial feeds.

4). Are there any researchers that you feel we should contact in addition to those on our list?

No other contacts.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: John Hamill PHONE NO. (303) 236-7398

AFFILIATION: U. S. Fish and Wildlife Service
MISC. COMMENTS: (Y/N): Y

DATE: 10-12-90 TIME: 2:00 pm

CALLER'S NAME: Richard Valdez

==

QUESTIONS

1). Is additional literature available?

None that he is aware of, but suggests contacting Pat Nelson.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

None; check with Pat Nelson.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

No.

4). Are there any researchers that you feel we should contact in addition to those on our list?

None.

==

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

1. Definition of hatchery is a key.
2. The purpose must be identified and its relationship to existing facilities described.
3. Should be a multipurpose facility for augmentation, research, technical work.
4. Facility needs to serve as a refugium (interface between public and biologist).

What is your opinion of the location ?

1. Need to evaluate location <u>thoroughly</u>.
2. Lower basin has been involved in culture much longer than upper, but logistics justify facility in upper basin.

Any additional comments ?

1. Should be designed to meet immediate needs with possibility for expansion.
2. Still need Dexter, but need to define roles of other facilities.
3. FWS should define roles of facilities.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Reed Harris PHONE NO. 801-524-4430

AFFILIATION: U.S. Fish and Wildlife Service
MISC. COMMENTS: (Y/N): Y

DATE: 9-19-90 TIME: 12:00

CALLER'S NAME: Richard Valdez

==

QUESTIONS

1). Is additional literature available?

Suggested the "compendium of existing knowledge on Colorado River native fishes". We already have it, and are using it.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

None that is not in our reference list.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

==

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

He is strongly opposed to a hatchery facility for production of Colorado squawfish and humpback chub, though he recognizes it was strongly pushed by Colorado. Razorback and bonytail need immediate attention and some sort of propagation.

What is your opinion of the location ?

Vernal is a better site for a razorback facility. For Colorado squawfish, not the Yampa River site, but near Grand Junction or maybe near the San Juan or Dolores where reintroduction may be necessary.

Any additional comments ?

1) We can raise these fish anywhere, culture requirements are known. Other elements prevent success of propagation -- exotics eat up all raised fish etc. Spawning not a problem, getting YOY to recruit is the problem -- do they get eaten?

2) Pond culture near a river system near the stocking area is good. Minimizes concern over genetics, impurity, transport stress and water quality. If concern over genetics is high, put a small facility on each river system.

3) Would rather see time spent on habitat issues instead of hatchery production for Colorado squawfish. Bonytail and Razorback need hatchery attention though.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dean Hendrickson PHONE NO. 512-471-9774

AFFILIATION: Univ. of Texas, Texas Memorial Museum
MISC. COMMENTS: (Y/N): N

DATE: 10-05-90 TIME: 2:15

CALLER'S NAME: Penny Trinca

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QUESTIONS

1). Is additional literature available?

All data and literature is at Arizona Fish and Game Department in dBASE files. No one there is very familiar with how to get it out.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

He has a chapter that he co-authored with Jim Brooks that will be coming out in Minckley and Deacon's book. He will have a report done soon on all the work with reintroduction done by AZFG. Some progress reports exist, but only cover bare bones of what was done.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Theophilus Inslee PHONE NO. 405-836-7150

AFFILIATION:
MISC. COMMENTS: (Y/N): Y

DATE: 10-05-90 TIME: 11:45

CALLER'S NAME: Penny Trinca

QUESTIONS

1). Is additional literature available?

Throw away two thirds of our literature, it is not pertinent.

He has unpublished 1983 manuscript, Spawning Razorback Suckers and Colorado Squawfish. He will send us a copy. Also He performed all work for Paul Marsh's paper on hybridization between bonytail and humpback chub.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

He feels that he could be of great benefit as a consultant to the design, construction, and operation of this facility. He would like to receive $50.00/Hr for his knowledge. He can help with rearing and cost estimation.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Yes, Humpback chub similar to bonytail in artificial spawning technique. Bonytail fecundity higher than humpback. The bonytails taken originally from Lake Mohave, 2 females and 3 males, were over 30 years old. Handling stress killed them.

4). Are there any researchers that you feel we should contact in addition to those on our list?

No

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

Doesn't need to be as fancy as we may be thinking. Just go with old style warm water hatchery design, but improve holding and spawning and hatching facilities. Need bigger and deeper tanks for holding humpback chub, minimum three feet in depth. Other raceways need to be at least 6 ft x 80 ft and 2 or 3 ft in depth.

What is your opinion of the location ?

Any additional comments ?

Could hold humpback, inject and spawn all in ponds.

His facility in Oklahoma is the only warm water hatchery that has run a closed water system for three years with no serious disease or loss problems. They have a hydroponic biofilter (greenhouse) to remove nutrients from water. They are using a unique treatment procedure for controlling fungi on channel catfish eggs that is quite successful. They specialize in the difficult to propagate species like largemouth bass, flathead catfish, and grass carp.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Eddie Kochman PHONE NO. 303-297-1192

AFFILIATION: Colorado Division of Wildlife
MISC. COMMENTS: (Y/N): Y

DATE: 02-14-91 TIME: 3:00

CALLER'S NAME: Rich Valdez

===

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No grey or other literature noted.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Has not personally worked with CS, HB, BT, or RZ culture.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Keep in contact with Larry Harris, CDOW - Propagation specialist.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

No opinion offered.

What is your opinion of the location ?

Refer to Clee Sealing (Grand Junction), Larry Harris (Ft. Collins), and Bob Coskey (Grand Junction).

Any additional comments ?

The Bellevue/Watson facility is planning on developing brood stock for Colorado squawfish.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. Douglas Markle PHONE NO. 503-737-4531

AFFILIATION: Department of Fish and Wildlife Unit at Oregon State University.
MISC. COMMENTS: (Y/N): N

DATE: 09-21-90 TIME: --

CALLER'S NAME: FishPro

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No reports available yet, has some projects underway with electrophoretic analyses and field work.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Dr. Markle has not worked with culture of these fish, but has done some endangered species work and is interested in genetic issues. Worked with Klammath Lake Sucker species. Had some problems rearing suckers intensively. He cautions that hybridization may be happening with cultured fish. Suggests Electrophoretic analysis as a tool for monitoring this. DNA sequencing is too expensive.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Minckley at Arizona Game and Fish Department is a good contact as well as Larry Dunsmoor with the Klammath Indian Tribe in Chiloquin, OR. Also Gary Scoppettone with USFWS in Reno and Jeff Ziller with Oregon Department of Fish and Wildlife in Eugene.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Paul Marsh PHONE NO. (602) 965-2977

AFFILIATION: Arizona State University
MISC. COMMENTS: (Y/N): N

DATE: TIME:

CALLER'S NAME: (Paul Marsh unavailable; having corrective surgery)

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QUESTIONS

1). Is additional literature available?

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Chuck McAda PHONE NO. (303) 245-9319

AFFILIATION: U. S. Fish and Wildlife Service
MISC. COMMENTS: (Y/N): Y

DATE: October 11, 1990 TIME: 12:35

CALLER'S NAME: Richard Valdez

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QUESTIONS

1). Is additional literature available?

Doug Omundson is summarizing raw data on razorback collecting, looking at where people are finding ripe razorbacks. Razorback Report out soon.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Yes; will send information described in #3 below.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

1. Took wild CS in spring, held in ponds until time of maturity, injected with hormones.
2. Unsuccessful because:
    a. wild fish not used to handling;
    b. males ripen up with injections;
    c. females didn't ovulate;
    d. same techniques as Dexter;
    e. small number of fish ($\approx$7 total).
3. Possible problem is fish were caught too far in advance; need to catch ripe fish, i.e., razorbacks in Green River, CS in Yampa River.
4. Small pond with fathead minnows.
5. Tried to also hold wild fish in small circular tanks; also unsuccessful from stress and handling - fish didn't feed!

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

1. For Green River sub-basin, premature to talk about stocking.
2. For Colorado sub-basin, need stocking of CS, RZ right now, BT also, but HB.
3. CS not doing well in Colorado sub-basin; okay in Green River - problem is water development.

What is your opinion of the location ?

1. In the <u>basin.</u>
2. Possibly Grand Junction.
3. One only.

Any additional comments ?

1. A lot of things we don't know about fish.
2. We don't want to go into indiscriminate stocking.
3. Possible gains from supplementing populations with hatchery fish.
4. We can't take water and replace it with hatchery fish.
5. Genetics is a major concern; use some fish genetics - probably no difference anyway.
6. Facility should be more "experimental" with some production aspects.
7. We need to save <u>habitat</u>, as well as species.
8. Don't like idea of production hatchery to solve problem; not a solution to our problem.
9. May not need a formal structure.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. W. L. Minckley PHONE NO. (602) 965-3571
or 965-6518

AFFILIATION: Arizona State University
MISC. COMMENTS: (Y/N): Y

DATE: October 11, 1990 TIME: 11:23

CALLER'S NAME: Richard Valdez

==

QUESTIONS

1). Is additional literature available?

Yes, but it is in University and agency files (ASU & AGF) and has not been analyzed. Dean Hendrickson collected a lot of data - and Paul Marsh- on growth rates, etc., but much is not available in open literature.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Most of it is with Paul Marsh - contact him. (NOTE: Paul Marsh had surgery recently and is unavailable.)

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Yes, through Paul Marsh and Dean Hendrickson.

4). Are there any researchers that you feel we should contact in addition to those on our list?

1. Dean Hendrickson: On List.
2. Paul Marsh: On List.
3. Francisco Abarca: On List.

===

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

1. There is a need for another facility besides Dexter.
2. The technology to raise these fish is developed already!
3. We can raise many millions of fish today (in 3 years' time) given the proper conditions, climate, etc.
4. We need to understand genetics first before releasing large numbers of fish, especially in the upper basin.
5. Need a second refugia.

What is your opinion of the location ?

1. Should be where climate is warm, remote (away from pesticides, etc.).
2. A lot of remote refuge land in lower basin.
3. Dexter should be a tech center; a second facility is needed for back-up refugia (i.e., all bonytails at Dexter are now in one pond).

Any additional comments ?

1. Hatchery facility needs to look at more than just 4 endangered fish; needs to look at all natives.
2. Needs versatility to deal with species; living streams, circular tanks, etc.
3. The fish can be recovered today (their survival made secure) with administrative backing. There is currently a conflict.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Bob Muth PHONE NO. 303-491-1848

AFFILIATION: Colorado State Univ. Larval Fish Lab.
MISC. COMMENTS: (Y/N): Y

DATE: 9-26-90 TIME: 9:50

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

He has sent additional literature.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Yes

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

He feels the role of this facility should be research until we know more about these fishes ecology. Feels there is no way to avoid hatchery production and population augmentation of bonytail, but not sure about razorback and squawfish.

What is your opinion of the location ?

None

Any additional comments ?

Morphology and physiology of early stages of these native endangered fishes needs to be addressed. Neuromast development studies should be included in research topics.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Wayne Parker PHONE NO. 619-359-0204

AFFILIATION: Imperial Valley State Warm Water Fish Hatchery
MISC. COMMENTS: (Y/N): Y

DATE: 10-05-90 TIME: 4:45

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Internal report for 1988 can be obtained from Mike Guisti

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Yes. Did not mean to close native fish culture section of Niland catfish hatchery, but white pelicans and double crested cormorants have become so numerous that predation threatens to wipe out all fish there. In 1.5 week, 15 cormorants ate 1,500 bonytails 8 - 10 inches in length. Bonytail of age 1+ (1988 hatch) have grown up to 1 pound, average was smaller. Many males were found to be sexually mature, also some females. Water temperatures average 95 - 97°F but peak at 107°F. Ice had to be added 150 lbs per week during peak summer temperatures. Razorback suckers from dexter were reared in ponds 5 ft deep which buffered temperatures. At stocking they were 0.5 - 1 pound. Some were mature.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Mike Guisti in coastal marshes division at Long Beach, Glen Black, and Kim Nichol.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

==

MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

What is your opinion of the location ?

Any additional comments ?

Have complete production records for native fish at their facility. Treated bonytail with 0.75 ppm Dronsit in a 4 ft x 2 ft round tank for 5 days, obtained 100% eradication of asian tape worms. Found that if they seined fish out of ponds directly into transport trucks, gills clogged with silt and fish died. Better success placing fish into an intermediate tank with antibiotic and a surface agitator. Could tolerate high densities.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Randy Radant PHONE NO. 801-538-4760

AFFILIATION: Utah Division of Wildlife Resources, Non-Game Division
MISC. COMMENTS: (Y/N): N

DATE: 12-10-90 TIME: 1:30

CALLER'S NAME: Richard Valdez

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QUESTIONS

1). Is additional literature available?

Doesn't seem to be any additional literature we have not included.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No progress reports or grey literature.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

No.

4). Are there any researchers that you feel we should contact in addition to those on our list?

No.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Greg Raisenen PHONE NO. 602-634-4805

AFFILIATION: Page Springs State Fish Hatchery Arizona Game and Fish Department
MISC. COMMENTS: (Y/N): Y

DATE: 02-21-91 TIME: 1000

CALLER'S NAME: Penny Trinca

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Greg and Roger have sent their project reports to us already. He knows of no other useful grey literature.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Page Springs/Bubbling Ponds have worked with Colorado squawfish and razorbacks, they will be getting humpback chubs within three months to do temperature tolerance studies.

4). Are there any researchers that you feel we should contact in addition to those on our list?

No other researchers noted.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

Greg feels that a decision needs to be made as to the function of this facility.

What is your opinion of the location ?

Any additional comments ?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Alan Ruger PHONE NO. 503-230-5365

AFFILIATION: B.P.A. (Willamette Hatchery)
MISC. COMMENTS: (Y/N): 09-21-90

DATE: – TIME: N

CALLER'S NAME: Fish Pro

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QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Only progress reports are those from Pyramid Lake Tribe

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Has worked with Pyramid Lake species (including Cui Cui) till 1985, and Walleye.

Alan feels there are some problems with locating a new facility in Colorado. Acid mine waste in the Colorado region is a problem;H_2SO_4 leaches heavy metals into water sources. Disaster on Eastern side of divide. Be aware! So many mines into the hills - cannot correct the problem. Also, Alan recommends NOT using a recycled/recirculating water system for warmwater fish culture.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Beverly Houten was the hatchery manager (at Pyramid Lake Hatchery) for at least 10 years.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Mr. Roger Sorenson PHONE NO. 602-942-3000

AFFILIATION: Arizona Game and Fish Department
MISC. COMMENTS: (Y/N): N

DATE: 09-25-90 TIME: --

CALLER'S NAME: FishPro

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QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Roger will send copies of AGFD annual reports.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Roger Sorenson, and Greg Raisenen have worked with CS, HB, BT, and RZ. Less work has been done with bonytail than the other species by AGFD. All species like 65°F temperatures, and spawn 1 week earlier than the fish held at Dexter due to warmer temperatures. AGFD is conducting photoperiod work.

Roger believes all four species are best suited to "static" pond culture. The AGFD brood may live 30-50 years. They like to hang on the surface (bird predation may be a problem), and are easy to handle "seem dumb". Fish are held in earthen ponds with fathead minnows, but seem to prefer trout chow (Silveray's). When Bubbling Pond Fish Hatchery is renovated, ponds will be lined to reduce macrophytes and leakage. An air injection system will be installed in "D" shaped ponds to simulate constant flow conditions.

Razorbacks prefer low densities i.e., 5,000 100/lb fingerling in a 0.7 surface acre pond. When stocked at 50,000 100/lb fish per 0.7 surface acre, Razorbacks yielded more uniform growth. All species tended to yield a "scattered growth response" ranging from 6-16 inches in length. Roger recommends razorbacks as a forage and bait fish (highly susceptible to predators) for their ease of handling.

AGFD will receive 30 humpback chubs this fall to do temperature tolerance tests in conjunction with the University.

Roger feel that Bubbling Pond with its new renovation, and Niland Fish Hatchery in

California (if its bird predation problem were solved) are the two best facilities for rearing native Colorado River fishes west of the Rocky Mountains.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Should contact Wayne Porter 619-348-0204 and Greg Raisenen 602-634-4805

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Clee Sealing PHONE NO. 303-248-7175

AFFILIATION: Colorado Division of Wildlife
MISC. COMMENTS: (Y/N): Y

DATE: 02-14-90 TIME: 2:00

CALLER'S NAME: Richard Valdez

==

QUESTIONS

1). Is additional literature available?

a. Lower Basin literature - there should be a large quantity of information from releases of RZ and CS in Lower Basin.
b. It seems that BIO/WEST has covered all sources.
c. I didn't realize there was that much literature.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

2. None that are not presently included.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

3. Not directly.

4). Are there any researchers that you feel we should contact in addition to those on our list?

4. Looks like all are included in the contact list.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

No opinion noted.

What is your opinion of the location ?

a. Concerned that CDOW was not initially involved in the site selection. Felt that the site should be in northwest region of Colorado.
b. Should consider:
   1. Horsethief Property - pumped water from river.
   2. Site above Roller Dam - 4 miles West of Parachute.
   3. Site at Debeque - Carter Elliott Pond - SOLD!
   4. United Sand and Gravel - large gravel pits near river.
   5. Abandoned water treatment facility near Craig - geothermal water.
   6. WWWA - Railhead Park
c. Issue was confused because CDOW is looking for ponds in Grand Junction area for brood ponds.
d. Consider pumping water from river flood plain. CDOW is in a position to mitigate water rights needed to offset pumping of river related water.

Any additional comments ?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Bruce Taubert PHONE NO. 602-942-3000

AFFILIATION: Arizona Game and Fish Department
MISC. COMMENTS: (Y/N): N

DATE: 09-21-90 TIME: –

CALLER'S NAME: FishPro

==

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Suggested Paul Marsh's temperature work, and Minckley's water Quality data for species in Colorado.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Bruce has not been involved with these species for many years.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Suggested Roger Sorenson be contacted regarding hatchery methods.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Don Toney PHONE NO. 801-789-0351

AFFILIATION: U.S. Fish and Wildlife Service
MISC. COMMENTS: (Y/N): Y

DATE: 9-26-90 TIME: 11:00

CALLER'S NAME: Penny Trinca

QUESTIONS

1). Is additional literature available?

No, only papers he knows of we have listed.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Yes

4). Are there any researchers that you feel we should contact in addition to those on our list?

None we don't have.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

He feels we should be studying warm water hatchery facilities in Texas and South East. Very similar to bass culture.

What is your opinion of the location ?

Any additional comments ?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. Harold Tyus PHONE NO. 789-0354

AFFILIATION: U. S. Fish and Wildlife Service
MISC. COMMENTS: (Y/N): N

DATE: October 16, 1990 TIME: 9:00 am

CALLER'S NAME: Richard Valdez

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QUESTIONS

1). Is additional literature available?

1. Two papers are available - one in press in PFC, and one still writing. (Explain use of Biokyowa, Ziegler B-1, Murray's Silvercup (double vitamin pack).
2. Primarily with razorback (from past Bonneville Chapter).
3. Also continuation of RZ work.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

All in reports; will be sent.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

1. Yes, currently intensively culturing RZ to develop brood stock with specific genetic tracing to given females and males.
2. Also holding CS.
3. Plan to obtain and hold HB from Yampa River.

4). Are there any researchers that you feel we should contact in addition to those on our list?

None besides the list.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Linda Ulmer PHONE NO. 303-945-2521

AFFILIATION: U.S. Forest Service - Glenwood Springs
MISC. COMMENTS: (Y/N): N

DATE: 9-26-90 TIME: 2:55

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

She had lots of unpublished reports that Mike Guisti should have now. There is a California Razorback Management Plan.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Bonytail - When water temperatures got to 83-85°F lots of spinal deformities were noted. Had to ice pools each week.

RZ - Electrofishing was very hard on these fish when temperatures were high, so used mostly nets to collect from Senator Wash Reservoir and lower Colorado River.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Kim Nichol, Glen Black, Mike Giusti, and Jim St Amant.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Joe Valentine PHONE NO. 801-538-4700

AFFILIATION: Utah Division of Wildlife
MISC. COMMENTS: (Y/N): N

DATE: 10-05-90 TIME: 9:45

CALLER'S NAME: Penny Trinca

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QUESTIONS

1). Is additional literature available?

He said we did a pretty good job of compiling the literature that he knows about.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. C. David Vanicek PHONE NO. 916-248-6569

AFFILIATION: Sacramento State University
MISC. COMMENTS: (Y/N): N

DATE: 10-10-90 TIME: 12:30

CALLER'S NAME: Penny Trinca

==

QUESTIONS

1). Is additional literature available?

None that he is aware of.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

4). Are there any researchers that you feel we should contact in addition to those on our list?

Royal Suttkas at Tulane University Department of Biology

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Dr. Gary Vinyard PHONE NO. 702-784-6793

AFFILIATION: University of Nevada, Reno
MISC. COMMENTS: (Y/N): N

DATE: 09-21-90 TIME: --

CALLER'S NAME: Fish Pro

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QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Has worked with Desert dace and Spring fish.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Dr. Vinyard knows of no new techniques for fish culture, but recommends the hatchery environment be kept as undisturbed and productive as possible. Small scale production is favored.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Suggests calling Pyramid Tribe Hatchery.

Also Dr. Peter Brussard - genetics of Cui Cui - hybridization with Taho suckers 702-784-6188, he has some information prepared on population genetics and Kendall Warm Springs dace.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Neal Ward PHONE NO. 303-872-3170

AFFILIATION: Hotchkiss National Fish Hatchery
MISC. COMMENTS: (Y/N): Y

DATE: 10-10-90 TIME: 3:45

CALLER'S NAME: Penny Trinca

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QUESTIONS

1). Is additional literature available?

No additional literature that he can think of.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Has one report that he can't locate. Holt Williamson or Lee Mills may have it. It pertains to 50,000 larval Colorado squawfish that they held in shallow ponds in the Chapita Unit that was wiped out by a land slide in 1981. They rescued 3,100 1-2 inch fish. These were sent to (maybe- can't remember) Dexter NFH and about 20 to an aquarium at the Regional Office. Water in the ponds averaged 70 - 80°F in the ponds and growth was good.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

They also had 800 humpback chubs from Dexter of which 200 survived the land slide. These were preserved and sent to Fort Collins. Colorado squawfish were observed to form a loose school in the ponds and when water temperatures decreased in winter, they all moved to the bottom. Humpback chub displayed similar behavior.

They also held several large adult Colorado squawfish and humpback chubs and roundtail chubs for Burdick's PIT tagging experiments. These fish were held at 13.3°C for about a year. They showed no growth, and developed ICH. In the learning process remove ich they tried salt, formalin, some other treatments and malachite green. The malachite green was totally successful (purchased already mixed from pet store). They also tried brushing Ich off of fish, this worked for squawfish, but killed the chubs. These fish that wouldn't feed on trout chow, or on live fish, were fed gammarus that was seined from cladophora beds. They didn't grow, but didn't die either.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Twelve squawfish (4 inch) were sent to Rene Schmidt " Genetic Analysis", P.O. Box 598, Smithfield, TX 78957, 512-237-2403 for non-lethal genetic analysis this year. They ship fish in milk dispenser bags, and will send us a bag and the shipping procedures they use.

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MISCELLANEOUS COMMENTS:

What is your opinion regarding the role of this facility ?

He feels that this needs to start out as a small facility with the ability for expansion at a later date. He favors an Ouray type set up with a few ponds, and some culture equipment and permanent staff members. He doesn't recommend attaching this activity onto an existing site, it will be short changed. His main concern is that we need to locate or generate a forage base to sustain large piscivorous fish in a refuge type system. Seining up fatheads or other wild fish will create too many disease and parasite problems. He feels trout would be an excellent, clean, dependable forage base.

What is your opinion of the location ?

Harold Ross has a warm artesian well 3 miles from Hotchkiss near Paonia. He and Holt Williamson are checking to see if he will sell it. Silver Springs facility has extensive ponds and might be able to warm water up to adequate temperatures, or maybe there is an orchard near Grand Junction with warm artesian water.

Any additional comments ?

Transportation of fish of any size is not a problem. We should prioritize on locating a good water source not on proximity to river system.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Bob White PHONE NO. 406-994-3491

AFFILIATION: Montana USFWS Cooperative Fish Research Unit, Bozeman
MISC. COMMENTS: (Y/N): 09-21-90

DATE: -- TIME: N

CALLER'S NAME: Fish Pro

==

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

No additional grey literature noted.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Bob worked with Northern squawfish. Bob was involved in writing the proposal but the project got going and finished after he left. Ted Bjorn will have information.

4). Are there any researchers that you feel we should contact in addition to those on our list?

No other contacts noted.

C.W.C.B. HATCHERY FEASIBILITY STUDY
RECORD OF TELEPHONE INTERVIEW

NAME: Jeff Ziller PHONE NO. 503-726-3515

AFFILIATION: Oregon Department of Fish and Wildlife, Springfield
MISC. COMMENTS: (Y/N): 09-21-90

DATE: -- TIME: N

CALLER'S NAME: Fish Pro

==

QUESTIONS

1). Is additional literature available?

No additional literature noted.

2). Do you have any progress reports, grey literature or personal information that may be of value to us?

Gary Scoppettone or Mark Coleman have progress reports from 1987-1988, and Larry Dunsmoor may have written a progress report to the ODFW research office in 1989.

3). Have you personally worked with the culture of these fish (CS, HB, BT, RZ) ?

Working with four species of suckers in Klamath Lake. Larry Dunsmoor and the tribal staff have a hatchery.

USFWS money - Klamath Tribe
ODFW money - Research program

Gary Scoppettone, Reno (UNR) is rearing fair numbers of Shortnose suckers - Chasmistes brevirostris, Lost River suckers - Catostomus (Deltistes) luxatus, and Klamath largescale sucker - Catostomus snyderi in a research and production facility.

4). Are there any researchers that you feel we should contact in addition to those on our list?

Should contact Al McGee of ODFW in Corvallis - 503-737-4431.

C.W.C.B. HATCHERY FEASIBILITY STUDY

SITE VISIT

DEXTER NATIONAL FISH HATCHERY

CWCB HATCHERY FEASIBILITY STUDY

Site Visit - Dexter National Fish Hatchery

DATE:	September 12-13, 1990
PARTICIPANTS:	Rich Valdez, Bill Masslich (Bio/West) Bill Wemmert (URS), Sue Uppendahl (CWCB) Ken Ferjancic (FishPro), Holt Williamson (USFWS)
OBJECTIVE:	View culture facilities and discuss culture techniques with Hatchery Manager, Buddy Jensen.

INTRODUCTION

Dexter National Fish Hatchery (NFH) is administered by the U.S. Fish and Wildlife Service. It located in southeastern New Mexico about 5 miles southeast of Roswell. The facility was built in 1931 as a warm water hatchery for raising largemouth bass and channel catfish for stocking in Federal and state waters throughout the Southwest. In 1974, its mission was changed to house and culture the endangered fishes of the Southwest.

In 1979 and 1980, Dexter NFH also assumed the role as the primary propagation facility for the Colorado River endangered fish when brood stocks of these species were transferred from Willow Beach NFH in Arizona. Culture techniques were initiated at Willow Beach NFH and work was continued and refined at Dexter NFH. The facility presently houses all four species of endangered Colorado River fishes, including Colorado squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), bonytail chub (Gila elegans), and razorback sucker (Xyrauchen texanus).

CULTURE METHODS

Successful hatchery culture of the four endangered Colorado River fishes has involved much experimentation and trial and error. Personnel at Dexter NFH, particularly Buddy Jensen (Hatchery Manager), Roger Hamman and Don Hales, possess some of the best available expertise on hatchery culture of these species. Details on the methods used at Dexter NFH are presented in Section 3.1 of this Task 1 report.

Brood stock of all four species are presently being held at Dexter NFH, although only Colorado squawfish, bonytail chub, and razorback sucker are propagated annually to meet demand for releases to the wild and for research purposes. Humpback chub have not been propagated recently at Dexter. Brood stock of Colorado squawfish includes about 160 adults from the 1974 year class and about 200 from the 1981 year class. The razorback sucker brood stock includes about 500 adults from four separate year classes, and the bonytail chub brood stock includes about 500 adults from one year class, progeny of Lake Mohave fish.

Eggs of Colorado squawfish, bonytail chub, and razorback sucker are procured in spring and early summer. Gonadal maturation occurs earliest in razorback suckers, usually between February 25 and March 10. Maturation of bonytail chub occurs in early to mid-May, while maturation of Colorado squawfish occurs in late May and early June. The females of all three species are usually injected with hormones to induce ovulation, Colorado squawfish and bonytail chub with acetone-dried carp pituitary and razorback suckers with human chorionic gonadotropin.

The eggs are held indoors in Heath Trays and McDonald Jars at about 20°C. Dexter NFH has a capacity of about 8.8 million eggs of these endangered species. Hatching of Colorado squawfish, bonytail chub, and razorback sucker usually occurs in 96 - 144 hours, 99 - 174 hours, and 96 - 144 hours, respectively. The eggs are very adhesive, particularly before water hardening, and require constant agitation or stirring with a feather. The fry are held for 3 - 4 days in concrete troughs, at which time the mouth is developed and the yolk sac absorbed. The fry are then transferred to specially prepared outdoor earthen ponds about one surface acre in size. These ponds are fertilized to provide the young fish with a natural food source of zooplankton, although the diet is supplemented with commercial fish food.

PREPARATION OF EARTHEN PONDS

A detailed description of the preparation of the earthen ponds at Dexter NFH is presented in Section 3.1.4 of this Task 1 Report. Earthen pond culture has been practiced for many years with a variety of warm-water species. This concept of extensive fish culture has been successfully adapted for culturing the Colorado River endangered fish at the Dexter NFH. Successfully rearing fish in earthen ponds depends on establishing a viable complement of zooplankton as a food source, combined with supplemental feeding. Fish are kept in a given pond on a 4 - 6 week rearing cycle and then transferred to another pond. This is the period of time in which zooplankton populations peak. Since the ponds are unlined, it is also the period of time in which growth of the aquatic plant, Chara sp. becomes excessive and interferes with water circulation, dissolved oxygen levels, and access to the fish.

Dexter NFH has 47 earthen ponds that vary in size from 0.143 to 1.082 surface acres. All are rectangular in shape ranging from 85 to 410 feet in length and 31 to 182 feet in width. The average depth of most of the ponds is 6 feet and each is filled with 3 - 4 feet of water. None of the ponds are lined, and hatchery personnel report loss of water through seepage and problems with the aquatic plant, Chara sp.

WATER SOURCE AND DISPOSAL

Water for Dexter NFH is pumped from three wells that are 100 - 110 feet deep and produce about 1800 gallons per minute. The water is 64°F and has a high TDS level and a nitrogen saturation of up to 110%. Since the water source is from wells, there is no disease problem common to surface water sources.

The Dexter water system is essentially a closed system. Waste-water is piped to two depressions south of the hatchery where the water infiltrates and evaporates. Because of this disposal system, no water leaves the station and therefore, there is no problem with fish escapement or disease, and no need for discharge permits.

C.W.C.B. HATCHERY FEASIBILITY STUDY

SITE VISIT

LOGAN EXPERIMENTAL FISH HATCHERY

CWCB HATCHERY FEASIBILITY STUDY

Site Visit - Logan Experimental Fish Hatchery

DATE: October 12, 1990

PARTICIPANTS: Rich Valdez (BIO/WEST)

OBJECTIVE: Discuss aspects of endangered fish culture with Propagation Specialist with Utah Division of Wildlife Resources, Dr. Ron Goede.

INTRODUCTION

The Logan Experimental Fish Hatchery is located in northern Utah near the city of Logan. The facility has in the past held Colorado squawfish, humpback chub, and bonytail chub. Hatchery Manager Ron Goede has extensive experience with the culture of numerous fish species and is a disease specialist for UDWR known throughout the U.S. for his advancements in fish health, disease recognition and control, and methods of evaluating fish condition.

The following are issues expressed by Dr. Goede relative to a facility for Colorado River endangered fish:

1. **Fish Escapement**. Fish escapement is a concern for any hatchery facility. Most states have instituted measures to prevent the accidental escape of exotic species into drainages. If a hatchery for Colorado River endangered fish is built in a basin outside of the Colorado River, provisions will have to be made to prevent escapement of these or other species into the wild.

2. **Disease Control**. Quarantine facilities are a must for any hatchery facility today, particularly one dealing with endangered species, where an epizootic can eliminate a particular brood stock. Quarantine facilities are necessary any time wild fish are brought into the facility. It will be necessary to hold fish through a few days to allow pathogens to manifest themselves, or it may be necessary to hold fish through an entire reproductive cycle if reproductive diseases are suspected.

Temperature control (increased levels) can speed up the cycle of some pathogens, but it could stress the fish.

3. **Genetic Diversity**. It is important to preserve genetic diversity in any species. It is easy to allow genetic drift to take over, particularly with species such as Colorado squawfish and razorback suckers with fecundities of 50,000-100,000 eggs. It is possible for most of the viable eggs to originate from a single female and to allow this to become the source brood stock. This leads to reduced genetic diversity.

4. **Define Role**. The role of any facility needs to be defined relative to other existing facilities. The role of this endangered species facility would need to be defined and the inter-relationships with other facilities (Ouray, Dexter, Bubbling Pond, Page Springs, etc.) described.

5. **Research Laboratory**. Depending on the function and role of the facility, a research laboratory may be necessary. Analyses such as electrophoresis, cytogenetics, mitochondrial DNA analysis require expensive equipment that needs ongoing maintenance and operation by well-trained personnel. These analyses can be "farmed out". But, a laboratory should be available to do basic water quality and fish health analyses.

6. **Feeds**. Many commercial feeds are available that could be well-suited for the endangered fish. The first month or so is the most critical in providing proper dietary needs. On-going research at the EEFH at Ouray and the FRH at Bellevue will help to provide answers. Microencapsulation has helped much in solving dietary problems for fish. With many species (e.g. striped bass) it is better to feed very young fish (swim-up fry) plankton such as copepods, cladocerans, etc., for which commercial sources are available. It is possible to provide a rich medium for young fish indoors under intensive culture conditions since the fry need nutrient rich diets early in their life and may absorb nutrients directly through the body. This indoor culture could require a lot of labor to maintain.

7. **Mass Production**. The idea of mass production is not a solution to the recovery of any endangered species.

C.W.C.B. HATCHERY FEASIBILITY STUDY

SITE VISIT

UTAH COOPERATIVE FISHERY RESEARCH UNIT (USU)

CWCB HATCHERY FEASIBILITY STUDY

Site Visit - Utah Cooperative Fishery Research Unit (USU)

DATE: October 12, 1990

PARTICIPANTS: Rich Valdez (BIO/WEST)

OBJECTIVE: Discuss aspects of endangered fish culture with Fishery Unit Leader Dr. Tim Modde.

INTRODUCTION

The Utah Cooperative Fishery Research Unit at Utah State University (USU) in Logan has held Colorado squawfish and bonytail chub for experimental purposes for several years. USU (W.T. Helm) and the U.S. Fish and Wildlife Service (H. Tyus) worked jointly on a study to determine the retention rates of surgically implanted radiotags. The fish were held at the mouth of Logan Canyon in USU's Water Resources Laboratory. The Unit is not currently holding Colorado River endangered fish except for small numbers Colorado squawfish and bonytail chub in aquaria in the lobby of the Natural Resources Building on campus.

The following are issues expressed by Dr. Modde relative to a facility for Colorado River endangered fish:

1. <u>**Water Quality**</u>. Sac-fry and swim-up fry of Colorado squawfish were extremely sensitive to water quality. Since USU's water source was chlorinated, there was difficulty in dechlorinating the water sufficiently. A dechlorinator of carbon-packed filters was used as well as aeration, but small surges in chlorine accounted for some mortality in young fish.

2. <u>**Diet**</u>. Fish were fed commercial trout diets. They seemed to do well on Silvercup, but best on Biokyowa which is expensive! Because of cold water temperature and limited facilities, the fish were pretty much on a maintenance mode. There was little growth with particularly Colorado squawfish. The fish were held at 10 to 12°C since there was little flexibility for heating water.

3. **Surface Water**. For a short period of time, surface water from the Logan River was run through tanks holding Colorado squawfish. A high incidence of pathogens was noted as a result.

4. **Role of Endangered Fish Hatchery**. The first priority is recruitment. There is potential for genetic disruption using hatchery stocks. Survival rates of domestic (hatchery-reared) fish may be lower. When we resort to hatchery culture, we admit to ourselves that the best we can do is maintenance of a species. It is a last ditch effort. We should look at habitat problems first, although these are complicated by the presence of large numbers of exotic species. We have no cases of successful reestablishment of a species where it was extinguished.

C.W.C.B. HATCHERY FEASIBILITY STUDY

SITE VISIT

PROPAGATION SPECIALIST
U.S. FISH AND WILDLIFE SERVICE

CWCB HATCHERY FEASIBILITY STUDY

Site Visit - Propagation Specialist for U.S. Fish and Wildlife Service

DATE: October 4, 1990

PARTICIPANTS: Rich Valdez and Bill Masslich (BIO/WEST)

OBJECTIVE: Discuss aspects of endangered fish culture with Dr. Holt Williamson.

INTRODUCTION

Dr. Williamson is a member of the Technical Advisory Committee for this Hatchery Feasibility Study. He provided us with the following information to help us assimilate additional literature and make additional contacts:

1. **Additional Contacts.**

Pat Nelson (USFWS, Denver) coordinated an assimilation of The Compendium of Existing Information on the Endangered Fishes of the Upper Colorado River Basin. He may have additional information or literature. Paul Marsh (ASU) has conducted much of the culture work with Dean Hendrickson in the lower basin. They have worked extensively in releasing Colorado squawfish, bonytail chub, and razorback sucker into the wild and evaluating their survival. Tim Modde (USU) has held Colorado squawfish and bonytail chub and may have insights on diets and culture. Ron Goede (UDWR) has extensive fish culture experience and is a specialist in diseases and fish health. Larry Harris (CDOW) is working on dietary needs at Bellvue/Watson near Ft. Collins. Neal Ward and Don Toney (USFWS) know a lot about Colorado Hatchery Sites. Most of the sites have already been surveyed by state and federal agencies.

2. **Intensive vs Extensive Culture.** The endangered fish have been raised using various techniques under intensive and extensive methods. The best manner for rearing these fish may be

a combination of the two methods. Intensive culture may cost more but provides greater control of water conditions, feed, growth, etc. Extensive culture may be cheaper but there is less control.

3. **Pond Culture**. Problems with water loss and vegetation may be controlled by lining ponds. This needs to be tested and its effects on zooplankton production evaluated.

4. **Water Source**. Surface water sources may create problems with disease, variable temperature, etc. It may be expensive to treat surface water with ozone, hot wash chlorine, and biological filters to remove nitrates and nitrites. Facilities such as Bubbling Pond are ideal because of the availability of heated water without a need to treat or pump.

5. **Functions**. At least 3 functions are needed: refugia, culture development, and production. There is need for flexibility with small ponds as well as a Fish Health Lab, Disease Lab, Quarantine Facility (See Pueblo Hatchery).

C.W.C.B. HATCHERY FEASIBILITY STUDY

SITE VISIT

PROPAGATION SPECIALIST
COLORADO DIVISION OF WILDLIFE

CWCB HATCHERY FEASIBILITY STUDY

Site Visit - Propagation Specialist for Colorado Division of Wildlife

DATE: October 4, 1990

PARTICIPANTS: Rich Valdez and Bill Masslich (BIO/WEST)

OBJECTIVE: Discuss aspects of endangered fish culture with Mr. Larry Harris

INTRODUCTION

The Colorado Division of Wildlife recently initiated a research program on the propagation of the Colorado River endangered fish using extensive culture methods. Propagation Specialist for this effort is Mr. Larry Harris of Fort Collins, Colorado. This research program is being conducted at two locations, a wet lab facility located on the campus of Colorado State University in Fort Collins, and The Fish Research Hatchery at Bellvue which is near Fort Collins. Mr. Harris works closely with Mr. Tom Mandis, Hatchery Manager at Bellvue.

Since the FRH at Bellvue is located at nearly 6,000 feet elevation with a water source of 52.6°F (11.7°C), outdoor pond culture is limited to a short time in the summer when ambient temperatures could warm ponds sufficient for fish growth. However, there is a good water supply and adequate indoor rearing facilities (including heater, incubation trays, rearing troughs, etc.) for intensive culture.

The purpose of this research program is to determine if Colorado squawfish can be successfully reared under intensive culture techniques. The work was initiated in late May 1989 with a shipment of about 150,000 fertilized eggs (14 hours post-fertilization) from Dexter NFH. The objective in this first year of study was to determine minimum temperature requirements and acceptable diets for Colorado squawfish under intensive culture. In late May, 1990, 135,000 fertilized eggs and 48,000 fry were shipped from Dexter NFH for additional research. The purpose for this second year of study was to determine which diet enhanced survival and growth rates of Colorado squawfish under intensive culture.

CULTURE METHODS

Details of the intensive culture methods used by CDOW are provided in Section 3.2.1 of this Task 1 Report. Fertilized eggs received from Dexter NFH were incubated at the FRH at Bellvue in Heath Trays in much the same manner as eggs are incubated at Dexter. The eggs were incubated at 70°F in stacked Heath Trays. Hatching occurred in 80 - 96 hours (94 - 110 hours total incubation since the eggs were 14 hours old when received). Eggs were also incubated at 52.6°F which is the temperature of the well water. The eggs failed to hatch and disintegrated in 12 days. Eggs of Colorado squawfish were also incubated at the FRH in small (12"x12"x2") screened trays suspended in rectangular troughs 12 feet long. The newly-hatched fry dropped through the screen into the rearing trough.

Newly-hatched fry were placed in small (24"x18"x4") plastic pans lined with fine screen (30 meshes to the inch) to allow circulation of water. These pans were suspended in the 12-foot troughs. These small pans were viewed advantageous because they concentrated the fish for feeding (less food waste), facilitated cleaning the trough, and facilitated monitoring the fish for diseases, growth, etc.

Similar problems with crowding and clumping by Colorado squawfish swim-up fry were reported at the FRH as experienced at Dexter NFH. The problem was resolved at the FRH by placing a white masonite base beneath the fry holding pans. Personnel at the FRH interpret dispersal by the fry as a response to the scattering of light caused by the white background. Swim-up fry were fed in the small pans for several days or until it was judged that they were becoming crowded. They were then released into the larger troughs (12'x1.5'x1').

Personnel at the FRH have experimented with an electronic fish egg sorter and counter, The Jensorter (Jensorter, Inc. 20255 Harvest Lane, Bend, Oregon 97701, 503-389-3591), and report favorable results when compared to actual counts. This instrument may increase accuracy of egg and fry counts for the endangered fish.

FEEDING EXPERIMENTS

Experiments with various commercial diets were conducted with Colorado squawfish at the FRH at Bellvue and at the wet lab at CSU. Test diets included (1) brine shrimp, (2) Biokyowa, (3) Ziegler's larvae, and (4) Rangen's Trout Formula.

Preliminary results showed that brine shrimp were not an advantage over the commercial feeds because they require additional culture efforts to maintain a source of live brine shrimp. Biokyowa B-250 provided the most favorable results. They were more aggressive during feeding, fed more readily, and therefore grew faster. However, this formulation was the most expensive of the diets administered. The cost of the feed alone to raise 10,000 Colorado squawfish to 5 inches in length was $7,000.

Ziegler's larvae was not viewed as an advantage and fish fed Rangen's Trout Formula were not as aggressive and did not feed as well as the fry on Biokyowa. Hatchery biologists observed that the individual granules of Rangen's Trout Formula did not dissolve when ingested and were visible moving through the gut of the fish suggesting little nutritional value. Granules of this formula also lodged in the gills of the young fish and caused suffocation or fungus infections.

A high incidence of scoliosis was noted particularly for fry fed with Rangen's Trout Formula. Thinking that this could be caused by a vitamin C deficiency, ascorbic acid was sprayed on the feed. Preliminary results indicate that this treatment did not alleviate the problem and the rate of scoliosis persisted.

Cannibalism was not identified as a problem under intensive culture as long as the fish were not overcrowded, graded by size, and fed regularly. A density greater than 1.5 pounds of fish per cubic foot of rearing space resulted in decreased fish growth caused by crowding.

APPENDIX C

COMPUTERIZED RETRIEVAL SYSTEM FOR CULTURE INFORMATION FOR THE COLORADO RIVER ENDANGERED FISH

USE OF RETRIEVAL SYSTEM

A computerized data storage and retrieval system was created in dBASE III+ to facilitate locating key information in the Library of Pertinent Culture Information on the Colorado River Endangered Fish. Ashton Tate's dBASE III+ is used by many of the agencies working with endangered fish in the Colorado River Basin, and is fairly easy to master. This data storage and retrieval system can be queried to identify all related documents or to list keywords associated with specific documents.

Each piece of information included in the library was assigned a unique serial reference number, and grouped into one or more of nine topics, including Life History, Disease, Water Quality, Production, Culture Techniques, Diet, Temperature, Transportation, and Research. All database fields and their descriptions are listed in Table 3-1. A "Y" for inclusion into a topic or a "-" for exclusion was entered into each category for each record entry. Similar notation was used to indicate which of the four endangered fish was discussed in the reference. If a species is referred to in the document, "Y" appears in the species code field. Furthermore, if a specific age group is referred to, a "Y" appears in the species age field as well. For example, a document discussing diet of larval humpback chub has a "Y" entry in the fields HB, HB_LAR, and DIET. A database user can query the retrieval system and locate this document by its "Y" entries and access information on the species, life stage, keywords, and topics discussed. A typical query statement might be as follows:

LIST ALL KEYWORDS FOR HB='Y'.AND. HB_LAR='Y'.AND. DIET='Y'

This statement would list every library reference number and associated keywords pertaining to the diet of larval humpback chubs.

Table 3-1. Data fields and descriptions for the dBASE III+ CWCB Hatchery Feasibility literature data base.

Field Name	Field Type	Description
REFERENCE INFORMATION		
Ref_Number	Character	Library reference number corresponding to a unique serial number assigned to the document.
Author	Character	Primary author
Date	Character	Date of publication
SPECIES AND LIFE STAGE		
HB	Character	
HB_Egg	Character	Indicates that information on the corresponding life stage of humpback chub is presented in the reference.
HB_Larvae	Character	
HB_Juv	Character	
HB_Adult	Character	
BT	Character	
BT_Egg	Character	Indicates that information on the corresponding life stage of bonytail chub is presented in the reference.
BT_Larvae	Character	
BT_Juv	Character	
BT_Adult	Character	
CS	Character	
CS_Egg	Character	Indicates that information on the corresponding life stage of Colorado squawfish is presented in the reference.
CS_Larvae	Character	
CS_Juv	Character	
CS_Adult	Character	
RZ	Character	
RZ_Egg	Character	Indicates that information on the corresponding life stage of razorback sucker is presented in the reference.
RZ_Larvae	Character	
RZ_Juv	Character	
RZ_Adult	Character	

Table 3-1. Continued

Field Name	Field Type	Description
		LITERATURE TOPICS
Life_Hist	Character	Logical expression (YES/NO) indicating information is presented on natural life history that may be pertinent.
Disease	Character	Logical expression indicating information is presented on disease, parasites and physiological disorders.
Production	Character	Logical expression indicating information is presented on survivability, density and production limitations.
Cultr_Tech	Character	Logical expression indicating information is presented on culture techniques.
Water_Qual	Character	Logical expression indicating information is presented on heavy metals, turbidity, conductivity, salinity, pH or other water quality parameters.
Transport	Character	Logical expression indicating information is presented on transport of fishes to and/or from hatchery.
Temp	Character	Logical expression indicating information is presented on temperature requirements for any aspect of propagation, culture techniques or hatchery design.
Diet	Character	Logical expression indicating information is presented on foods, feeding and other topics related to diet.
Research	Character	Logical expression indicating information is presented on specialized or unique hatchery

Table 3-1. Continued

Field Name	Field Type	Description
		research and research techniques for the 4 species.
	KEYWORDS	
Keywords	Character	List of all key words associated with the reference.

APPENDIX D

LIST OF SITE OWNERS/CONTACT NAMES AND ADDRESSES

APPENDIX D

SITE LIST OWNERS/ CONTACT NAMES AND ADDRESSES

Revised 5-31-91

1. Glenwood Desalinization Facility

   Contact: Mr. Rob Downey
   Energy Ingenuity
   9085 Mineral Circle
   Suite 350
   Englewood, CO 80112
   (303) 792-3037 (303) 792-5603 Fax

2. CC Craig Ranch

   Contact: Mr. Jim Ross
   Intermountain Real Estate
   1620 East Highway 40
   Craig, CO 81625
   (303) 824-3481

   Owner: Mr. Charles C. Craig

3. CO-Ute Plant/CIRG Site

   Contact: Doug Tarr
   CIRG (Craig Industrial Recruitment Group Inc.)
   500 Spruce Drive
   P. O. Box 423
   Craig, CO 81626
   (303) 824-3263

4. Hayden Power Plant

   Contact: Raymond Keith
   Chief Operating Officer
   Colorado-Ute Electric Association
   P. O. Box 1149
   Montrose, CO 81402
   (303) 249-4501

5. Ross Ranch

Contact: Jim Ross
Intermountain Real Estate
1620 East Highway 40
Craig, CO 81625
(303) 824-3481
Owner: Harold Ross

6. Rifle Falls SFH

Contact: Ed Allen
Rifle Falls State Fish Hatchery
11466 Highway 325
Box 2
Rifle, CO 81650
(303) 625-1865

cc: Mr. Jerry Whitaker
State Hatchery Supervisor
Colorado Division of Wildlife
6060 Broadway
Denver, CO 80216

7. Hotchkiss NFH

Contact: Don Toney
Hotchkiss National Fish Hatchery
807 - 3150 Lane
Hotchkiss, CO 81419
(303) 872-3170

8. Clines Fish Hatchery

Contact: Kenneth Cline
Clines Trout Farms
5555 Valmont Road
Boulder, CO 80301
(303) 442-2817

9. Putnam Fish Hatchery

Contact: Anne Putnam
Rainbow Springs Trout Ranch
1157 Country Road 214
Durango, CO 81301
(303) 247-2939

10. Silver Springs Trout Farm

Contact: David Gann
Silver Springs Trout Farm
13221 Marine Road
Montrose, CO 81401
(303) 249-5888

11. McMillan's Trout Farm

Contact: Miles and Marge McMillan
McMillan's Trout Farm
P. O. Box 394
Hotchkiss, CO 81419
(303) 872-3421

12. Steele Ranch

Contact: Don Steele
P. O. Box 37
Maybell, CO 81640
(303) 272-3259

13. Cameo Power Plant

Contact: Virgil Wetzbarger
Public Service Company of Colorado
P. O. Box J
Palisade, CO 81526
(303) 464-5681

14. Water User's Association #1 Property - near Kenney Reservoir

Contact: Tim Katers
Economic Development Director
Town of Rangley
209 East Main Street
Rangley, CO 81648
(303) 675-8469

15. Crystal Properties Site

Contact: Dave Marsh
Mountain Top Farmers
10027 Lane 5 North
Mosca, CO 81126
(719) 378-2000

16. Horsethief Canyon

Contact: Clee Sealing
Regional Fisheries Biologist
Colorado Division of Wildlife
711 Independent Avenue
Grand Junction, CO 81505
(303) 248-7175

17. Hereford Haven

Contact: Jim Bennett
Aquatic Nongame Program Specialist
Colorado Division of Wildlife
6060 Broadway
Denver, CO 80216
(303) 291-7273

18. Walter Walker State Wildlife Area

Contact: Clee Sealing
Regional Fisheries Biologist
Colorado Division of Wildlife
711 Independent Avenue
Grand Junction, CO 81505
(303) 248-7175

19. DeBeque Gravel Pit

Contact: Clee Sealing
Regional Fisheries Biologist
Colorado Division of Wildlife
711 Independent Avenue
Grand Junction, CO 81505
(303) 248-7175

20. Etter Pond

Contact: Clee Sealing
Regional Fisheries Biologist
Colorado Division of Wildlife
711 Independent Avenue
Grand Junction, CO 81505
(303) 248-7175

21. Una Pond, near Parachute, CO

Contact: Clee Sealing
Regional Fisheries Biologist
Colorado Division of Wildlife
711 Independent Avenue
Grand Junction, CO 81505
(303) 248-7175

22. Humphrey's Pond

Contact: Clee Sealing
Regional Fisheries Biologist
Colorado Division of Wildlife
711 Independent Avenue
Grand Junction, CO 81505
(303) 248-7175

23. Rangeview Trout Ranch

Contact: Mr. Jerry Wintz
Rangeview Trout Ranch
14473 Highway 285
Saguache, CO 81149
(719) 655-2237

24. John Stroh Trout Farm

Contact: John Stroh
Stroh Trout Farm
3256 J Road
Hotchkiss, CO 81419
(303) 872-2133

25. Russell Lake State Wildlife Area

Contact: Dave Langlois
Regional Fisheries Biologist
Colorado Division of Wildlife
2300 South Townsend
Montrose, CO 81401
(303) 249-3431

26. Closed Basin Project

Contact: Larry Harris
Colorado Division of Wildlife
317 West Prospect
Ft. Collins, CO 80526

27. Moffet County Fair Grounds, Craig, CO

Contact: Don Birkner
City of Craig
300 West 4th Street
Craig, CO 81625
(303) 824-8151
(303) 824-6539 fax

28. New Wastewater Treatment Plant, Craig, CO

Contact: Don Birkner
City of Craig
300 West 4th Street
Craig, CO 81625
(303) 824-8151
(303) 824-6539 fax

29. Old Wastewater Treatment Plant, Craig, CO

Contact: Don Birkner
City of Craig
300 West 4th Street
Craig, CO 81625
(303) 824-8151
(303) 824-6539 fax

30. Water Treatment Plant, Craig, CO

Contact: Don Birkner
City of Craig
300 West 4th Street
Craig, CO 81625
(303) 824-8151
(303) 824-6539 fax

31. Colorado Highway #394, Craig, CO

Contact: Don Birkner
City of Craig
300 West 4th Street
Craig, CO 81625
(303) 824-8151
(303) 824-6539 fax

32. Grand Junction Site #1

Contact: Mr. Greg Trainor
City of Grand Junction
250 N. 5th Street
Grand Junction, CO 81501-2668
(303) 244-1509

33. Grand Junction Site #2

Contact: Mr. Greg Trainor
City of Grand Junction
250 N. 5th Street
Grand Junction, CO 81501-2668
(303) 244-1509

APPENDIX E

SITE DATA COLLECTION SHEET

APPENDIX E

STATE OF COLORADO

HATCHERY FEASIBILITY STUDY FOR ENDANGERED FISHES OF THE UPPER COLORADO RIVER BASIN

SITE DATA COLLECTION SHEET

Site Name: ______________________________

Data Sheet Prepared By: Date: ______________

Name: ______________________________

Address: ______________________________

____

Telephone: ____________________

Water Source and Water Quality Information

Source 1: Groundwater or Surface Water (Circle One)

Continuous reliable flow rate ______________ gpm/cfs (Circle One)

Average Temperature - Winter __________ °C/°F (Circle One)

Average Temperature - Summer __________ °C/°F (Circle One)

Total Dissolved Solids ________________ mg/l

pH ______________

Lab test results available? Y/N (Please attach)

Water rights (please attach status and legal information, if available)

Source 2: Groundwater or Surface Water (Circle One)

Continuous reliable flow rate ______________ gpm/cfs (Circle One)

Average Temperature - Winter __________ °C/°F (Circle One)

Average Temperature - Summer __________ °C/°F (Circle One)

Total Dissolved Solids ________________ mg/l

pH ______________

Lab test results available? Y/N (Please attach)

Water rights (please attach status and legal information, if available)

Source 3: Groundwater or Surface Water (Circle One)

Continuous reliable flow rate ________________ gpm/cfs (Circle One)

Average Temperature - Winter ____________ °C/°F (Circle One)

Average Temperature - Summer ____________ °C/°F (Circle One)

Total Dissolved Solids ____________________ mg/l

pH _________________

Lab test results available? Y/N (Please attach)

Water rights (please attach status and legal information, if available)

Additional Information - please describe

Surface Water - Source: Name of stream, canal, lake, reservoir; type of diversion.

Groundwater - Source: Location of well, depth of well.

<u>Site Characteristics</u>

Site Map Available? Y/N (Please Attach)

Provide sketch if map is not available. Desired information includes:

Site layout of existing buildings, ponds, water features, other manmade features, geologic features, roads, adjacent property.

Are plans for existing buildings and facilities available? Y/N (Please Attach)

Property ownership information:

Name: ____

Address: ____

____

Telephone: _________________________

Property Description (Section, Township, and Range)

Is Property For Sale Y/N For Lease Y/N Comment: ________

____

Site area: ______________ acres

General Site Topography - Description ________________________

____

____

Site Access - Description ________________________

____

____

____

Is Site Within Floodplain? Y/N

Site Elevation: ______________ feet

Site Geology:

Any Geologic Faults? Y/N Describe ________________________

____

Any Landslides or Other Geologic Hazards Y/N Describe ____________

____

Climate/Exposure: Does site receive relatively full sun year-round? Y/N

Describe: ____

____

Does property contain any sensitive habitats (wetlands, protected areas, species?) Y/N

Describe ____

____

List and Describe Adjacent Properties ________________________

____

____

____

____

____

____

____

____

Utilities

Is potable water service available at site? Y/N Service Size ______________

Is sanitary sewer service available at site? Y/N Service Size ______________

Is electric power service available at site? Y/N Service type and capacity ________

____

Is gas service available at site? Y/N Service Size ______________

List Utility Suppler's name(s) and address(es):

____

____

____

____

If any or all of the above utilities are not available at the site, provide information on the proximity and possibility of such services. ______________

____

____

____

Community Resources

Proximity of site to community resources, such as housing, schools, etc. ________

____

Nature of available community resources. ______________

____

____

APPENDIX F

FINAL SCREENING SITE DESCRIPTIONS

SITE DESCRIPTIONS

This section provides brief descriptions of the 16 proposed sites evaluated in the final screening effort. The Final Report includes more detailed description of these sites.

1. Glenwood Desalinization Facility (near Glenwood Springs, CO):

This proposed hatchery site is located west of Glenwood Springs in a canyon south of I-70. The site was proposed in conjunction with a proposed desalinization plant project. The concept is to use the waste heat from the desalinization plant to heat hatchery water. The site is undeveloped. The site received a fatal flaw for: Water Reliability - The hatchery warm water supply would be contingent on the operation of the desalination plant. The site is also located downstream of a solid waste landfill operation.

2. CO-Ute Plant/CIRG Site (near Craig, CO):

This proposed hatchery site is located near Craig, on private property. The site was proposed as part of a larger site development project for industries which would use waste heat from the power plant, in this case, to heat the hatchery water. This site received a fatal flaw for: Water Reliability - With current information, the hatchery warm water supply would be contingent on the operation of the power plant. There may be the possibility of geothermal water at the site. The area of available land is small.

6. Rifle Falls SFH (near Rifle, CO):

This proposed hatchery site is located near Rifle, on property partially occupied by the existing Colorado Division of Wildlife - Rifle Falls Fish Hatchery. The water supply for the site would be cold surface water. Existing cold well water is used by the Rifle Falls Hatchery.

8. Clines Fish Hatchery (Monte Vista, CO):

This proposed hatchery site, located within the San Luis Valley, is currently the site of an existing private fish hatchery. The existing hatchery has an artisan geothermal well water supply. Acquisition of farm land adjacent to the Clines property would be required for the site to be feasible. The existing hatchery rearing ponds are generally small.

9. Putnam Fish Hatchery (Durango, CO):

This proposed hatchery site is currently the site of an existing private fish hatchery. The existing hatchery has a cold water supply from springs. The site has a large area of available land in addition to the area occupied by the hatchery. The site has good topographical relief for reaeration of water. The rearing ponds are generally small and grouped on different terraces across the site.

10. Silver Springs Trout Farm (Montrose, CO)

This proposed hatchery site is currently the site of an existing private fish hatchery. The existing hatchery has a cold water supply from springs. The existing hatchery rearing ponds are medium in size.

11. McMillan's Trout Farm (Hotchkiss, CO)

This proposed hatchery site is currently the site of an existing private fish hatchery. The existing hatchery has a cold water supply from springs. This spring water is likely mixed with surface runoff due the configuration of the existing water collection system. The site is situated on a small bench adjacent to the Gunnison River. The rearing ponds are small. This site received a fatal flaw for: Land Accessibility/Useability - The site is small and is relatively inaccessible.

15. Crystal Properties (near Hooper, CO)

This proposed hatchery site, located within the San Luis Valley, was formally the site of a private fish hatchery and a hot pool resort. Some remnants of both businesses remain. The property has a warm artisan well water supply. Effluent from the hatchery would be to open ground.

16. Horsethief Site (near Grand Junction, CO)

This proposed hatchery site is within a State Wildlife Area. This site received a fatal flaw for: Land Area - All available land has been used by existing rearing ponds.

18. Walter Walker State Wildlife Area (Grand Junction, CO)

This proposed hatchery site is within a State Wildlife Area. The site would have a surface water supply, from the Colorado River. The site is within the floodplain of the Colorado River.

23. Rangeview Trout Ranch (Saguache, CO)

This proposed hatchery site, located within the San Luis Valley, is currently the site of an existing private fish hatchery. The existing hatchery has an artisan geothermal well water supply. There may be additional geothermal water available at the site. The size of existing hatchery raceways and rearing ponds range from medium to small.

24. Crystal Springs Hatchery (near Hotchkiss, CO)

This proposed hatchery site is currently the site of an existing private fish hatchery. The existing hatchery has a cold water supply from springs and a surface water supply. The surface water supply is from water canals. The hatchery is adjacent to the former USFWS Chipeta Springs Hatchery, which was destroyed by a landslide. The existing hatchery rearing ponds are generally small.

25. Russell Lakes SWA (Saguache, CO)

This proposed hatchery site, located within the San Luis Valley, is within the State Wildlife Area. The property has a warm partially-artisan well water supply from a number of small wells. There may be additional geothermal water available at the site. The site has previously been used as a hatchery and currently is being used by the Rangeview Trout Ranch to raise fish.

26. Closed Basin Project (near San Luis Lake, CO)

This proposed hatchery site, located within the San Luis Valley, is on property which is part of the Bureau of Reclamation Closed Basin Project. The water supply would be ground water pumped from the Closed Basin Wells. There also may be geothermal water available at the site. Land is available for the proposed hatchery.

28. New Wastewater Treatment Plant (near Craig, CO)

This proposed hatchery site is located at the site of the City of Craig new wastewater treatment plant. While the plant site does not have adequate land area, there is open land adjacent to the site. The water supply would be surface water from the Yampa River. There also may be geothermal water available at the site.

32. Grand Junction Site #1 (Summerville Ranch, CO)

This proposed hatchery site is located southeast of City of Grand Junction. The water supply would be surface water, from the City of Grand Junction raw water supply system. There is available land for the proposed hatchery.

GLOSSARY OF TERMS

Augmentation Stock - Those fish which are released for the purpose of increasing the existing fish population.

Biomass - The pounds of fish which are either maintained or produced at the recovery facility. The capacity of the facility to hold and grow fish is expressed in terms of pounds of fish or total biomass.

Broodstock - Fish of a particular species, represented by both sexes which are held in captivity until and during maturity for the distinct purpose of crossbreeding. The genetic history is usually known for these animals and they are usually bred according to strict protocols designed to maintain a level of genetic diversity in the progeny. For the purposes of this facility, refugia and broodstock populations are considered the same.

Culture Techniques - Different methodologies which are used to hatch and produce fish. For this report, the two categories of culture techniques are intensive culture and extensive culture.

Extensive Culture - A culture methodology which emphasizes more natural rearing conditions for fish that are reared in an artificial environment. Under extensive culture conditions fish are reared at low density in outdoor ponds. Rearing is conducted at ambient temperatures and natural feed items are encouraged to grow in the pond environment. This strategy is employed to alleviate hatchery induced pressures which may work selectively on the genetic diversity of the fish being cultured. This method requires less water and more land than intensive culture.

Intensive Culture - A culture methodology designed to achieve maximum productivity for fish held in artificial culture environments. The fish are held at higher densities in tanks or raceways and fed an artificial diet. Rearing temperatures are held at values which are known to achieve maximum growth rates. Water flow rate are high to maintain water quality by carrying away waste products, and excess feed. The primary goal of intensive culture is to achieve maximum fish production levels for a given rearing space while maintaining healthy stocks of fish.

Refugia - Individual fish representing genetically distinct stocks of a particular species held in captive habitat. Usually held in reserve for use as future broodstock and to provide an environment for protection and survival of declining number of endangered fish in the wild. The purpose is to maintain the genetic diversity of a species by maintaining representative examples of distinct, genetically diverse strains from specific native habitats.

APPENDIX G

FACILITY DESIGN REQUIREMENT BIOPROGRAMS

FACILITY DESIGN REQUIREMENT
BIOPROGRAMS

Table: **A.1.**
Species: **Colorado Squawfish**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date		Event	Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Jun	1	troughs	69.0	100%	0.40	0.000	57870	0	0	224,366	4
1-Jul	31		69.0	100%	0.70	0.000	10,615	0	0	217,064	20
1-Aug	62		69.0	100%	1.01	0.000	3,555	0	0	209,764	59
1-Sep	93	circulars	69.0	100%	1.32	0.001	1,597	0	0	202,710	127
1-Oct	123		69.0	100%	1.62	0.001	866	0	0	196,113	227
1-Nov	154		69.0	100%	1.93	0.002	513	0	0	189,518	370
1-Dec	184		69.0	100%	2.23	0.003	333	0	0	183,350	551
1-Jan	215		69.0	100%	2.54	0.004	225	0	0	177,184	787
1-Feb	246		69.0	100%	2.85	0.006	160	0	0	171,226	1,073
1-Mar	275		69.0	100%	3.13	0.008	121	0	0	166,025	1,378
1-Apr	306		69.0	100%	3.44	0.011	91	0	0	160,441	1,767
1-May	336		69.0	100%	3.74	0.014	71	0	0	155,220	2,196
1-Jun	367	release	69.0	100%	4.05	0.018	56	150,000	2,694	0	0
				Total Number of Fish Released and Weight (lb):				150,000	2,694		

Table: **A.1.**
Species: **Colorado Squawfish**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Oxygen Consumption (lbO2/lbfeed/d)	Oxygen Consumption (lb/100 lb/d)	Food Conversion	Required Feed (lb)
1-Jun	7.42	95%	7.05	0.337	10.00	2.00	35
1-Jul	7.42	95%	7.05	0.337	4.46	2.00	81
1-Aug	7.42	95%	7.05	0.337	2.75	2.00	145
1-Sep	7.42	95%	7.05	0.337	1.90	2.00	214
1-Oct	7.42	95%	7.05	0.337	1.55	2.00	312
1-Nov	7.42	95%	7.05	0.337	1.22	2.00	400
1-Dec	7.42	95%	7.05	0.337	1.07	2.00	525
1-Jan	7.42	95%	7.05	0.337	0.93	2.00	648
1-Feb	7.42	95%	7.05	0.337	0.73	2.00	696
1-Mar	7.42	95%	7.05	0.337	0.73	2.00	901
1-Apr	7.42	95%	7.05	0.337	0.64	2.00	1,006
1-May	7.42	95%	7.05	0.337	0.61	2.00	1,184
1-Jun	7.42	95%	7.05	0.337	0.60	2.00	2,225

Total Feed Required (lb): 6,147

Table: A.1.
Species: **Colorado Squawfish**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Location	Rearing Density (lbs/cu ft)	Required Space (cu ft)	Container Area (cu ft)	Required Units	Based on O2 Consumption		
						Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
1-Jun	trough	0.43	9	5	2	12.47	0.25	16
1-Jul	trough	0.43	48	5	10	5.87	0.55	37
1-Aug	trough	0.43	137	5	28	3.73	0.89	66
1-Sep	12' circular	0.43	295	339	1	2.31	1.30	98
1-Oct	12' circular	1.00	227	339	1	3.37	1.59	142
1-Nov	12' circular	1.00	370	339	2	2.16	2.03	182
1-Dec	12' circular	1.00	551	339	2	2.83	2.30	240
1-Jan	12' circular	1.00	787	339	3	2.33	2.66	295
1-Feb	12' circular	1.00	1073	339	4	1.88	3.38	317
1-Mar	12' circular	1.00	1378	339	5	1.94	3.35	411
1-Apr	12' circular	1.00	1767	339	6	1.81	3.85	459
1-May	12' circular	1.00	2196	339	7	1.82	4.07	540
1-Jun	release	1.00	2694	339	8	1.94	4.11	656

Table: **A.1.**
Species: **Colorado Squawfish**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**				
Elevation (ft above MSL):		6500	**Task 7 Datasheet**				
Maximum pH:		8.20	**Task 7 Datasheet**				
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	**Assumed**				
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth: 0.75
12' circular (cu. ft.):		339.12	Diameter:	12	Depth:	3	
Fish length at transfer to large circulars (in		1.20	Aron Kriss (CDOW 1992) rec. 1.5, 1.2 set to save space				
Swimup Fry Stocking Density (fish/cf):		300	Knott, 1990				
Species Parameters							
Species:		Colorado Squawfish					
Species Code:		13					
C factor:	L (inches) > 0.30	2.70E-04	W/L^3 formula using CDOW data (Harris 1991)				
	L (inches) > 2.00	2.70E-04					
	L (inches) >= 3.00	2.70E-04					
Monthly Temp. Units per inch of growth:		100	Criss, Aron; CDOW telephone correspondence use 0.3"/mo.				
Mortality rate (%/month):		3.30%	Harris,et al 1991				
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits				
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"				

Table: **A.2.**
Species: **Razorback Sucker**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	69.0	100%	0.33	0.00	30,435	0	0	198,569	7
1-Apr	32		69.0	100%	0.85	0.00	1,804	0	0	193,510	107
1-May	62	circulars	69.0	100%	1.35	0.00	1,384	0	0	188,739	136
1-Jun	93		69.0	100%	1.86	0.00	523	0	0	183,931	352
1-Jul	123		69.0	100%	2.36	0.01	170	0	0	179,396	1,057
1-Aug	154		69.0	100%	2.88	0.01	94	0	0	174,826	1,864
1-Sep	185		69.0	100%	3.39	0.02	57	0	0	170,372	2,979
1-Oct	215		69.0	100%	3.89	0.03	38	0	0	166,171	4,387
1-Nov	246		69.0	100%	4.41	0.04	26	0	0	161,938	6,211
1-Dec	276		69.0	100%	4.91	0.05	19	0	0	157,945	8,359
1-Jan	307		69.0	100%	5.43	0.07	14	0	0	153,921	10,995
1-Feb	release		69.0	100%	5.94	0.09	11	150,000	14,074	0	0
							Total Number of Fish Released and Weight (lb):	150,000	14,074		

Table: A.2.
Species: **Razorback Sucker**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Oxygen Consumption (lbO2/lbfeed/d)	Oxygen Consumption (lb/100 lb/d)	Food Conversion	Required Artificial Feed (lb)
1-Mar	7.42	95%	7.05	0.337	35.65	2.00	207
1-Apr	7.42	95%	7.05	0.337	0.68	2.00	65
1-May	7.42	95%	7.05	0.337	3.70	2.00	450
1-Jun	7.42	95%	7.05	0.337	4.67	2.00	1,463
1-Jul	7.42	95%	7.05	0.337	1.82	2.00	1,711
1-Aug	7.42	95%	7.05	0.337	1.44	2.00	2,387
1-Sep	7.42	95%	7.05	0.337	1.15	2.00	3,037
1-Oct	7.42	95%	7.05	0.337	1.02	2.00	3,973
1-Nov	7.42	95%	7.05	0.337	0.85	2.00	4,718
1-Dec	7.42	95%	7.05	0.337	0.79	2.00	5,848
1-Jan	7.42	95%	7.05	0.337	0.70	2.00	6,893
1-Feb	7.42	95%	7.05	0.337	0.67	2.00	7,108

Total Feed Required (lb): 30,752

Table: **A.2.**
Species: **Razorback Sucker**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Location	Rearing Density (lb/cf)	Required Space (cf)	Container Area (cf)	Required Units	Based on O2 Consumption		
						Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
1-Mar	troughs	0.43	15	5	3	49.86	0.07	94
1-Apr	troughs	0.43	249	5	50	0.94	3.61	30
1-May	12' circulars	0.43	317	339	1	4.85	0.67	205
1-Jun	12' circulars	1.00	352	339	2	7.89	0.53	667
1-Jul	12' circulars	1.00	1057	339	4	4.61	1.35	780
1-Aug	12' circulars	1.00	1864	339	6	4.29	1.71	1,088
1-Sep	12' circulars	1.00	2979	339	9	3.64	2.15	1,385
1-Oct	12' circulars	1.00	4387	339	13	3.30	2.42	1,811
1-Nov	12' circulars	1.00	6211	339	19	2.68	2.89	2,151
1-Dec	12' circulars	1.00	8359	339	25	2.52	3.14	2,666
1-Jan	12' circulars	1.00	10995	339	33	2.25	3.50	3,143
1-Feb	release	1.00	14074	339	42	2.16	3.68	3,827

Table:	**A.2.**
Species:	**Razorback Sucker**
Rearing Method:	**Intensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
12' circular (cu. ft.):		339.12	Diameter:	12	Depth:	3		
Fish length at transfer to large circulars (in		1.22	Aron Kriss (CDOW 1992) rec. 1.5, 1.2 set to save space					
Swimup Fry Stocking Density (fish/cf):		300	Knott, 1990					
Species Parameters								
Species:		Razorback Sucker						
Species Code:		14						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.47E-04						
Monthly Temp. Units per inch of growth:		60	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					

Table: **A.3.**
Species: **Bonytail Chub**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Day	Event	Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	69.0	100%	0.33	0.000	30,435	0	0	166,171	5
1-Jun	32	to circulars	69.0	100%	1.22	0.001	1,317	0	0	161,938	123
1-Jul	62		69.0	100%	2.07	0.003	388	0	0	157,945	407
1-Aug	93		69.0	100%	2.96	0.007	133	0	0	153,921	1,154
1-Sep	124	release	69.0	100%	3.84	0.016	61	150,000	2,467	0	0

Total Number of Fish Released and Weight (lb): 150,000 2,467

Table: A.3.
Species: Bonytail Chub
Rearing Method: Intensive Culture
Water Supply: Warm Well Water

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Oxygen Consumption (lbO2/lbfeed/d)	Oxygen Consumption (lb/100 lb/d)	Food Conversion	Required Artificial Feed (lb)
1-May	7.42	95%	7.05	0.337	49.68	2.00	241
1-Jun	7.42	95%	7.05	0.337	5.38	2.00	589
1-Jul	7.42	95%	7.05	0.337	4.29	2.00	1,554
1-Aug	7.42	95%	7.05	0.337	2.68	2.00	2,755
1-Sep	7.42	95%	7.05	0.337	1.17	2.00	3,400

Total Feed Required (lb): 5,139

Table: **A.3.**
Species: **Bonytail Chub**
Rearing Method: **Intensive Culture**
Water Supply: **Warm Well Water**

Date	Location	Rearing Density (lb/cf)	Required Space (cf)	Container Area (cf)	Required Units	Based on O2 Consumption: Change-overs per Hour	Based on O2 Consumption: Carrying Capacity (lb/gpm)	Based on O2 Consumption: Required Flow (gpm)
1-May	troughs	0.43	13	5	3	58.15	0.05	110
1-Jun	12' circulars	0.43	286	339	1	6.35	0.46	269
1-Jul	12' circulars	1.00	407	339	2	8.38	0.57	708
1-Aug	12' circulars	1.00	1154	339	4	7.43	0.92	1,256
1-Sep	release	1.00	2467	339	8	3.46	2.11	1,171

Table:	**A.3.**
Species:	**Bonytail Chub**
Rearing Method:	**Intensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cu. ft.)		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
12' circular (cu. ft.):		339.12	Diameter:	12	Depth:	3.0		
Fish length at transfer to large circulars (in)		1.20	Aron Kriss (CDOW 1992) rec. 1.5, 1.2 set to save space					
Swimup Fry Stocking Density (fish/cf):		300	Knott, 1990					
Species Parameters								
Species:		Bonytail Chub						
Species Code:		16						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.00	4.23E-04						
	L (inches) >= 2.00	2.90E-04						
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					

Table: A.4.
Species: Humpback Chub
Rearing Method: Intensive Culture
Water Supply: Warm Well Water

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	69.0	100%	0.33	0.000	30,435	0	0	166,171	5
1-Jun	32	circulars	69.0	100%	1.22	0.001	1,881	0	0	161,938	86
1-Jul	62		69.0	100%	2.07	0.004	268	0	0	157,945	588
1-Aug	93		69.0	100%	2.96	0.011	92	0	0	153,921	1,667
1-Sep	124	release	69.0	100%	3.84	0.024	42	150,000	3,564	0	0

Total Number of Fish Released and Weight (lb): 150,000 3,564

Table:	A.4.
Species:	**Humpback Chub**
Rearing Method:	**Intensive Culture**
Water Supply:	**Warm Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Oxygen Consumption (lbO2/lbfeed/d)	Oxygen Consumption (lb/100 lb/d)	Food Conversion	Required Artificial Feed (lb)
1-May	7.42	95%	7.05	0.337	34.10	2.00	166
1-Jun	7.42	95%	7.05	0.337	13.50	2.00	1,034
1-Jul	7.42	95%	7.05	0.337	4.29	2.00	2,245
1-Aug	7.42	95%	7.05	0.337	2.68	2.00	3,980
1-Sep	7.42	95%	7.05	0.337	1.19	2.00	4,200

Total Feed Required (lb): 7,425

Table: A.4.
Species: Humpback Chub
Rearing Method: Intensive Culture
Water Supply: Warm Well Water

Date	Location	Rearing Density (lb/cf)	Required Space (cf)	Container Area (cf)	Required Units	Based on O2 Consumption: Change-overs per Hour	Based on O2 Consumption: Carrying Capacity (lb/gpm)	Based on O2 Consumption: Required Flow (gpm)
1-May	troughs	0.43	13	5	3	39.91	0.07	76
1-Jun	12' circulars	1.00	86	339	1	11.16	0.18	472
1-Jul	12' circulars	1.00	588	339	2	12.10	0.57	1,023
1-Aug	12' circulars	1.00	1667	339	5	8.59	0.92	1,815
1-Sep	release	1.00	3564	339	11	3.70	2.07	1,721

Table:	**A.4.**
Species:	**Humpback Chub**
Rearing Method:	**Intensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH_3 mg/l):		0.0002	Assumed					
Trough size (cu. ft.):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
12' circular (cu. ft.):		339.12	Diameter:	12	Depth:	3		
Fish length at transfer to large circulars (in		1.20	Aron Kriss (CDOW 1992) rec. 1.5, 1.2 set to save space					
Swimup Fry Stocking Density (fish/cf):		300	Knott, 1990					
Species Parameters								
Species:		Humpback Chub						
Species Code:		15						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.19E-04						
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					

Table: A.5.
Species: **Colorado Squawfish**
Rearing Method: **Extensive Culture**
Water Supply: **Warm Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	69.0	100%	0.33	0.00	30,435	0	0	224,366	7
1-Apr	32	ponds	69.0	100%	0.64	0.00	4,176	0	0	216,820	52
1-May	62		69.0	100%	0.94	0.00	1,319	0	0	209,764	159
1-Jun	93		69.0	100%	1.25	0.00	1,731	0	0	202,710	117
1-Jul	123		69.0	100%	1.55	0.00	908	0	0	196,113	216
1-Aug	154		69.0	100%	1.86	0.00	525	0	0	189,518	361
1-Sep	185		69.0	100%	2.17	0.01	193	0	0	183,144	949
1-Oct	215		69.0	100%	2.47	0.01	131	0	0	177,184	1,354
1-Nov	246		69.0	100%	2.78	0.01	92	0	0	171,226	1,866
1-Dec	276		69.0	100%	3.08	0.01	67	0	0	165,653	2,454
1-Jan	307		69.0	100%	3.39	0.02	51	0	0	160,082	3,163
1-Feb	338		69.0	100%	3.70	0.03	39	0	0	154,699	3,974
1-Mar	366	release	69.0	100%	3.98	0.03	31	150,000	4,795	0	0
							Total Number of Fish Released and Weight (lb):	150,000	4,795		

Table:	A.5.
Species:	Colorado Squawfish
Rearing Method:	Extensive Culture
Water Supply:	Warm Well Water

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-Mar	7.42	95%	7.05	2.3	0
1-Apr	7.42	95%	7.05	2.3	3
1-May	7.42	95%	7.05	2.3	8
1-Jun	7.42	95%	7.05	2.3	6
1-Jul	7.42	95%	7.05	2.3	11
1-Aug	7.42	95%	7.05	2.3	18
1-Sep	7.42	95%	7.05	2.3	47
1-Oct	7.42	95%	7.05	2.3	68
1-Nov	7.42	95%	7.05	2.3	93
1-Dec	7.42	95%	7.05	2.3	123
1-Jan	7.42	95%	7.05	2.3	158
1-Feb	7.42	95%	7.05	2.3	199
1-Mar	7.42	95%	7.05	2.3	0
				Total Feed Required (lb):	734

Table: A.5.
Species: Colorado Squawfish
Rearing Method: Extensive Culture
Water Supply: Warm Well Water

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers		
						Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
1-Mar	troughs	0.43	17	5.06	4	2.000	1.46	5
1-Apr	ponds	110,000	2	0.25	8	0.002	0.60	87
1-May	ponds	110,000	2	0.25	8	0.002	1.83	87
1-Jun	ponds	50,000	4	0.25	17	0.002	0.63	185
1-Jul	ponds	49,000	4	0.25	17	0.002	1.17	185
1-Aug	ponds	47,500	4	0.25	16	0.002	2.08	174
1-Sep	ponds	46,000	4	0.25	16	0.002	5.46	174
1-Oct	ponds	44,500	4	0.25	16	0.002	7.79	174
1-Nov	ponds	43,000	4	0.25	16	0.002	10.74	174
1-Dec	ponds	41,500	4	0.25	16	0.002	14.12	174
1-Jan	ponds	40,000	4	0.25	17	0.002	17.13	185
1-Feb	ponds	38,500	4	0.25	17	0.002	21.52	185
1-Mar	release	35,000	4	0.25	18	0.002	24.53	195

Table:	**A.5.**
Species:	**Colorado Squawfish**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

			Reference					
Site Parameters								
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	TAC pond size requirement					
Fish length at transfer to ponds (in):		0.40	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Colorado Squawfish						
Species Code:		13						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	5.08E-04						
Monthly Temp. Units per inch of growth:		100	Calculated from data supplied by Biowest					
Mortality rate (%/month):		3.30%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: A.6.
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Warm Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	69.0	100%	0.33	0.00	30,435	0	0	198,569	7
1-Apr	32	ponds	69.0	100%	0.85	0.00	1,804	0	0	193,510	107
1-May	62		69.0	100%	1.35	0.00	1,384	0	0	188,739	136
1-Jun	93		69.0	100%	1.86	0.00	523	0	0	183,931	352
1-Jul	123		69.0	100%	2.36	0.01	170	0	0	179,396	1,057
1-Aug	154		69.0	100%	2.88	0.01	94	0	0	174,826	1,864
1-Sep	185		69.0	100%	3.39	0.02	57	0	0	170,372	2,979
1-Oct	215		69.0	100%	3.89	0.03	38	0	0	166,171	4,387
1-Nov	246		69.0	100%	4.41	0.04	26	0	0	161,938	6,211
1-Dec	276		69.0	100%	4.91	0.05	19	0	0	157,945	8,359
1-Jan	307		69.0	100%	5.43	0.07	14	0	0	153,921	10,995
1-Feb	338	release	69.0	100%	5.94	0.09	11	150,000	14,074	0	0

Total Number of Fish Released and Weight (lb): 150,000 14,074

Table:	**A.6.**
Species:	**Razorback Sucker**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-Mar	7.42	95%	7.05	2.3	0
1-Apr	7.42	95%	7.05	2.3	5
1-May	7.42	95%	7.05	2.3	7
1-Jun	7.42	95%	7.05	2.3	18
1-Jul	7.42	95%	7.05	2.3	53
1-Aug	7.42	95%	7.05	2.3	93
1-Sep	7.42	95%	7.05	2.3	149
1-Oct	7.42	95%	7.05	2.3	219
1-Nov	7.42	95%	7.05	2.3	311
1-Dec	7.42	95%	7.05	2.3	418
1-Jan	7.42	95%	7.05	2.3	550
1-Feb	7.42	95%	7.05	2.3	0

Total Feed Required (lb): 1,823

Table: A.6.
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Warm Well Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
						Based on Changeovers		
1-Mar	troughs	0.43	15	5.06	3	2.000	1.72	4
1-Apr	ponds	110,000	2	0.25	8	0.002	1.23	87
1-May	ponds	110,000	2	0.25	7	0.002	1.79	76
1-Jun	ponds	53,000	3	0.25	14	0.002	2.32	152
1-Jul	ponds	52,000	3	0.25	14	0.002	6.95	152
1-Aug	ponds	50,000	3	0.25	14	0.002	12.26	152
1-Sep	ponds	49,000	3	0.25	14	0.002	19.59	152
1-Oct	ponds	48,500	3	0.25	14	0.002	28.85	152
1-Nov	ponds	47,250	3	0.25	14	0.002	40.85	152
1-Dec	ponds	46,100	3	0.25	14	0.002	54.97	152
1-Jan	ponds	45,000	3	0.25	14	0.002	72.31	152
1-Feb	release	44,000	3	0.25	14	0.002	92.56	152

Table:	**A.6.**
Species:	**Razorback Sucker**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	TAC pond size requirement					
Fish length at transfer to ponds (in):		0.40	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Razorback Sucker						
Species Code:		14						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.47E-04						
Monthly Temp. Units per inch of growth:		60	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table:	**A.7.**
Species:	**Bonytail Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	69.0	100%	0.33	0.000	30,435	0	0	166,171	5
1-Jun	32	ponds	69.0	100%	1.22	0.001	1,317	0	0	161,938	123
1-Jul	62		69.0	100%	2.07	0.003	388	0	0	157,945	407
1-Aug	93		69.0	100%	2.96	0.007	133	0	0	153,921	1,154
1-Sep	124	release	69.0	100%	3.84	0.016	61	150,000	2,467	0	0

Total Number of Fish Released and Weight (lb): 150,000 2,467

Table: A.7.
Species: Bonytail Chub
Rearing Method: Extensive Culture
Water Supply: Warm Well Water

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-May	7.42	95%	7.05	2.30	0
1-Jun	7.42	95%	7.05	2.30	6
1-Jul	7.42	95%	7.05	2.30	20
1-Aug	7.42	95%	7.05	2.30	58
1-Sep	release	95%	7.05	2.30	0

Total Feed Required (lb): 84

Table:	**A.7.**
Species:	**Bonytail Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Based on Changeovers: Carrying Capacity (lb/gpm)	Based on Changeovers: Required Flow (gpm)
1-May	troughs	0.43	13	5.06	3	2.000	1.44	4
1-Jun	pond	110,000	1	0.25	6	0.002	1.80	68
1-Jul	pond	110,000	1	0.25	6	0.002	5.95	68
1-Aug	pond	50,000	3	0.25	13	0.002	7.78	148
1-Sep	release	49,000	3	0.25	13	0.002	16.64	148

Table:	**A.7.**
Species:	**Bonytail Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**				
Elevation (ft above MSL):		6500	Task 7 Datasheet				
Maximum pH:		8.20	Task 7 Datasheet				
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed				
Trough size (cu. ft.)		5.06	Length: 4.5	Depth:	1.5	Width:	0.75
Pond size (ac):		0.25	TAC pond size requirement				
Fish length at transfer to ponds (in):		0.40	Hamman, 1987				
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987				
Species Parameters							
Species:		Bonytail Chub					
Species Code:		16					
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data				
	L (inches) > 1.00	4.23E-04					
	L (inches) >= 2.00	2.90E-04					
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest				
Mortality rate (%/month):		2.50%	Hamman, 1987				
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits				
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"				
Required feed, based upon 5% supplemental per pound			Hamman, 1987				

Table: A.8.
Species: **Humpback Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Warm Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	69.0	100%	0.33	0.000	30,435	0	0	166,171	5
1-Jun	32	ponds	69.0	100%	1.22	0.001	1,881	0	0	161,938	86
1-Jul	62		69.0	100%	2.07	0.004	268	0	0	157,945	588
1-Aug	93		69.0	100%	2.96	0.011	92	0	0	153,921	1,667
1-Sep	124	release	69.0	100%	3.84	0.024	42	150,000	3,564	0	0

Total Number of Fish Released and Weight (lb): 150,000 3,564

Table:	**A.8.**
Species:	**Humpback Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-May	7.42	95%	7.05	2.3	0
1-Jun	7.42	95%	7.05	2.3	4
1-Jul	7.42	95%	7.05	2.3	29
1-Aug	7.42	95%	7.05	2.3	83
1-Sep	7.42	95%	7.05	2.3	0

Total Feed Required (lb): 117

Table: A.8.
Species: **Humpback Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Warm Well Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Based on Changeovers: Carrying Capacity (lb/gpm)	Based on Changeovers: Required Flow (gpm)
1-May	trough	0.43	13	5	3	2.000	1.44	4
1-Jun	pond	110,000	1	0	6	0.002	1.32	65
1-Jul	pond	110,000	1	0	6	0.002	9.03	65
1-Aug	pond	50,000	3	0	13	0.002	11.81	141
1-Sep	release	49,000	3	0	13	0.002	25.24	141

Table:	**A.8.**
Species:	**Humpback Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Warm Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cu. ft.):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	TAC pond size requirement					
Fish length at transfer to ponds (in):		0.40	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Humpback Chub						
Species Code:		15						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.19E-04						
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: A.9.
Species: **Colorado Squawfish**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	64.0	100%	0.33	0.000	30,435	0	0	293,998	10
1-Apr	32	ponds	57.6	100%	0.59	0.000	5,357	0	0	284,111	53
1-May	62		57.6	100%	0.78	0.000	2,339	0	0	274,865	118
1-Jun	93		57.6	100%	0.97	0.001	1,199	0	0	265,621	222
1-Jul	123		57.6	100%	1.16	0.001	706	0	0	256,977	364
1-Aug	154		57.6	100%	1.35	0.001	1,369	0	0	248,335	181
1-Sep	185		57.6	100%	1.54	0.001	916	0	0	239,984	262
1-Oct	215		57.6	100%	1.73	0.002	650	0	0	232,174	357
1-Nov	246		57.6	100%	1.93	0.002	473	0	0	224,366	475
1-Dec	276		57.6	100%	2.11	0.005	209	0	0	217,064	1,040
1-Jan	307		57.6	100%	2.31	0.006	160	0	0	209,764	1,307
1-Feb	338		57.6	100%	2.50	0.008	126	0	0	202,710	1,609
1-Mar	366		57.6	100%	2.67	0.010	103	0	0	196,553	1,911
1-Apr	397		57.6	100%	2.87	0.012	83	0	0	189,943	2,278
1-May	427		57.6	100%	3.06	0.014	69	0	0	183,761	2,664
1-Jun	458		57.6	100%	3.25	0.017	57	0	0	177,582	3,096
1-Jul	488		57.6	100%	3.44	0.021	48	0	0	171,802	3,543
1-Aug	519		57.6	100%	3.63	0.024	41	0	0	166,025	4,036
1-Sep	550		57.6	100%	3.82	0.028	35	0	0	160,441	4,558
1-Oct	580		57.6	100%	4.01	0.033	30	0	0	155,220	5,091
1-Nov	611	release	57.6	100%	4.21	0.038	26	150,000	5,667	0	0

Total Number of Fish Released and Weight (lb): 150,000 5,667

Table: A.9.
Species: **Colorado Squawfish**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
Mar 1	7.78	95%	7.39	2.3	0
Apr 1	8.31	95%	7.90	2.3	3
May 1	8.31	95%	7.90	2.3	6
Jun 1	8.31	95%	7.90	2.3	11
Jul 1	8.31	95%	7.90	2.3	18
Aug 1	8.31	95%	7.90	2.3	9
Sep 1	8.31	95%	7.90	2.3	13
Oct 1	8.31	95%	7.90	2.3	18
Nov 1	8.31	95%	7.90	2.3	24
Dec 1	8.31	95%	7.90	2.3	52
Jan 1	8.31	95%	7.90	2.3	65
Feb 1	8.31	95%	7.90	2.3	80
Mar 1	8.31	95%	7.90	2.3	96
Apr 1	8.31	95%	7.90	2.3	114
May 1	8.31	95%	7.90	2.3	133
Jun 1	8.31	95%	7.90	2.3	155
Jul 1	8.31	95%	7.90	2.3	177
Aug 1	8.31	95%	7.90	2.3	202
Sep 1	8.31	95%	7.90	2.3	228
Oct 1	8.31	95%	7.90	2.3	255
Nov 1	8.31	95%	7.90	2.3	0
			Total Feed Required (lb):		1,659

Table: A.9.
Species: Colorado Squawfish
Rearing Method: Extensive Culture
Water Supply: Cold Well Water

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
						Based on Changeovers		
Mar 1	troughs	0.43	22	5.06	5	2.000	1.53	6
Apr 1	pond	110,000	3	0.25	11	0.002	0.44	119
May 1	pond	110,000	2	0.25	10	0.002	1.08	109
Jun 1	pond	50,000	5	0.25	22	0.002	0.93	239
Jul 1	pond	48,000	5	0.25	22	0.002	1.52	239
Aug 1	pond	47,000	5	0.25	22	0.002	0.76	239
Sep 1	pond	45,500	5	0.25	22	0.002	1.10	239
Oct 1	pond	44,000	5	0.25	22	0.002	1.50	239
Nov 1	pond	42,500	5	0.25	22	0.002	1.99	239
Dec 1	pond	40,000	5	0.25	22	0.002	4.35	239
Jan 1	pond	38,500	5	0.25	22	0.002	5.47	239
Feb 1	pond	37,000	5	0.25	22	0.002	6.73	239
Mar 1	pond	36,000	5	0.25	22	0.002	8.00	239
Apr 1	pond	35,000	5	0.25	22	0.002	9.53	239
May 1	pond	34,500	5	0.25	22	0.002	11.15	239
Jun 1	pond	33,500	5	0.25	22	0.002	12.96	239
Jul 1	pond	32,500	5	0.25	22	0.002	14.83	239
Aug 1	pond	31,500	5	0.25	22	0.002	16.89	239
Sep 1	pond	30,500	5	0.25	22	0.002	19.08	239
Oct 1	pond	29,500	5	0.25	22	0.002	21.30	239
Nov 1	release	28,500	5	0.25	22	0.002	23.72	239

Table:	**A.9.**
Species:	**Colorado Squawfish**
Rearing Method:	**Extensive Culture**
Water Supply:	**Cold Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	Pond size set by TAC					
Fish length at transfer to ponds (in):		0.35	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Colorado Squawfish						
Species Code:		13						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	5.08E-04						
Monthly Temp. Units per inch of growth:		100	Calculated from data supplied by Biowest					
Mortality rate (%/month):		3.30%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: **A.10.**
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Day	Event	Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	64.0	100%	0.33	0.00	30,435	0	0	236,885	8
1-Apr	32	ponds	57.6	100%	0.76	0.00	2,478	0	0	230,850	93
1-May	62		57.6	100%	1.07	0.00	884	0	0	225,158	255
1-Jun	93		57.6	100%	1.40	0.00	1,239	0	0	219,422	177
1-Jul	123		57.6	100%	1.71	0.00	677	0	0	214,012	316
1-Aug	154		57.6	100%	2.03	0.00	267	0	0	208,560	781
1-Sep	185		57.6	100%	2.35	0.01	171	0	0	203,246	1,185
1-Oct	215		57.6	100%	2.67	0.01	118	0	0	198,235	1,680
1-Nov	246		57.6	100%	2.99	0.01	84	0	0	193,185	2,306
1-Dec	276		57.6	100%	3.30	0.02	62	0	0	188,422	3,031
1-Jan	307		57.6	100%	3.62	0.02	47	0	0	183,622	3,907
1-Feb	338		57.6	100%	3.95	0.03	36	0	0	178,944	4,918
1-Mar	366		57.6	100%	4.24	0.03	29	0	0	174,826	5,950
1-Apr	397		57.6	100%	4.56	0.04	24	0	0	170,372	7,226
1-May	427		57.6	100%	4.87	0.05	19	0	0	166,171	8,597
1-Jun	458		57.6	100%	5.20	0.06	16	0	0	161,938	10,155
1-Jul	488		57.6	100%	5.51	0.07	13	0	0	157,945	11,799
1-Aug	519		57.6	100%	5.83	0.09	11	0	0	153,921	13,641
1-Sep	550	release	57.6	100%	6.15	0.10	10	150,000	15,624	0	0
							Total Number of Fish Released and Weight (lb):	150,000	15,624		

Table: A.10.
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-Mar	7.78	95%	7.39	2.3	0
1-Apr	8.31	95%	7.90	2.3	5
1-May	8.31	95%	7.90	2.3	13
1-Jun	8.31	95%	7.90	2.3	9
1-Jul	8.31	95%	7.90	2.3	16
1-Aug	8.31	95%	7.90	2.3	39
1-Sep	8.31	95%	7.90	2.3	59
1-Oct	8.31	95%	7.90	2.3	84
1-Nov	8.31	95%	7.90	2.3	115
1-Dec	8.31	95%	7.90	2.3	152
1-Jan	8.31	95%	7.90	2.3	195
1-Feb	8.31	95%	7.90	2.3	246
1-Mar	8.31	95%	7.90	2.3	297
1-Apr	8.31	95%	7.90	2.3	361
1-May	8.31	95%	7.90	2.3	430
1-Jun	8.31	95%	7.90	2.3	508
1-Jul	8.31	95%	7.90	2.3	590
1-Aug	8.31	95%	7.90	2.3	682
1-Sep	8.31	95%	7.90	2.3	0

Total Feed Required (lb): 1,230

Table: **A.10.**
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
1-Mar	troughs	0.43	18	5.06	4	2.000	1.54	5
1-Apr	pond	110,000	2	0.25	9	0.002	0.95	98
1-May	pond	110,000	2	0.25	9	0.002	2.61	98
1-Jun	pond	50,000	4	0.25	18	0.002	0.91	195
1-Jul	pond	50,000	4	0.25	18	0.002	1.62	195
1-Aug	pond	49,000	4	0.25	18	0.002	4.00	195
1-Sep	pond	47,500	4	0.25	18	0.002	6.06	195
1-Oct	pond	46,000	4	0.25	18	0.002	8.59	195
1-Nov	pond	44,500	4	0.25	18	0.002	11.80	195
1-Dec	pond	43,000	4	0.25	18	0.002	15.50	195
1-Jan	pond	41,500	4	0.25	18	0.002	19.98	195
1-Feb	pond	40,000	4	0.25	18	0.002	25.15	195
1-Mar	pond	40,000	4	0.25	18	0.002	30.43	195
1-Apr	pond	40,000	4	0.25	18	0.002	36.96	195
1-May	pond	38,000	4	0.25	18	0.002	43.97	195
1-Jun	pond	38,000	4	0.25	18	0.002	51.94	195
1-Jul	pond	36,000	4	0.25	18	0.002	60.36	195
1-Aug	pond	36,000	4	0.25	18	0.002	69.77	195
1-Sep	release	35,000	4	0.25	18	0.002	79.92	195

Table: **A.10.**
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	Pond size set by TAC					
Fish length at transfer to ponds (in):		0.40	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Razorback Sucker						
Species Code:		14						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.47E-04						
Monthly Temp. Units per inch of growth:		60	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: **A.11.**
Species: **Bonytail Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (Inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	64.0	100%	0.33	0.000	30,435	0	0	179,245	6
1-Jun	32	ponds	57.6	100%	1.07	0.001	1,931	0	0	174,679	90
1-Jul	62		57.6	100%	1.60	0.002	572	0	0	170,372	298
1-Aug	93		57.6	100%	2.16	0.003	343	0	0	166,031	484
1-Sep	124		57.6	100%	2.71	0.006	173	0	0	161,801	935
1-Oct	154		57.6	100%	3.25	0.010	101	0	0	157,812	1,566
1-Nov	185		57.6	100%	3.80	0.016	63	0	0	153,792	2,447
1-Dec	215	release	57.6	100%	4.34	0.024	42	150,000	3,544	0	0

Total Number of Fish Released and Weight (lb): 150,000 3,544

Table:	**A.11.**
Species:	**Bonytail Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Cold Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-May	7.78	95%	7.39	2.30	0
1-Jun	8.31	95%	7.90	2.30	5
1-Jul	8.31	95%	7.90	2.30	15
1-Aug	8.31	95%	7.90	2.30	24
1-Sep	8.31	95%	7.90	2.30	47
1-Oct	8.31	95%	7.90	2.30	78
1-Nov	8.31	95%	7.90	2.30	122
1-Dec	8.31	95%	7.90	2.30	0

Total Feed Required (lb): 169

Table: **A.11.**
Species: **Bonytail Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Based on Changeovers: Carrying Capacity (lb/gpm)	Based on Changeovers: Required Flow (gpm)
1-May	troughs	0.43	14	5.06	3	2.000	1.56	4
1-Jun	pond	110,000	2	0.25	7	0.002	1.13	80
1-Jul	pond	110,000	2	0.25	7	0.002	3.73	80
1-Aug	pond	50,000	3	0.25	14	0.002	3.03	160
1-Sep	pond	49,000	3	0.25	14	0.002	5.86	160
1-Oct	pond	48,000	3	0.25	14	0.002	9.81	160
1-Nov	pond	47,000	3	0.25	14	0.002	15.33	160
1-Dec	release	46,000	3	0.25	14	0.002	22.20	160

Table: **A.11.**
Species: **Bonytail Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

List of Assumptions:

Site Parameters			**Reference**
Elevation (ft above MSL):		6500	Task 7 Datasheet
Maximum pH:		8.20	Task 7 Datasheet
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed
Trough size (cu. ft.)		5.06	Length: 4.5 Depth: 1.5 Width: 1.0
Pond size (ac):		0.25	Pond size set by TAC
Fish length at transfer to ponds (in):		0.40	Hamman, 1987
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987
Species Parameters			
Species:		Bonytail Chub	
Species Code:		16	
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data
	L (inches) > 1.00	4.23E-04	
	L (inches) >= 2.00	2.90E-04	
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest
Mortality rate (%/month):		2.50%	Hamman, 1987
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"
Required feed, based upon 5% supplemental per pound			Hamman, 1987

Table: A.12.
Species: **Humpback Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	64.0	100%	0.33	0.000	30,435	0	0	179,245	6
1-Jun	32	ponds	57.6	100%	1.07	0.001	894	0	0	174,679	195
1-Jul	62		57.6	100%	1.60	0.001	816	0	0	170,372	209
1-Aug	93		57.6	100%	2.16	0.004	237	0	0	166,031	699
1-Sep	124		57.6	100%	2.71	0.008	120	0	0	161,801	1,351
1-Oct	154		57.6	100%	3.25	0.014	70	0	0	157,812	2,263
1-Nov	185		57.6	100%	3.80	0.023	43	0	0	153,792	3,536
1-Dec	215	release	57.6	100%	4.34	0.034	29	150,000	5,121	0	0

Total Number of Fish Released and Weight (lb): 150,000 5,121

Table:	**A.12.**
Species:	**Humpback Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Cold Well Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-May	7.78	95%	7.39	2.3	0
1-Jun	8.31	95%	7.90	2.3	10
1-Jul	8.31	95%	7.90	2.3	10
1-Aug	8.31	95%	7.90	2.3	35
1-Sep	8.31	95%	7.90	2.3	68
1-Oct	8.31	95%	7.90	2.3	113
1-Nov	8.31	95%	7.90	2.3	177
1-Dec	8.31	95%	7.90	2.3	0

Total Feed Required (lb): 236

Table: **A.12.**
Species: **Humpback Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Cold Well Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Based on Changeovers: Carrying Capacity (lb/gpm)	Based on Changeovers: Required Flow (gpm)
1-May	trough	0.43	14	5	3	2.000	1.56	4
1-Jun	pond	110,000	2	0	7	0.002	2.57	76
1-Jul	pond	110,000	2	0	7	0.002	2.74	76
1-Aug	pond	50,000	3	0	14	0.002	4.60	152
1-Sep	pond	49,000	3	0	14	0.002	8.89	152
1-Oct	pond	48,000	3	0	14	0.002	14.88	152
1-Nov	pond	47,000	3	0	14	0.002	23.25	152
1-Dec	release	46,000	3	0	14	0.002	33.68	152

Table:	**A.12.**
Species:	**Humpback Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Cold Well Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cu. ft.):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	Pond size set by TAC					
Fish length at transfer to ponds (in):		0.40	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Humpback Chub						
Species Code:		15						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.19E-04						
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: **A.13.**
Species: **Colorado Squawfish**
Rearing Method: **Extensive Culture**
Water Supply **Surface Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	43.7	100%	0.33	0.000	30,435	0	0	347,279	11
1-Apr	32	ponds	50.4	100%	0.38	0.000	19,626	0	0	335,600	17
1-May	62		58.6	100%	0.50	0.000	8,859	0	0	324,678	37
1-Jun	93		63.5	100%	0.70	0.000	3,159	0	0	313,759	99
1-Jul	123		70.5	100%	0.95	0.001	1,285	0	0	303,548	236
1-Aug	154		66.6	100%	1.27	0.001	1,636	0	0	293,340	179
1-Sep	185		62.4	100%	1.56	0.001	893	0	0	283,475	318
1-Oct	215		52.9	100%	1.79	0.002	586	0	0	274,250	468
1-Nov	246		43.0	100%	1.94	0.002	463	0	0	265,027	572
1-Dec	276		34.0	100%	1.99	0.002	429	0	0	256,402	597
1-Jan	307		32.2	100%	2.04	0.004	232	0	0	247,779	1,066
1-Feb	338		34.5	100%	2.09	0.005	216	0	0	239,447	1,108
1-Mar	366		43.7	100%	2.14	0.005	201	0	0	232,174	1,153
1-Apr	397		50.4	100%	2.19	0.005	187	0	0	224,366	1,198
1-May	427		58.6	100%	2.31	0.006	160	0	0	217,064	1,353
1-Jun	458		63.5	100%	2.51	0.008	124	0	0	209,764	1,686
1-Jul	488		70.5	100%	2.76	0.011	94	0	0	202,938	2,158
1-Aug	519		66.6	100%	3.08	0.015	67	0	0	196,113	2,915
1-Sep	550		62.4	100%	3.37	0.019	52	0	0	189,518	3,673
1-Oct	580		52.9	100%	3.60	0.024	42	0	0	183,350	4,350
1-Nov	611		43.0	100%	3.75	0.027	37	0	0	177,184	4,734
1-Dec	641		34.0	100%	3.80	0.028	36	0	0	171,418	4,766
1-Jan	672		32.2	100%	3.85	0.029	35	0	0	165,653	4,790
1-Feb	703		34.5	100%	3.90	0.030	33	0	0	160,082	4,812
1-Mar	731		43.7	100%	3.95	0.031	32	0	0	155,220	4,848
1-Apr	762	release	50.4	100%	4.00	0.032	31	150,000	4,872	0	0

Total Number of Fish Released and Weight (lb): 150,000 4,872

Table:	**A.13.**
Species:	**Colorado Squawfish**
Rearing Method:	**Extensive Culture**
Water Supply	**Surface Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-Mar	9.88	95%	9.38	2.3	1
1-Apr	9.04	95%	8.59	2.3	1
1-May	8.22	95%	7.81	2.3	2
1-Jun	7.82	95%	7.43	2.3	5
1-Jul	7.32	95%	6.96	2.3	12
1-Aug	7.59	95%	7.21	2.3	9
1-Sep	7.90	95%	7.51	2.3	16
1-Oct	8.77	95%	8.33	2.3	23
1-Nov	9.98	95%	9.48	2.3	29
1-Dec	11.56	95%	10.98	2.3	30
1-Jan	11.96	95%	11.36	2.3	53
1-Feb	11.45	95%	10.87	2.3	55
1-Mar	9.88	95%	9.38	2.3	58
1-Apr	9.04	95%	8.59	2.3	60
1-May	8.22	95%	7.81	2.3	68
1-Jun	7.82	95%	7.43	2.3	84
1-Jul	7.32	95%	6.96	2.3	108
1-Aug	7.59	95%	7.21	2.3	146
1-Sep	7.90	95%	7.51	2.3	184
1-Oct	8.77	95%	8.33	2.3	218
1-Nov	9.98	95%	9.48	2.3	237
1-Dec	11.56	95%	10.98	2.3	238
1-Jan	11.96	95%	11.36	2.3	240
1-Feb	11.45	95%	10.87	2.3	241
1-Mar	9.88	95%	9.38	2.3	242
1-Apr	9.04	95%	8.59	2.3	0
				Total Feed Required (lb):	1,396

Table: A.13.
Species: **Colorado Squawfish**
Rearing Method: **Extensive Culture**
Water Supply **Surface Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
1-Mar	troughs	0.43	27	5.06	6	2.000	1.51	8
1-Apr	pond	110,000	3	0.25	13	0.002	0.12	141
1-May	pond	110,000	3	0.25	12	0.002	0.28	130
1-Jun	pond	55,000	6	0.25	23	0.002	0.40	250
1-Jul	pond	53,000	6	0.25	23	0.002	0.95	250
1-Aug	pond	52,000	6	0.25	23	0.002	0.72	250
1-Sep	pond	50,000	6	0.25	23	0.002	1.27	250
1-Oct	pond	49,850	6	0.25	23	0.002	1.87	250
1-Nov	pond	48,150	6	0.25	23	0.002	2.29	250
1-Dec	pond	46,600	6	0.25	23	0.002	2.39	250
1-Jan	pond	45,000	6	0.25	23	0.002	4.27	250
1-Feb	pond	43,500	6	0.25	23	0.002	4.44	250
1-Mar	pond	42,150	6	0.25	23	0.002	4.62	250
1-Apr	pond	40,750	6	0.25	23	0.002	4.79	250
1-May	pond	39,450	6	0.25	23	0.002	5.42	250
1-Jun	pond	38,100	6	0.25	23	0.002	6.75	250
1-Jul	pond	36,850	6	0.25	23	0.002	8.64	250
1-Aug	pond	35,650	6	0.25	23	0.002	11.67	250
1-Sep	pond	34,450	6	0.25	23	0.002	14.70	250
1-Oct	pond	33,300	6	0.25	23	0.002	17.41	250
1-Nov	pond	32,200	6	0.25	23	0.002	18.95	250
1-Dec	pond	31,150	6	0.25	23	0.002	19.08	250
1-Jan	pond	30,100	6	0.25	23	0.002	19.18	250
1-Feb	pond	29,100	6	0.25	23	0.002	19.26	250
1-Mar	pond	28,200	6	0.25	23	0.002	19.41	250
1-Apr	release	27,250	6	0.25	23	0.002	19.50	250

Table:	**A.13.**
Species:	**Colorado Squawfish**
Rearing Method:	**Extensive Culture**
Water Supply:	**Surface Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cf):		5.06	Length:	4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	Pond size set by TAC					
Fish length at transfer to ponds (in):		0.35	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Colorado Squawfish						
Species Code:		13						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	5.08E-04						
Monthly Temp. Units per inch of growth:		100	Calculated from data supplied by Biowest					
Mortality rate (%/month):		3.30%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: **A.14.**
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-Mar	1	troughs	43.7	100%	0.33	0.00	30,435	0	0	255,522	8
1-Apr	32	ponds	50.4	100%	0.42	0.00	15,125	0	0	249,012	16
1-May	62		58.6	100%	0.61	0.00	4,821	0	0	242,873	50
1-Jun	93		63.5	100%	0.95	0.00	1,275	0	0	236,685	186
1-Jul	123		70.5	100%	1.36	0.00	1,343	0	0	230,850	172
1-Aug	154		66.6	100%	1.90	0.00	491	0	0	224,968	458
1-Sep	185		62.4	100%	2.38	0.01	167	0	0	219,237	1,315
1-Oct	215		52.9	100%	2.77	0.01	105	0	0	213,832	2,027
1-Nov	246		43.0	100%	3.01	0.01	82	0	0	208,384	2,542
1-Dec	276		34.0	100%	3.08	0.01	76	0	0	203,246	2,661
1-Jan	307		32.2	100%	3.13	0.01	73	0	0	198,068	2,722
1-Feb	338		34.5	100%	3.18	0.01	69	0	0	193,022	2,781
1-Mar	366		43.7	100%	3.23	0.02	66	0	0	188,580	2,848
1-Apr	397		50.4	100%	3.32	0.02	61	0	0	183,776	3,004
1-May	427		58.6	100%	3.51	0.02	52	0	0	179,245	3,472
1-Jun	458		63.5	100%	3.85	0.03	39	0	0	174,679	4,466
1-Jul	488		70.5	100%	4.26	0.03	29	0	0	170,372	5,897
1-Aug	519		66.6	100%	4.80	0.05	20	0	0	166,031	8,230
1-Sep	550		62.4	100%	5.28	0.07	15	0	0	161,801	10,641
1-Oct	580		52.9	100%	5.67	0.08	12	0	0	157,812	12,864
1-Nov	611		43.0	100%	5.91	0.09	11	0	0	153,792	14,214
1-Dec	641	release	34.0	100%	5.99	0.10	10	150,000	14,376	0	0
				Total Number of Fish Released and Weight (lb):				150,000	14,376		

Table: **A.14.**
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-Mar	9.88	95%	9.38	2.3	0
1-Apr	9.04	95%	8.59	2.3	1
1-May	8.22	95%	7.81	2.3	3
1-Jun	7.82	95%	7.43	2.3	9
1-Jul	7.32	95%	6.96	2.3	9
1-Aug	7.59	95%	7.21	2.3	23
1-Sep	7.90	95%	7.51	2.3	66
1-Oct	8.77	95%	8.33	2.3	101
1-Nov	9.98	95%	9.48	2.3	127
1-Dec	11.56	95%	10.98	2.3	133
1-Jan	11.96	95%	11.36	2.3	136
1-Feb	11.45	95%	10.87	2.3	139
1-Mar	9.88	95%	9.38	2.3	142
1-Apr	9.04	95%	8.59	2.3	150
1-May	8.22	95%	7.81	2.3	174
1-Jun	7.82	95%	7.43	2.3	223
1-Jul	7.32	95%	6.96	2.3	295
1-Aug	7.59	95%	7.21	2.3	411
1-Sep	7.90	95%	7.51	2.3	532
1-Oct	8.77	95%	8.33	2.3	643
1-Nov	9.98	95%	9.48	2.3	711
1-Dec	11.56	95%	10.98	2.3	0

Total Feed Required (lb): 4,029

Table: A.14.
Species: **Razorback Sucker**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Carrying Capacity (lb/gpm)	Required Flow (gpm)
1-Mar	troughs	0.43	20	5.06	4	2.000	1.66	5
1-Apr	pond	110,000	2	0.25	10	0.002	0.15	109
1-May	pond	110,000	2	0.25	9	0.002	0.52	98
1-Jun	pond	50,000	5	0.25	19	0.002	0.90	206
1-Jul	pond	50,000	5	0.25	19	0.002	0.83	206
1-Aug	pond	49,000	5	0.25	19	0.002	2.22	206
1-Sep	pond	48,000	5	0.25	19	0.002	6.37	206
1-Oct	pond	47,000	5	0.25	19	0.002	9.82	206
1-Nov	pond	46,000	5	0.25	19	0.002	12.32	206
1-Dec	pond	45,000	5	0.25	19	0.002	12.90	206
1-Jan	pond	44,000	5	0.25	19	0.002	13.19	206
1-Feb	pond	42,500	5	0.25	19	0.002	13.48	206
1-Mar	pond	41,000	5	0.25	19	0.002	13.80	206
1-Apr	pond	40,000	5	0.25	19	0.002	14.56	206
1-May	pond	39,000	5	0.25	19	0.002	16.83	206
1-Jun	pond	38,000	5	0.25	19	0.002	21.64	206
1-Jul	pond	37,000	5	0.25	19	0.002	28.57	206
1-Aug	pond	36,000	5	0.25	19	0.002	39.88	206
1-Sep	pond	35,000	5	0.25	19	0.002	51.57	206
1-Oct	pond	34,000	5	0.25	19	0.002	62.34	206
1-Nov	pond	33,000	5	0.25	19	0.002	68.88	206
1-Dec	release	32,000	5	0.25	19	0.002	69.67	206

Table:	**A.14.**
Species:	**Razorback Sucker**
Rearing Method:	**Extensive Culture**
Water Supply:	**Surface Water**

List of Assumptions:

Site Parameters				**Reference**				
Elevation (ft above MSL):		6500		Task 7 Datasheet				
Maximum pH:		8.20		Task 7 Datasheet				
Inflow un-ionized ammonia (NH3 mg/l):		0.0002		Assumed				
Trough size (cf):		5.06		Length: 4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25		Pond size set by TAC				
Fish length at transfer to ponds (in):		0.35		Hamman, 1987				
Swimup Fry Stocking Density (fish/ac)		110000		Hamman, 1987				
Species Parameters								
Species:		Razorback Sucker						
Species Code:		14						
C factor:	L (inches) > 0.20	9.14E-04		W/L^3 formula using Dexter NFH data				
	L (inches) > 1.20	2.96E-04						
	L (inches) >= 2.00	4.47E-04						
Monthly Temp. Units per inch of growth:		60		Calculated from data supplied by Biowest				
Mortality rate (%/month):		2.50%		Hamman, 1987				
Minimum oxygen level allowed (mg/l):		5.00		Environmentally determined due to temp limits				
Nitrogen loading (lbs N/lbs food):		0.032		Piper et al. 1986, "Fish Hatchery Management"				
Required feed, based upon 5% supplemental per pound				Hamman, 1987				

Table: **A.15.**
Species: **Bonytail Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	58.6	100%	0.33	0.000	30,435	0	0	170,372	6
1-Jun	32	ponds	63.5	100%	0.91	0.001	1,435	0	0	166,031	116
1-Jul	62		70.5	100%	1.62	0.002	561	0	0	161,938	289
1-Aug	93		66.6	100%	2.54	0.005	209	0	0	157,812	754
1-Sep	124		62.4	100%	3.36	0.011	91	0	0	153,792	1,690
1-Oct	154	release	52.9	100%	4.03	0.019	53	150,000	2,847	0	0

Total Number of Fish Released and Weight (lb): 150,000 2,847

Table: **A.15.**
Species: **Bonytail Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	**Oxygen at 100% Sat. (mg/l)**	**Oxygen Saturation (%)**	**Inflow Oxygen (mg/l)**	**Food Conversion**	**Required Artificial Feed (lb)**
1-May	8.22	95%	7.81	2.30	0
1-Jun	7.82	95%	7.43	2.30	6
1-Jul	7.32	95%	6.96	2.30	14
1-Aug	7.59	95%	7.21	2.30	38
1-Sep	7.90	95%	7.51	2.30	84
1-Oct	release	95%	8.33	2.30	0

Total Feed Required (lb): 143

Table: **A.15.**
Species: **Bonytail Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Based on Changeovers: Carrying Capacity (lb/gpm)	Based on Changeovers: Required Flow (gpm)
1-May	troughs	0.43	13	5.06	3	2.000	1.48	4
1-Jun	pond	110,000	2	0.25	7	0.002	1.45	80
1-Jul	pond	110,000	1	0.25	6	0.002	4.22	68
1-Aug	pond	50,000	3	0.25	13	0.002	5.09	148
1-Sep	pond	50,000	3	0.25	13	0.002	11.40	148
1-Oct	release	49,000	3	0.25	13	0.002	19.20	148

Table:	**A.15.**
Species:	**Bonytail Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Surface Water**

List of Assumptions:

Site Parameters			**Reference**					
Elevation (ft above MSL):		6500	Task 7 Datasheet					
Maximum pH:		8.20	Task 7 Datasheet					
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed					
Trough size (cu. ft.)		5.06	Length:	4.5	Depth:	1.5	Width:	0.75
Pond size (ac):		0.25	Pond size set by TAC					
Fish length at transfer to ponds (in):		0.40	Hamman, 1987					
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987					
Species Parameters								
Species:		Bonytail Chub						
Species Code:		16						
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data					
	L (inches) > 1.00	4.23E-04						
	L (inches) >= 2.00	2.90E-04						
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest					
Mortality rate (%/month):		2.50%	Hamman, 1987					
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits					
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"					
Required feed, based upon 5% supplemental per pound			Hamman, 1987					

Table: A.16.
Species: **Humpback Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Day/Event		Average Temp. (°F)	Percent of Feed Ration	Length (inches)	Fish Weight (lb)	Fish per Pound	Number of Fish Released	Weight Released (lb)	Number of Fish On Station	Weight On Station (lb)
1-May	1	troughs	58.6	100%	0.33	0.000	30,435	0	0	170,372	6
1-Jun	32	ponds	63.5	100%	0.91	0.001	1,435	0	0	166,031	116
1-Jul	62		70.5	100%	1.62	0.001	801	0	0	161,938	202
1-Aug	93		66.6	100%	2.54	0.007	145	0	0	157,812	1,089
1-Sep	124		62.4	100%	3.36	0.016	63	0	0	153,792	2,441
1-Oct	154	release	52.9	100%	4.03	0.027	36	150,000	4,113	0	0

Total Number of Fish Released and Weight (lb): 150,000 4,113

Table:	A.16.
Species:	**Humpback Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Surface Water**

Date	Oxygen at 100% Sat. (mg/l)	Oxygen Saturation (%)	Inflow Oxygen (mg/l)	Food Conversion	Required Artificial Feed (lb)
1-May	8.22	95%	7.81	2.3	0
1-Jun	7.82	95%	7.43	2.3	6
1-Jul	7.32	95%	6.96	2.3	10
1-Aug	7.59	95%	7.21	2.3	54
1-Sep	7.90	95%	7.51	2.3	122
1-Oct	8.77	95%	8.33	2.3	0

Total Feed Required (lb): 193

Table: A.16.
Species: **Humpback Chub**
Rearing Method: **Extensive Culture**
Water Supply: **Surface Water**

Date	Location	Surface Area or Density (lb/cf or fish/ac)	Required Space (cf or ac)	Container Area (cf or ac)	Required Units	Based on Changeovers: Change-overs per Hour	Based on Changeovers: Carrying Capacity (lb/gpm)	Based on Changeovers: Required Flow (gpm)
1-May	troughs	0.43	13	5	3	2.000	1.48	4
1-Jun	pond	110,000	2	0	7	0.002	1.52	76
1-Jul	pond	110,000	1	0	6	0.002	3.10	65
1-Aug	pond	50,000	3	0	13	0.002	7.72	141
1-Sep	pond	50,000	3	0	13	0.002	17.29	141
1-Oct	release	49,000	3	0	13	0.002	29.13	141

Table:	**A.16.**
Species:	**Humpback Chub**
Rearing Method:	**Extensive Culture**
Water Supply:	**Surface Water**

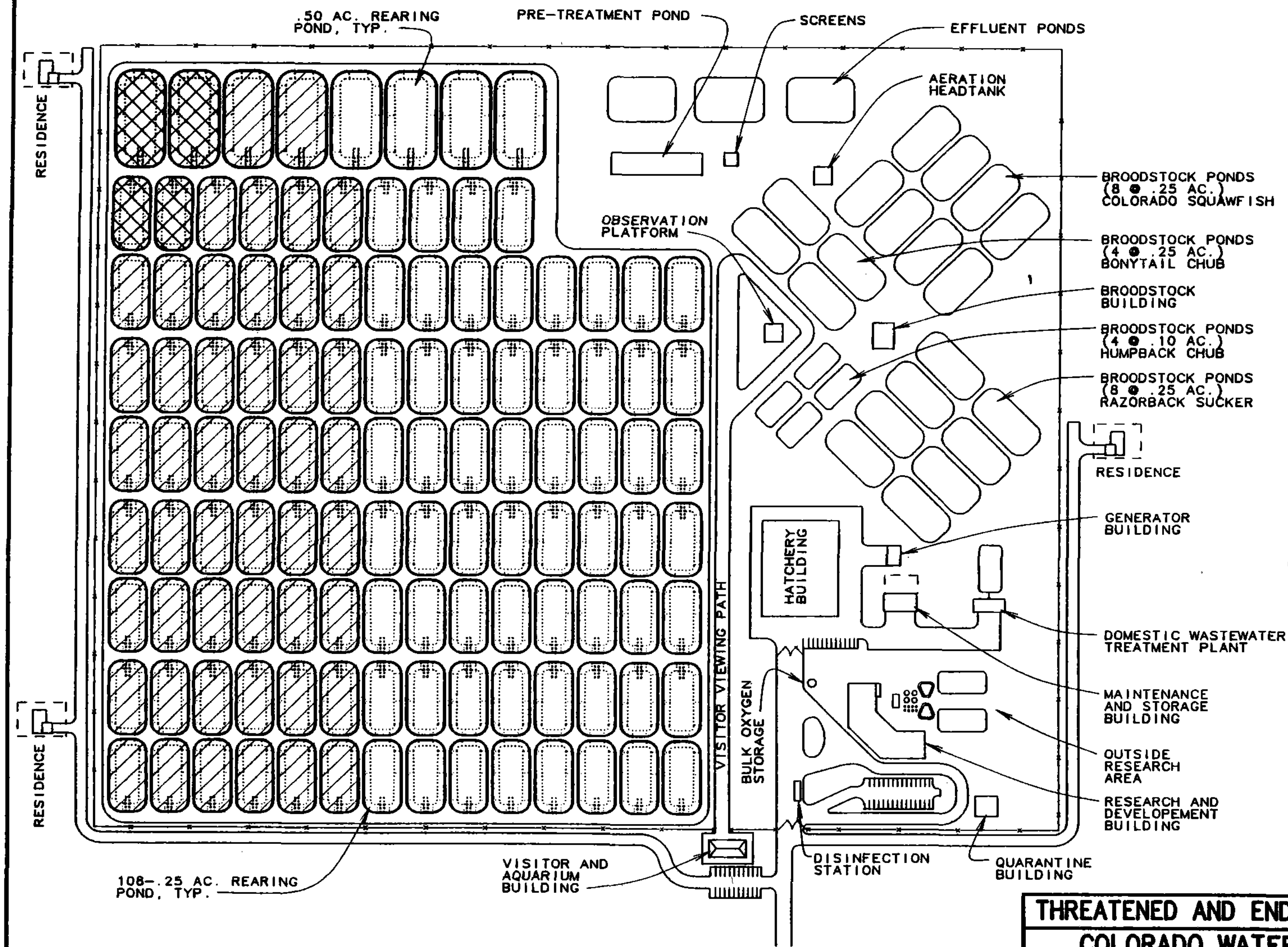
List of Assumptions:

Site Parameters			**Reference**				
Elevation (ft above MSL):		6500	Task 7 Datasheet				
Maximum pH:		8.20	Task 7 Datasheet				
Inflow un-ionized ammonia (NH3 mg/l):		0.0002	Assumed				
Trough size (cu. ft.):		5.06	Length: 4.5	Width:	1.5	Depth:	0.75
Pond size (ac):		0.25	Pond size set by TAC				
Fish length at transfer to ponds (in):		0.40	Hamman, 1987				
Swimup Fry Stocking Density (fish/ac)		110000	Hamman, 1987				
Species Parameters							
Species:		Humpback Chub					
Species Code:		15					
C factor:	L (inches) > 0.20	9.14E-04	W/L^3 formula using Dexter NFH data				
	L (inches) > 1.20	2.96E-04					
	L (inches) >= 2.00	4.19E-04					
Monthly Temp. Units per inch of growth:		35	Calculated from data supplied by Biowest				
Mortality rate (%/month):		2.50%	Hamman, 1987				
Minimum oxygen level allowed (mg/l):		5.00	Environmentally determined due to temp limits				
Nitrogen loading (lbs N/lbs food):		0.032	Piper et al. 1986, "Fish Hatchery Management"				
Required feed, based upon 5% supplemental per pound			Hamman, 1987				

APPENDIX H

FACILITY LAYOUT DRAWINGS

FACILITY LAYOUT DRAWINGS



NOTE:

THE SITE PLANS FOR SCENARIO 2, WARM WATER, COLD WATER AND SURFACE WATER ARE THE SAME EXCEPT AS FOLLOWS:

TYPE	REQUIRED 1/2 ACRE REARING PONDS	REQUIRED 1/4 ACRE REARING PONDS
WARM WATER	4	60
COLD WATER	6	106
SURFACE WATER	8	108

PONDS REQUIRED FOR SURFACE WATER SCENARIO 2.

PONDS REQUIRED FOR COLD WATER SCENARIO 2.

PONDS REQUIRED FOR WARM WATER SCENARIO 2.

0 200 400

SCALE IN FEET

TOTAL ACREAGE - 86.8

THREATENED AND ENDANGERED SPECIES FACILITY

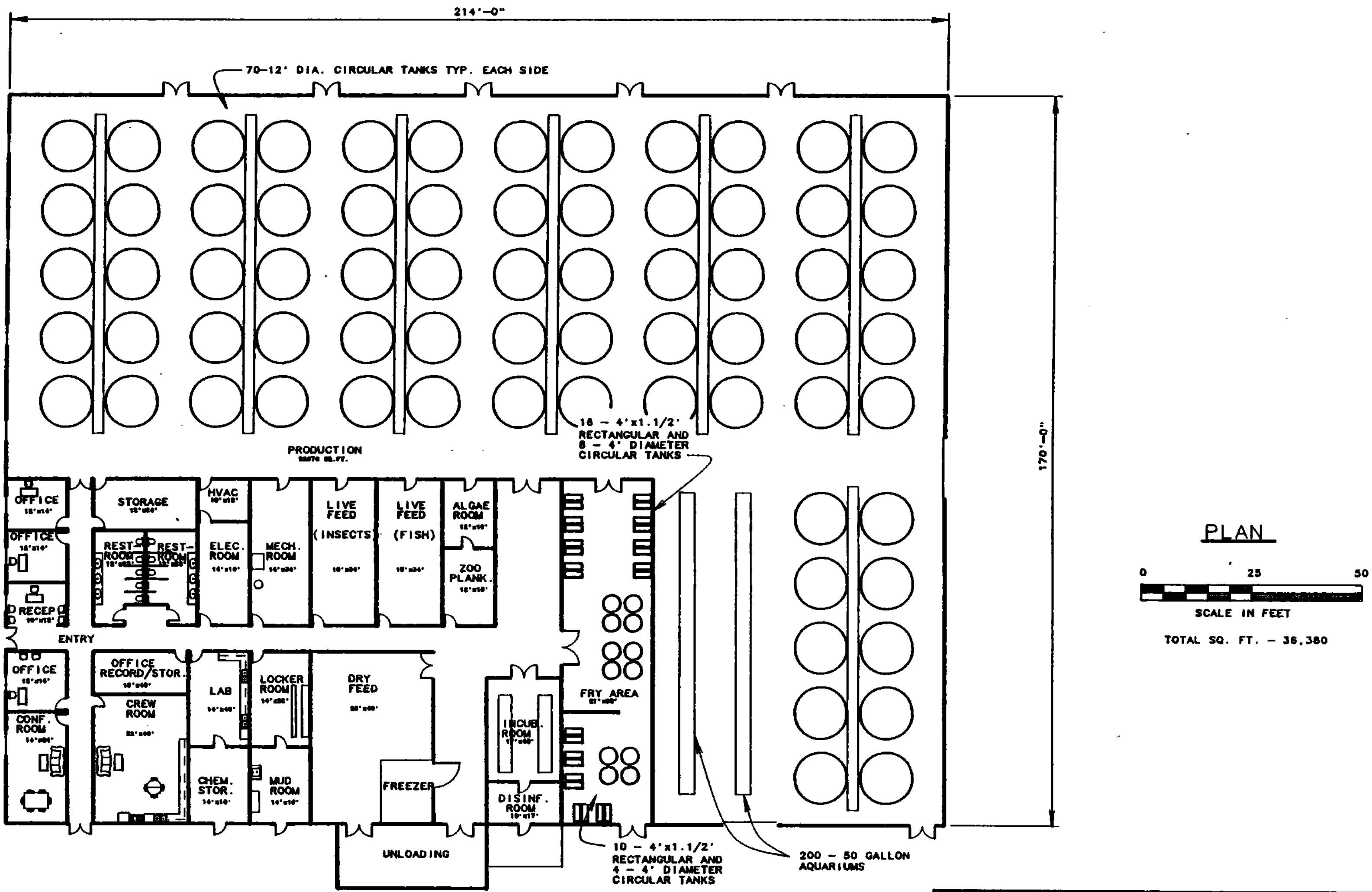
COLORADO WATER CONSERVATION BOARD

SITE PLAN-SCENARIO 2

DESIGNED KF/ED
DRAWN AB
CHECKED KF

FISHPRO, INC.
PREPARED FOR THE URS TEAM

DATE 10/29/92
SHEET NO. 1

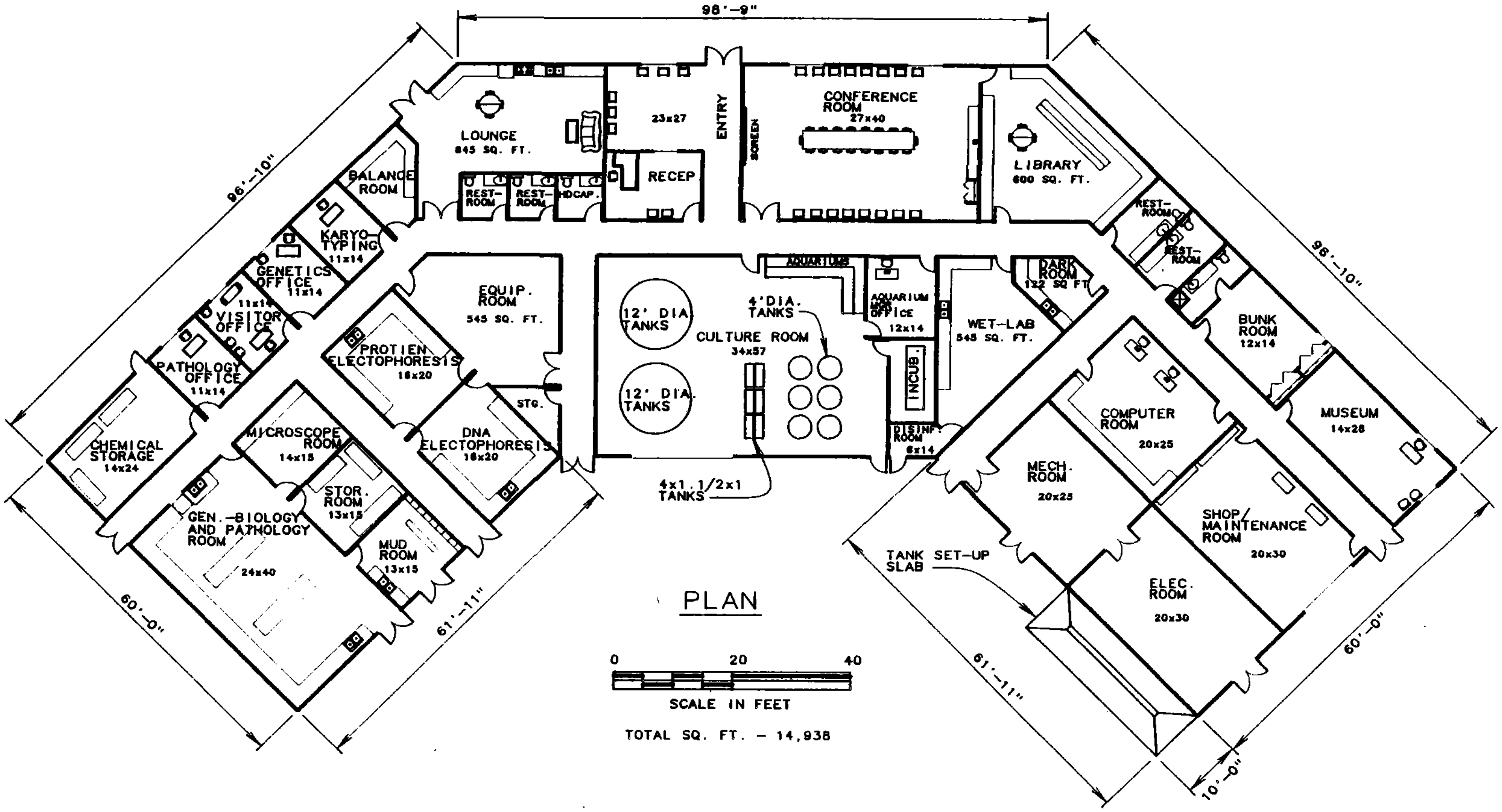


COLORADO WATER CONSERVATION BOARD

THREATENED AND ENDANGERED SPECIES FACILITY

HATCHERY BUILDING-SCENARIO 2

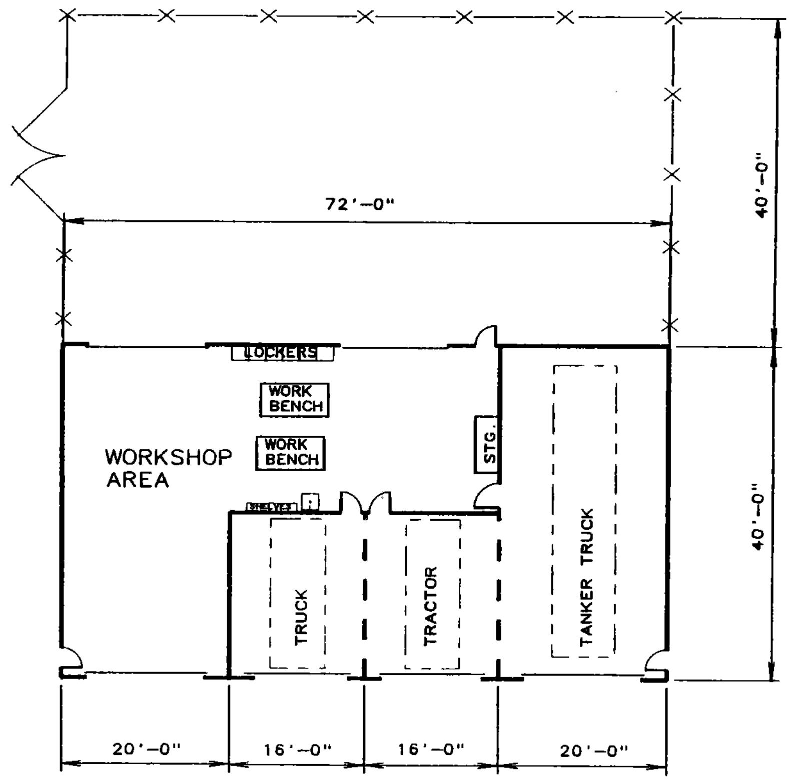
DESIGNED KF/RC DRAWN JS/RC CHECKED KF/ED	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 2



PLAN

TOTAL SQ. FT. – 14,938

COLORADO WATER CONSERVATION BOARD		
THREATENED AND ENDANGERED SPECIES FACILITY		
RESEARCH BUILDING		
DESIGNED KF/RC DRAWN JS/RC CHECKED KF/ED	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 3

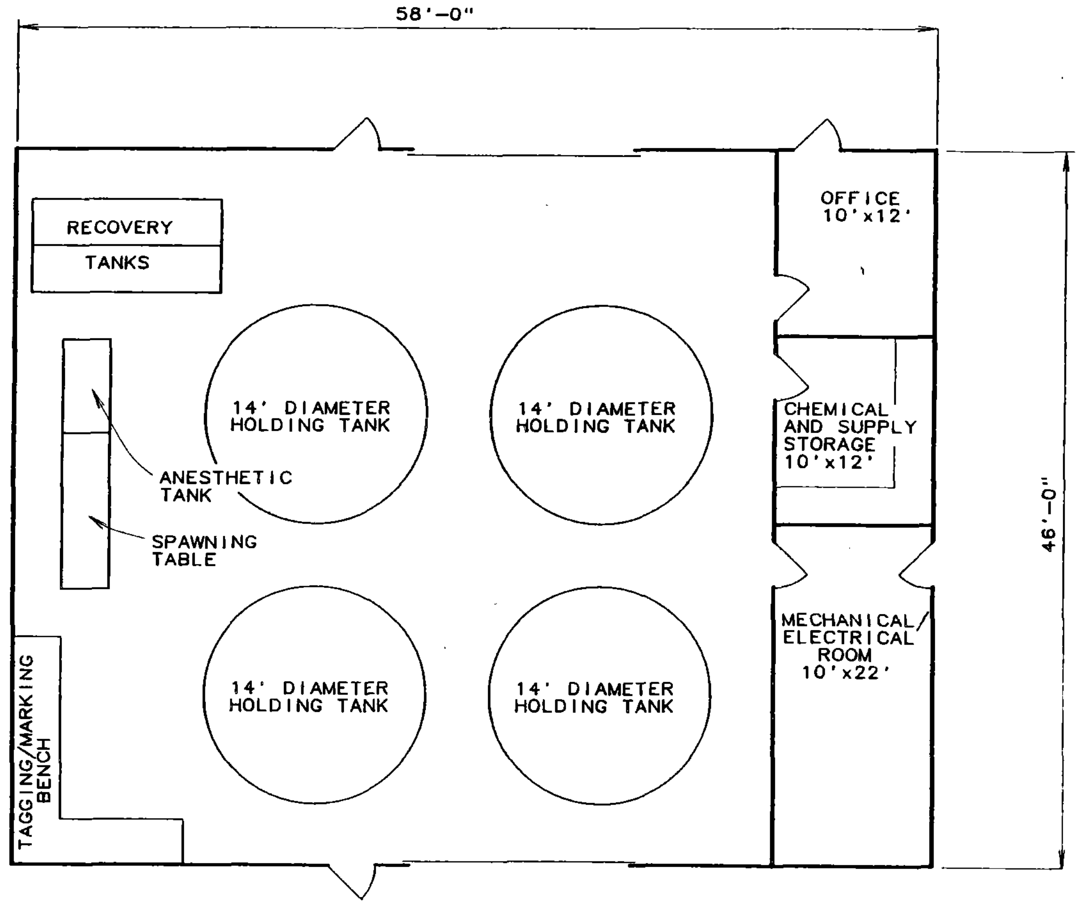


PLAN

0 15 30
SCALE IN FEET

TOTAL SQ. FT. – 2080

COLORADO WATER CONSERVATION BOARD		
THREATENED AND ENDANGERED SPECIES FACILITY		
MAINTENANCE/STORAGE BUILDING		
DESIGNED RC DRAWN RC/JS CHECKED KF/ED	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 10/29/92 SHEET NO. 4



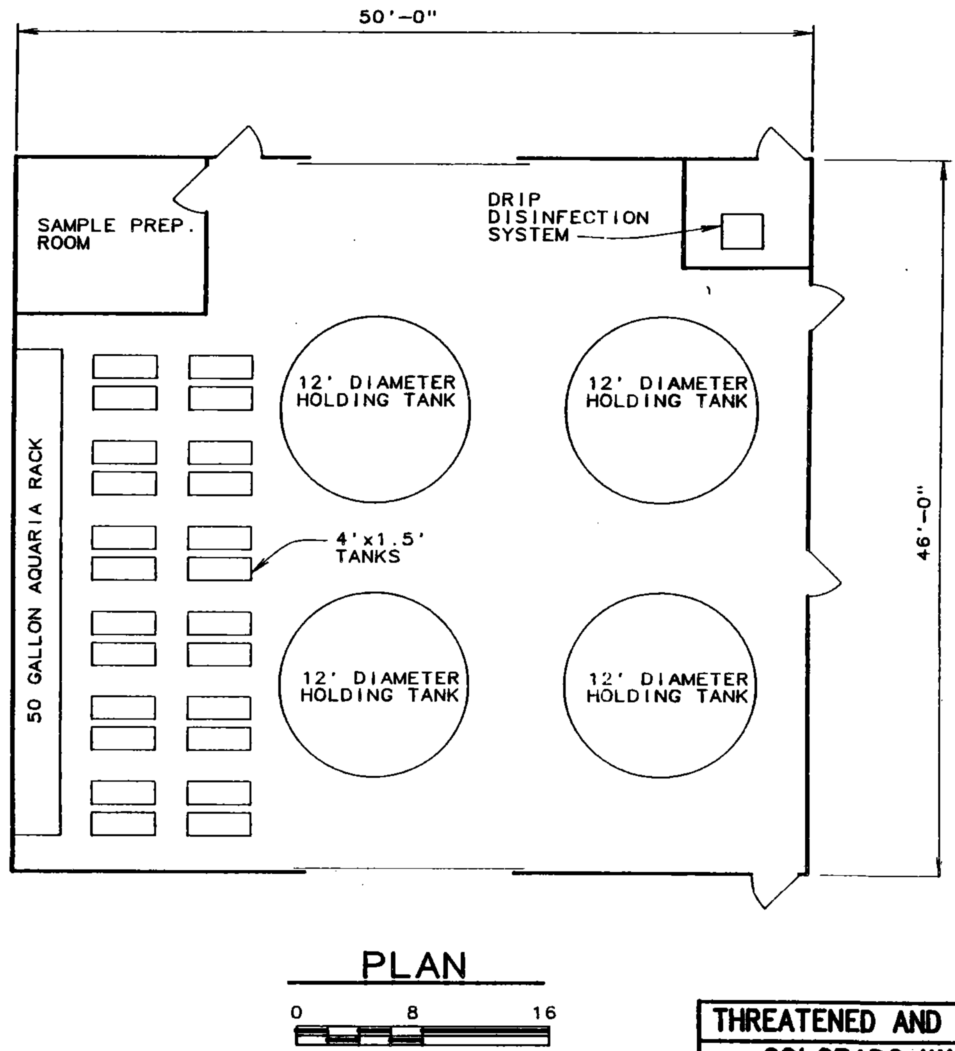
PLAN

0 8 16

SCALE IN FEET

TOTAL SQ. FT. – 2668

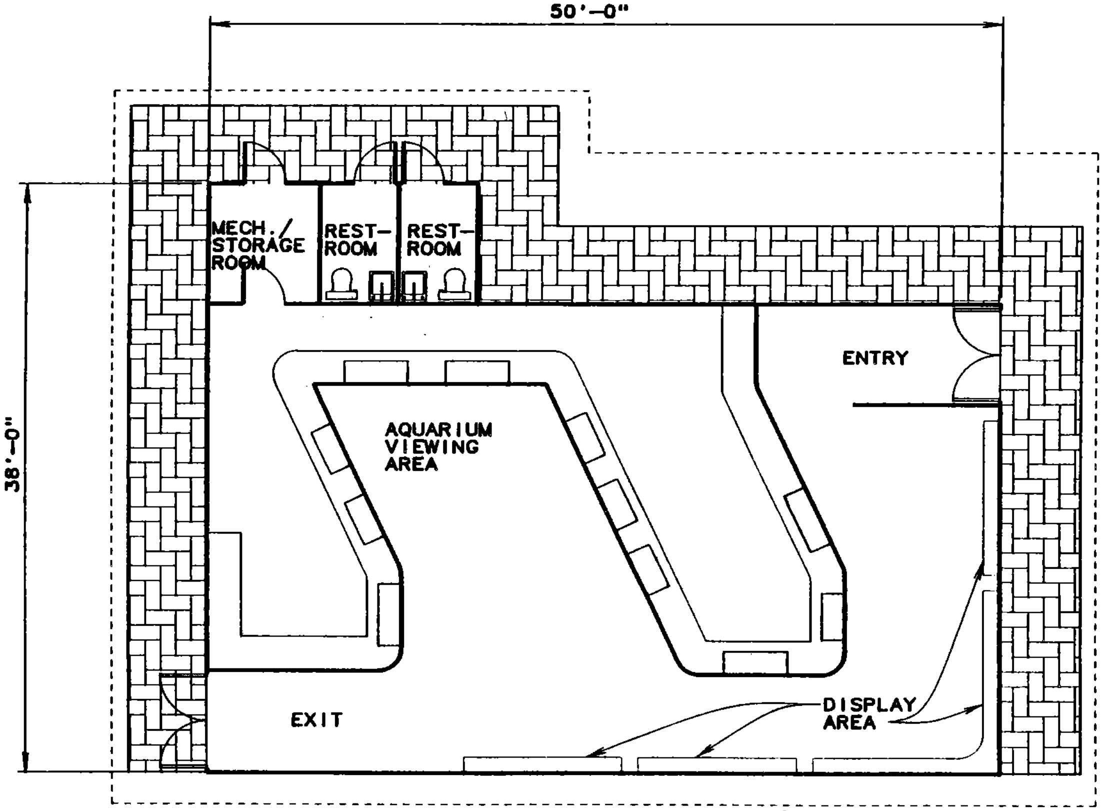
COLORADO WATER CONSERVATION BOARD		
THREATENED AND ENDANGERED SPECIES FACILITY		
BROODSTOCK BUILDING		
DESIGNED AB DRAWN AB CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 10/29/92 SHEET NO. 5



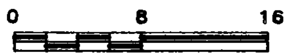
PLAN

TOTAL SQ. FT. – 2300

THREATENED AND ENDANGERED SPECIES FACILITY	
COLORADO WATER CONSERVATION BOARD	
QUARANTINE BUILDING	
DESIGNED KF/ED DRAWN JS CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM
DATE 10/29/92	SHEET NO. 6

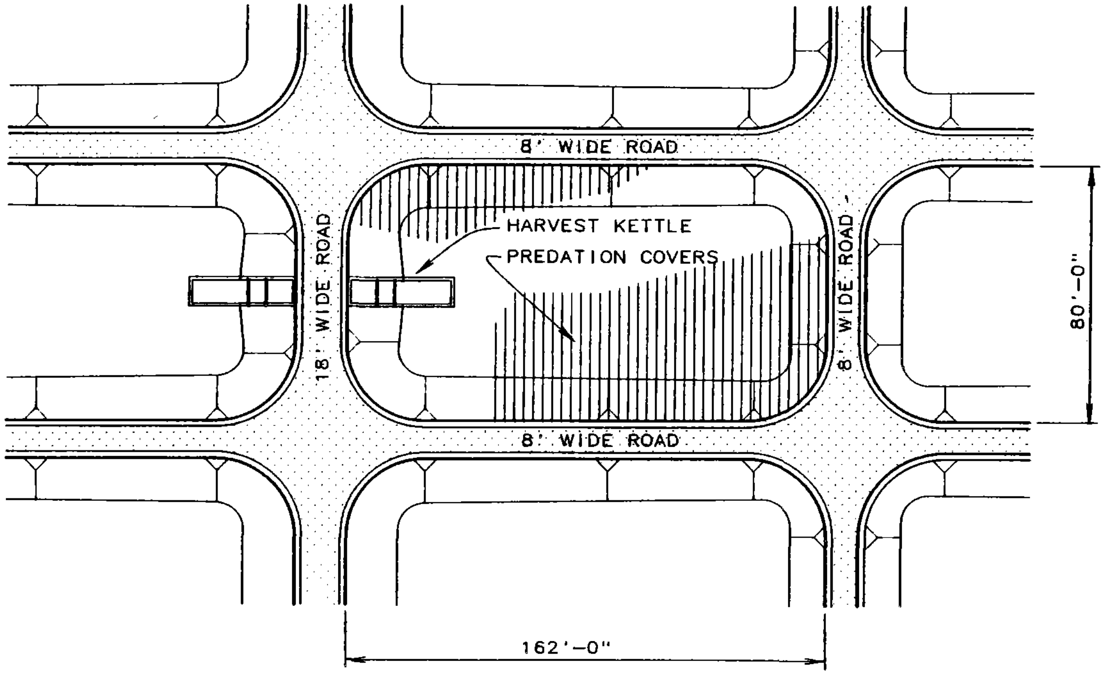


PLAN



TOTAL SQ. FT. – 1900

COLORADO WATER CONSERVATION BOARD		
THREATENED AND ENDANGERED SPECIES FACILITY		
VISITOR/AQUARIUM FACILITY		
DESIGNED KS/JS DRAWN JS CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 7



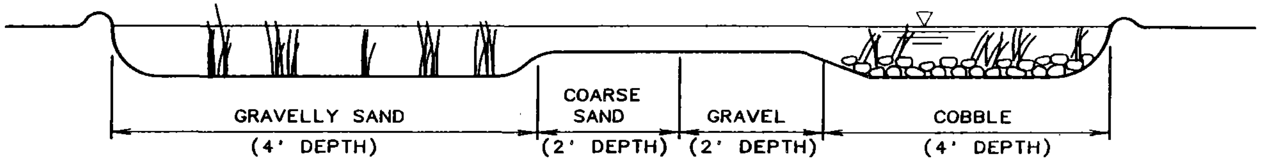
PLAN

0 40 80
SCALE IN FEET

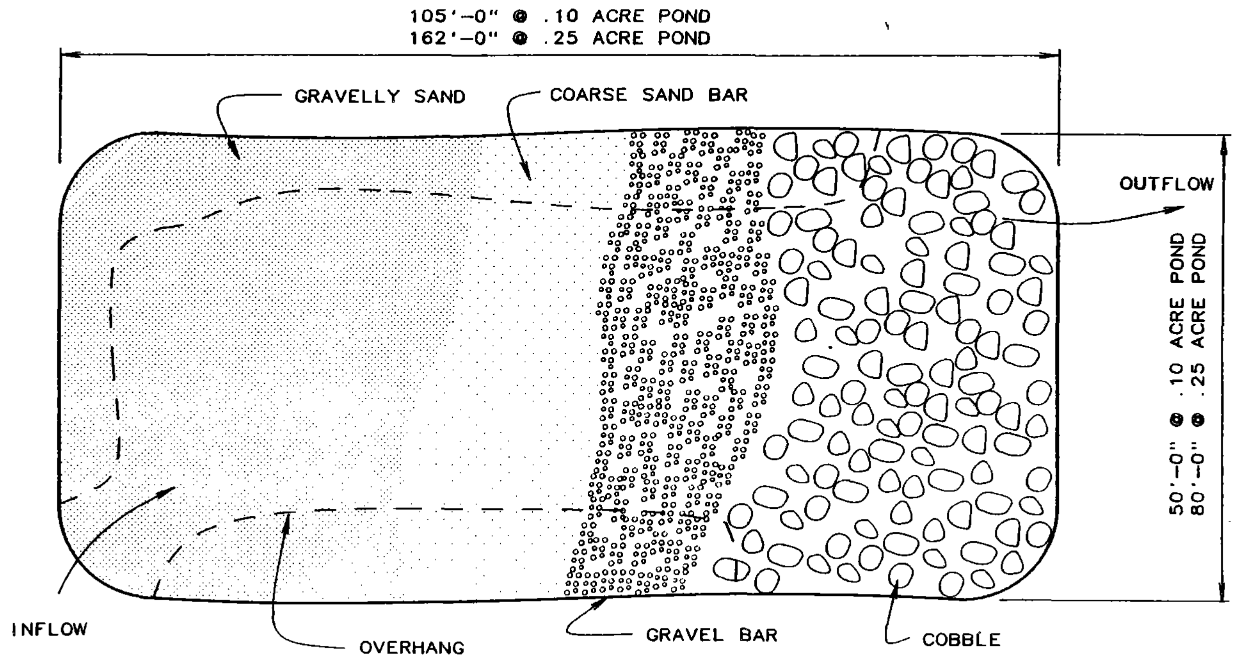
WETTED SURFACE AREA - .25 ACRES

COLORADO WATER CONSERVATION BOARD
THREATENED AND ENDANGERED SPECIES FACILITY
REARING POND (.25 ACRE)

DESIGNED RC DRAWN AB CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 8



SECTION

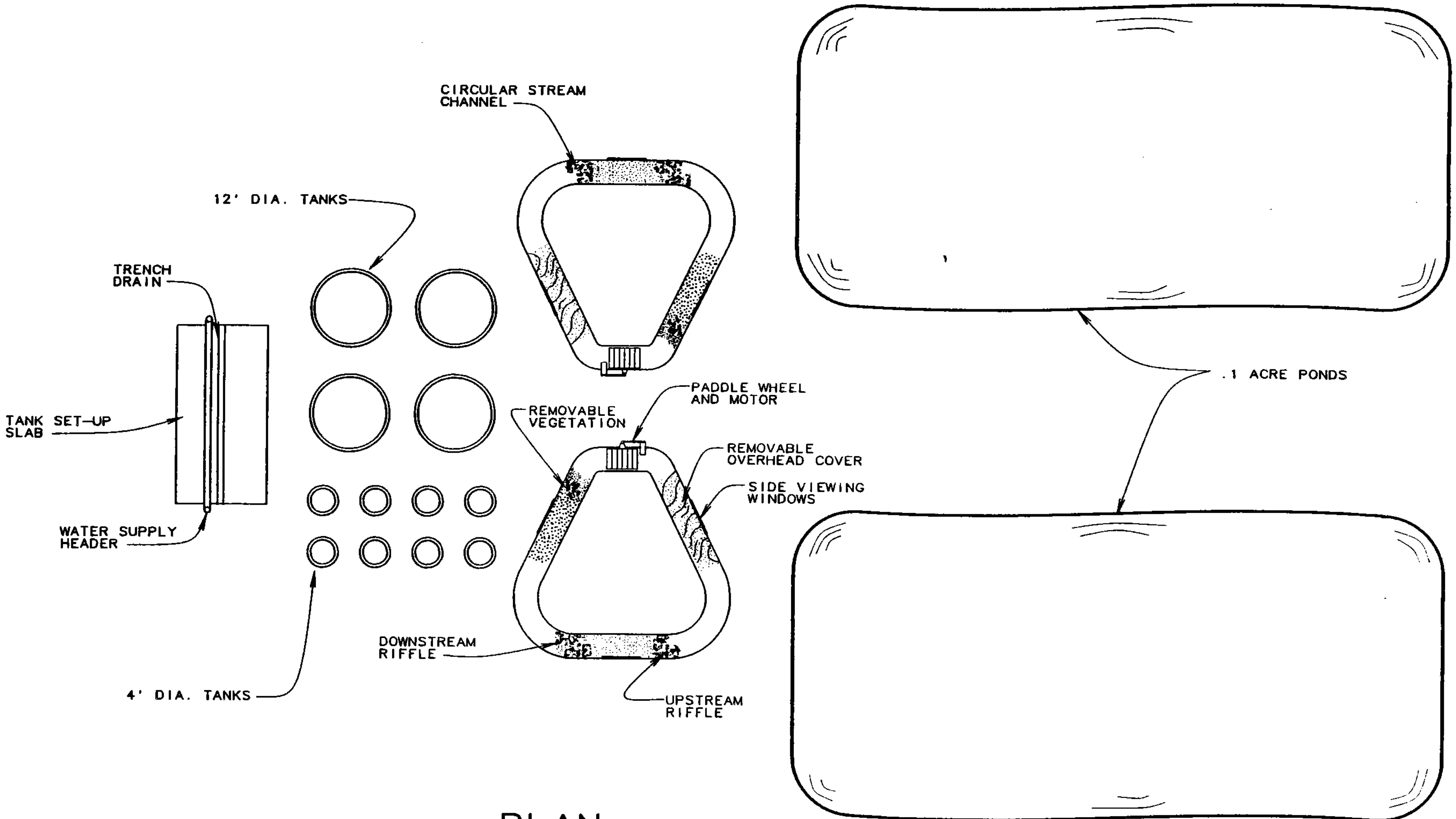


PLAN

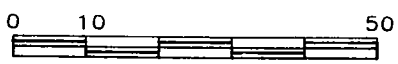
WETTED SURFACE AREA
.10 ACRE OR .25 ACRES

0 15 30
SCALE IN FEET

COLORADO WATER CONSERVATION BOARD		
THREATENED AND ENDANGERED SPECIES FACILITY		
BROOD REARING POND		
DESIGNED GS DRAWN AB CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 9



PLAN

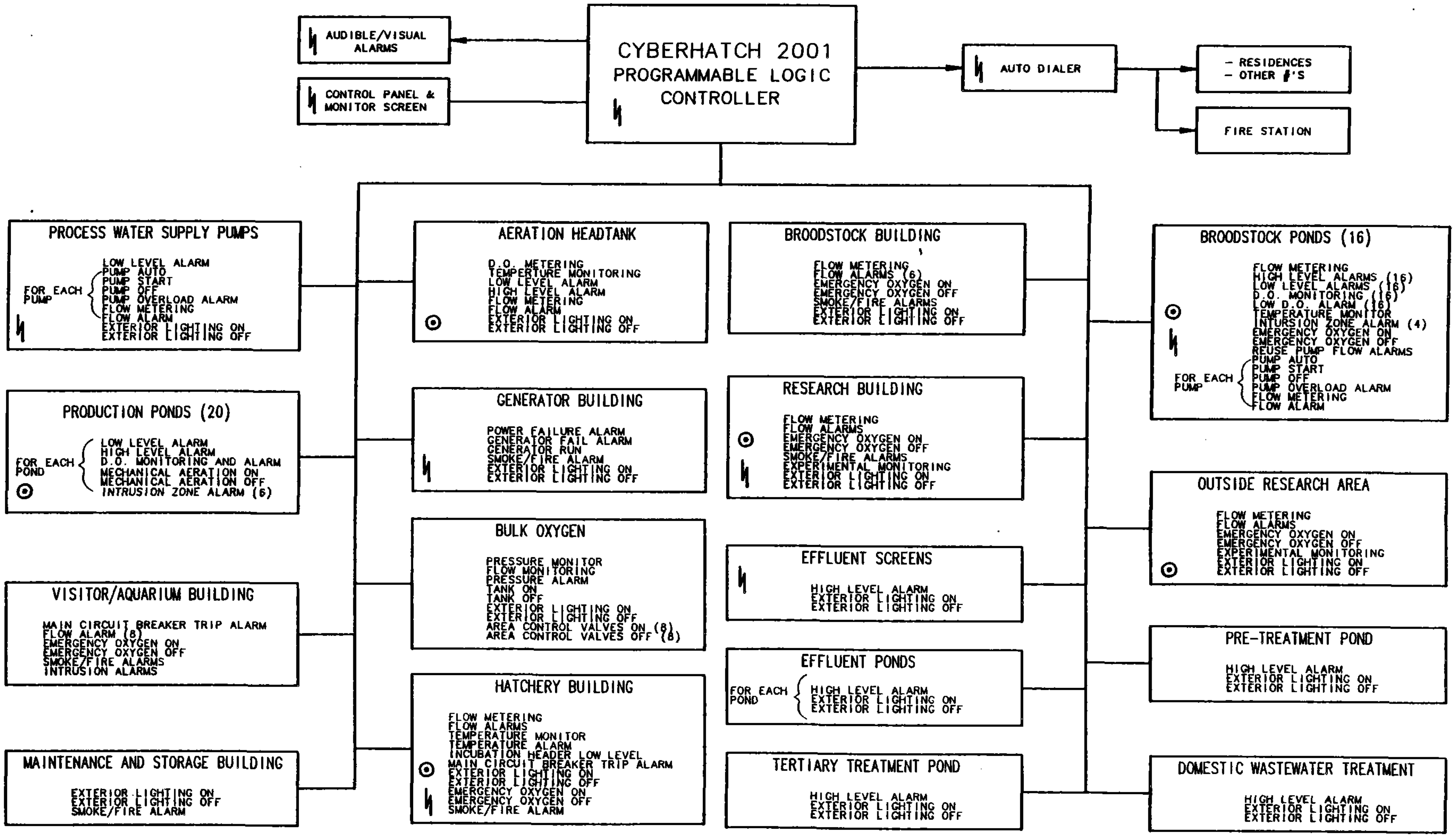


THREATENED AND ENDANGERED SPECIES FACILITY

COLORADO WATER CONSERVATION BOARD

OUTSIDE RESEARCH AREA

DESIGNED KF/ED DRAWN JS/AB CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 10/29/92 SHEET NO. 10

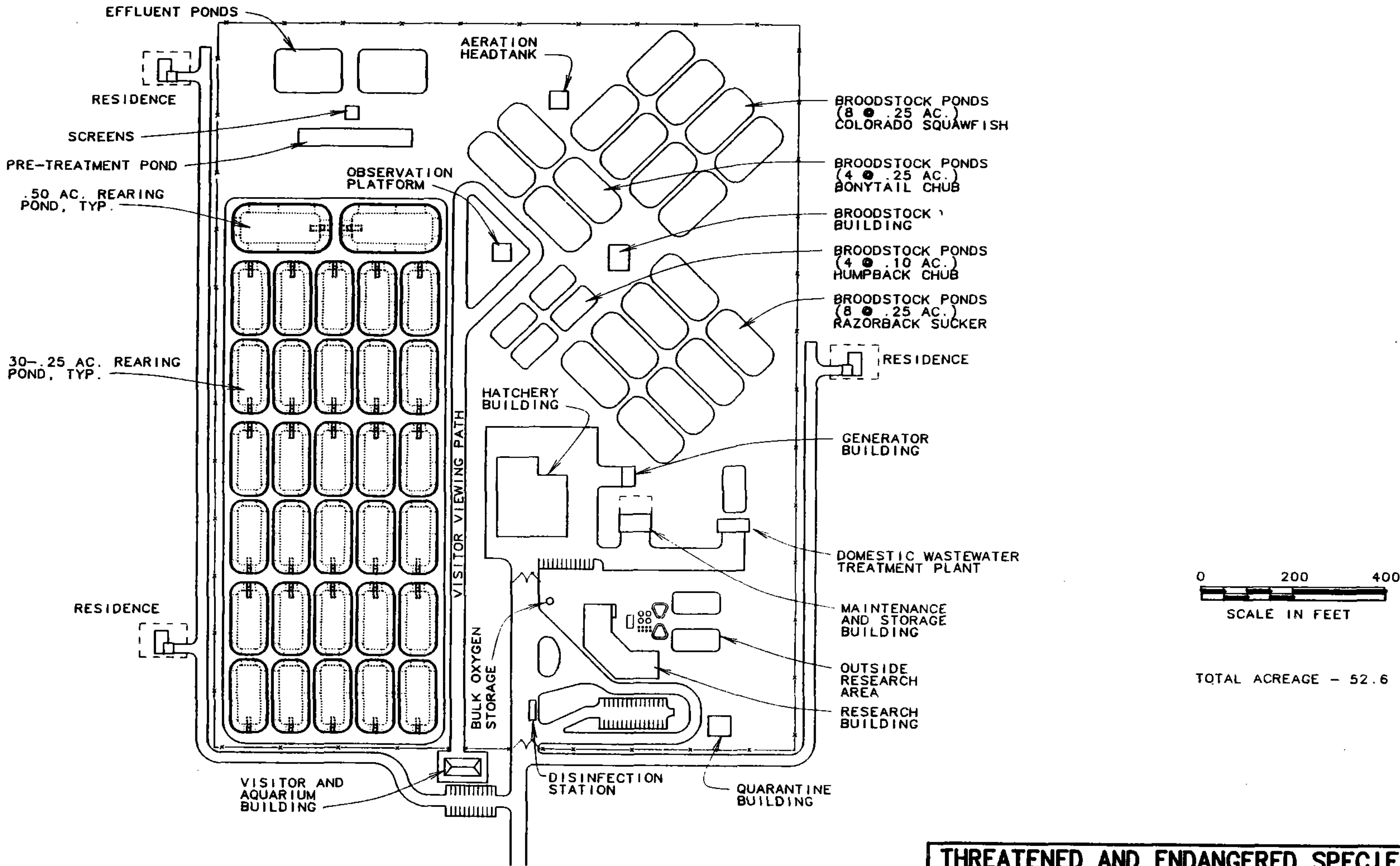


LEGEND

ϟ - ON BACKUP POWER SYSTEM

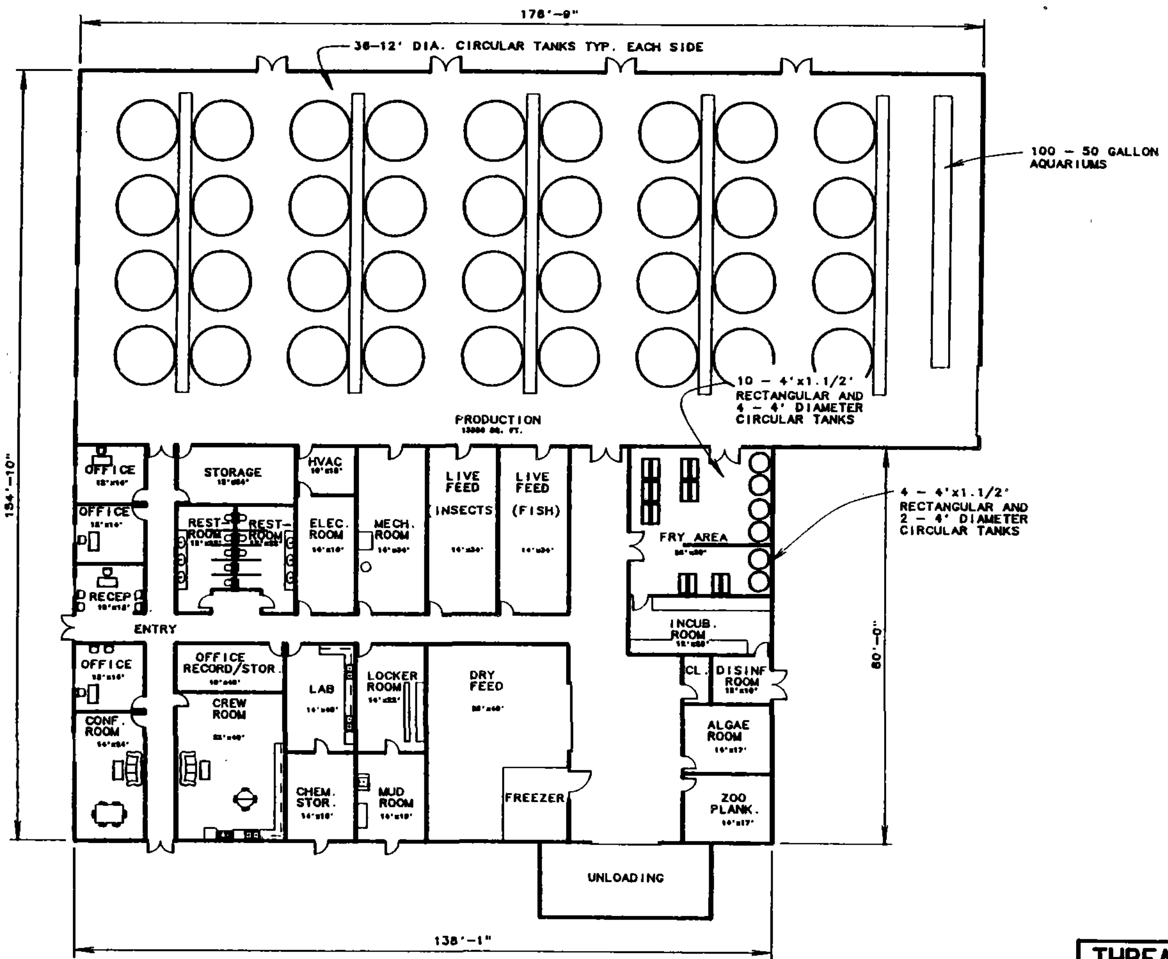
⊙ - ON EMERGENCY OXYGEN SYSTEM

COLORADO WATER CONSERVATION BOARD		
MONITORING AND ALARM DIAGRAM		
DESIGNED RC DRAWN AB CHECKED RC	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 11



THREATENED AND ENDANGERED SPECIES FACILITY
COLORADO WATER CONSERVATION BOARD
SITE PLAN-SCENARIO 1-WARM WELL WATER

DESIGNED KF/ED DRAWN AB CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 10/29/92 SHEET NO. 12



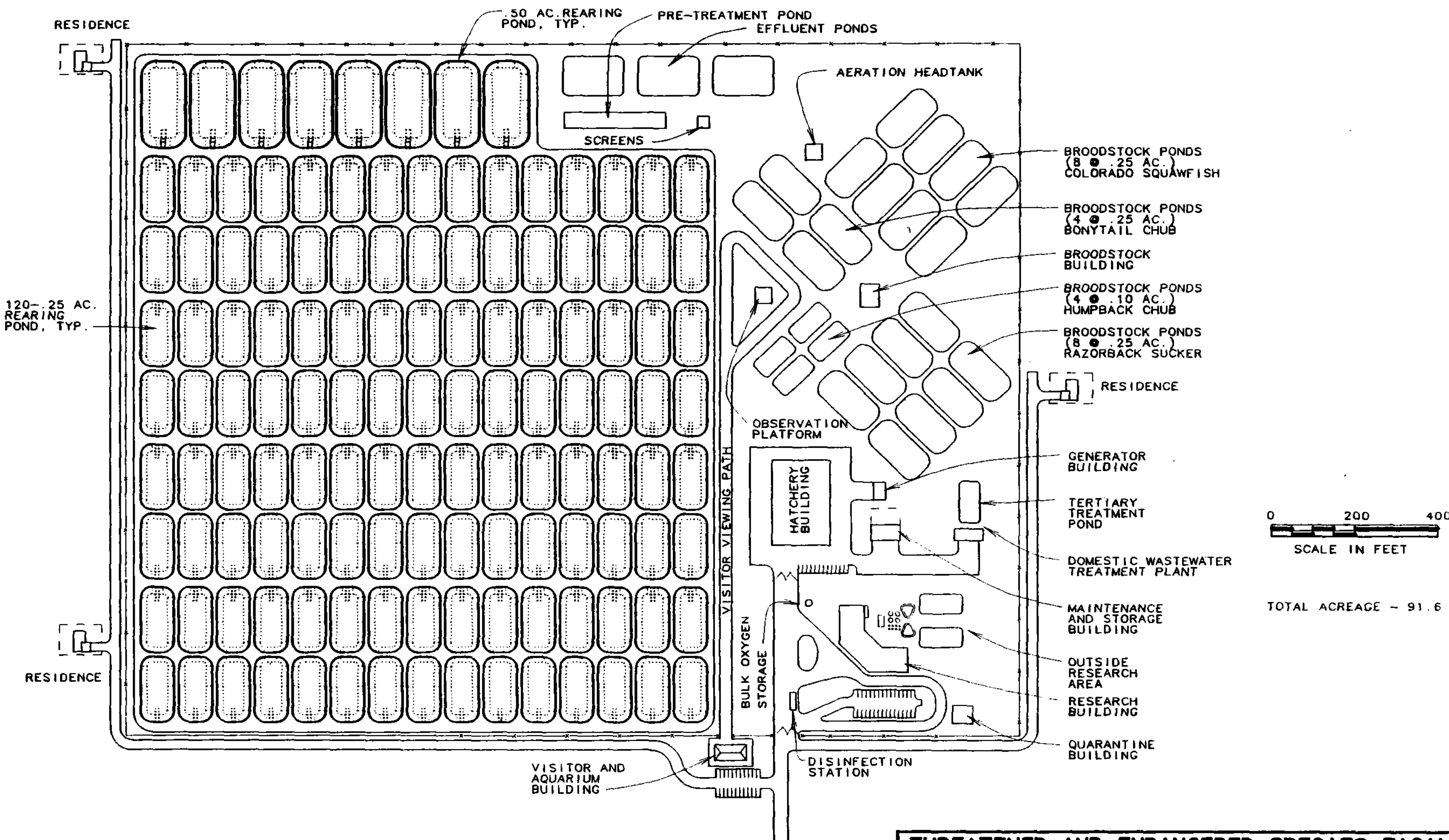
PLAN

0 25 50

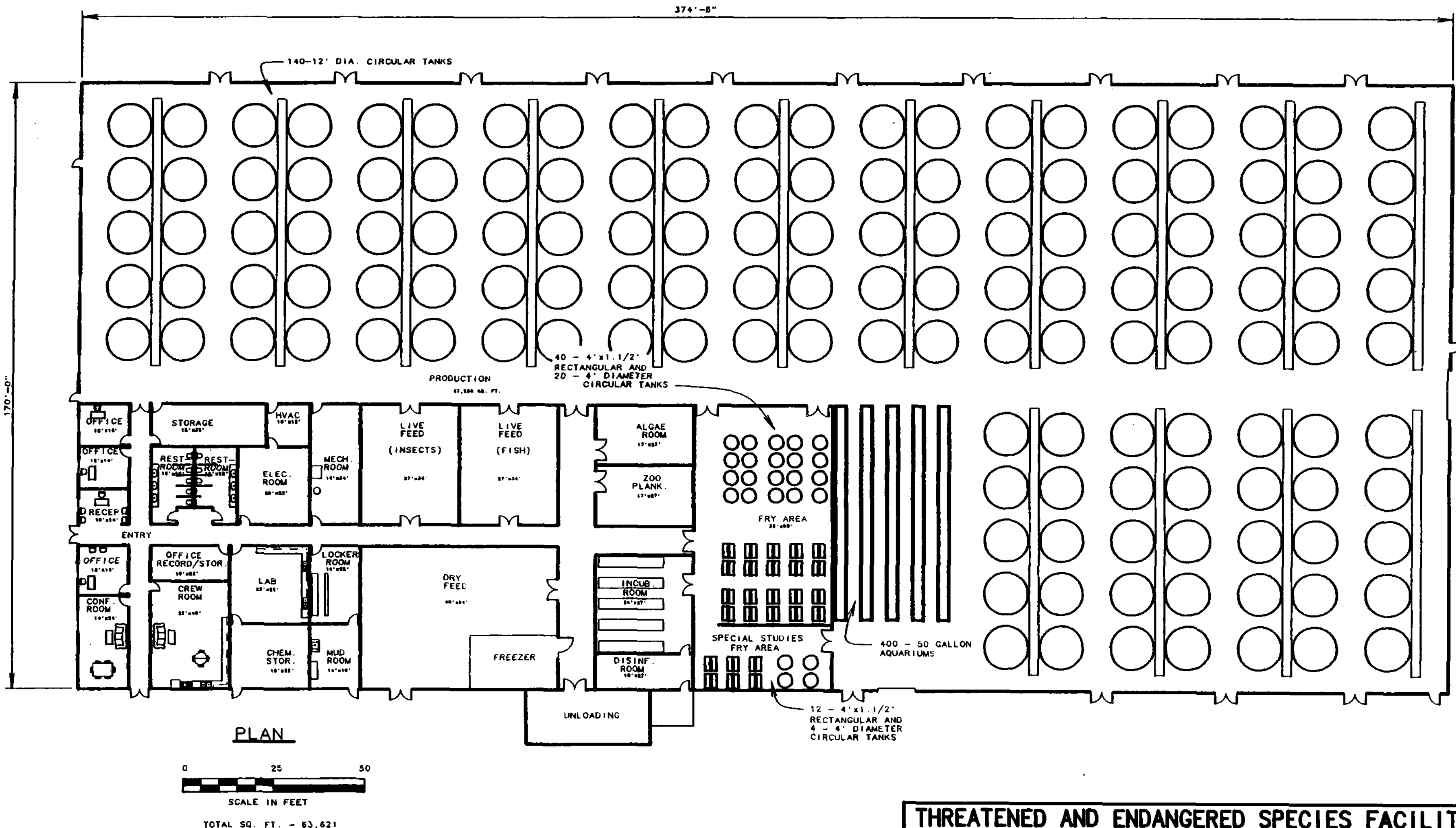
SCALE IN FEET

TOTAL SQ. FT. - 24,530

THREATENED AND ENDANGERED SPECIES FACILITY		
COLORADO WATER CONSERVATION BOARD		
HATCHERY BUILDING-SCENARIO 1		
DESIGNED KF/ED DRAWN JS/RC CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92 SHEET NO. 13



THREATENED AND ENDANGERED SPECIES FACILITY		
COLORADO WATER CONSERVATION BOARD		
SITE PLAN-SCENARIO 3-WARM WELL WATER		
DESIGNED KF/ED DRAWN AB CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 10/29/92 SHEET NO. 14



THREATENED AND ENDANGERED SPECIES FACILITY

COLORADO WATER CONSERVATION BOARD

HATCHERY BUILDING–SCENARIO 3

DESIGNED KF/ED DRAWN JS/RC CHECKED KF	FISHPRO, INC. PREPARED FOR THE URS TEAM	DATE 7/17/92	SHEET NO. 15

APPENDIX I

ESTIMATES OF PROBABLE COSTS

ESTIMATES OF PROBABLE COSTS

Table C.1. Estimate of Probable Costs (Itemized)

Scenario 1 - 150,000 Fish - Intensive/Extensive with Warm Well Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	52.6 AC	$1,000.00	$52,600	
	Grading	76,300 SY	$0.50	$38,150	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	26,800 SY	$4.00	$107,200	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$55,000.00	$55,000	
	Stormwater Control	1 LS	$20,000.00	$20,000	
	Fencing	6,500 LF	$19.50	$126,750	
					$550,020
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$90,000.00	$90,000	
	Communications Systems	1 LS	$25,000.00	$25,000	
					$770,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	18,945 SF	$94.00	$1,780,830	
	Freezer	1 LS	$25,000.00	$25,000	
					$2,280,555
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.1. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	30 EA	$25,000.00	$750,000	
	Lining	30 EA	$16,000.00	$480,000	
	Outlet Structure (Kettle)	30 EA	$12,500.00	$375,000	
	Predation Control	30 EA	$7,000.00	$210,000	
					$1,815,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	2 EA	$50,000.00	$100,000	
	Lining	2 EA	$32,000.00	$64,000	
	Outlet Structure (Kettle)	2 EA	$12,500.00	$25,000	
	Predation Control	2 EA	$12,000.00	$24,000	
					$213,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.1. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Well Supply				
	Well, Screens, Pump, Isolation Valve, Flow Meters and Vaults	4 EA	$150,000.00	$600,000	**$600,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$294,000.00	$294,000	
	Process Water Lines	1 LS	$310,000.00	$310,000	
	Process Water Hydrant System	1 LS	$24,000.00	$24,000	
					$628,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$41,000.00	$41,000	
					$191,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$60,000.00	$60,000	
	Instrumentation Package	1 LS	$321,000.00	$321,000	
	Levels, Oxygen, Temperature, Controller				**$381,000**

Table C.1. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	42 EA	$2,000.00	$84,000	
	4' Tanks	12 EA	$400.00	$4,800	
	4-1/2' X 1-1/2' Troughs	44 EA	$300.00	$13,200	
	Incubation	2 EA	$1,500.00	$3,000	
	Insect Prod	1 LS	$17,000.00	$17,000	
	Fish Prod	1 LS	$8,000.00	$8,000	
	Algae Prod	1 LS	$17,000.00	$17,000	
	Zooplankton	1 LS	$17,000.00	$17,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$38,000.00	$38,000	
	Feed Distribution - Ponds	32 EA	$5,000.00	$160,000	
					$398,000
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Cooling Equipment	1 LS	$115,000.00	$115,000	**$115,000**
	Total				**$12,893,875**
	Contingency 25%*				$3,223,500
	Total (with Contingency)**				**$16,117,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.2. Estimate of Probable Costs (Summary)

Scenario 1 - 150,000 Fish - Intensive/Extensive with Warm Well Water

1.	Site Work	$550,020
2.	Utilities	$770,000
3.	Residences	$483,040
4.	Hatchery Building	$2,280,555
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$1,815,000
14.	Production Ponds (1/2 Acre)	$213,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$600,000
20.	Yard Piping	$628,000
21.	Oxygen System	$191,000
22.	Monitoring and Alarm System	$381,000
23.	Fish Rearing Equipment	$398,000
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$115,000
	Total	$12,893,875
	Contingency 25%	$3,223,469
	Total (with Contingency)	**$16,117,000**

Table C.3. Estimate of Probable Costs (Itemized)

Scenario 1 - 150,000 Fish - Intensive/Extensive with Cold Well Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	59.7 AC	$1,000.00	$59,700	
	Grading	86,600 SY	$0.50	$43,300	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	35,000 SY	$4.00	$140,000	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$55,000.00	$55,000	
	Stormwater Control	1 LS	$20,000.00	$20,000	
	Fencing	7,000 LF	$19.50	$136,500	
					$604,820
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$90,000.00	$90,000	
	Communications Systems	1 LS	$25,000.00	$25,000	
					$770,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	18,945 SF	$94.00	$1,780,830	
	Freezer	1 LS	$25,000.00	$25,000	
					$2,280,555
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.3. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	48 EA	$25,000.00	$1,200,000	
	Lining	48 EA	$16,000.00	$768,000	
	Outlet Structure (Kettle)	48 EA	$12,500.00	$600,000	
	Predation Control	48 EA	$7,000.00	$336,000	
					$2,904,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	3 EA	$50,000.00	$150,000	
	Lining	3 EA	$32,000.00	$96,000	
	Outlet Structure (Kettle)	3 EA	$12,500.00	$37,500	
	Predation Control	3 EA	$12,000.00	$36,000	
					$319,500
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.3. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Well Supply				
	Well, Screen, Pump, Isolation Valve, Flow Meter and Vaults	4 EA	$100,000.00	$400,000	**$400,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$313,000.00	$313,000	
	Process Water Lines	1 LS	$330,000.00	$330,000	
	Process Water Hydrant System	1 LS	$25,000.00	$25,000	
					$668,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$51,000.00	$51,000	
					$201,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$66,000.00	$66,000	
	Instrumentation Package	1 LS	$353,000.00	$353,000	
	Levels, Oxygen, Temperature, Controller				**$419,000**

Table C.3. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	42 EA	$2,000.00	$84,000	
	4' Tanks	12 EA	$400.00	$4,800	
	4-1/2' X 1-1/2' Troughs	44 EA	$300.00	$13,200	
	Incubation	2 EA	$1,500.00	$3,000	
	Insect Prod	1 LS	$17,000.00	$17,000	
	Fish Prod	1 LS	$8,000.00	$8,000	
	Algae Prod	1 LS	$17,000.00	$17,000	
	Zooplankton	1 LS	$17,000.00	$17,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$38,000.00	$38,000	
	Feed Distribution - Ponds	26 EA	$5,000.00	$130,000	
					$368,000
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Heating Equipment	1 LS	$277,000.00	$277,000	
	Degassing Equipment	1 LS	$120,000.00	$120,000	
	Cooling Equipment	1 LS	$40,000.00	$40,000	
					$437,000
	Total				**$14,324,175**
	Contingency 25%*				$3,581,044
	Total (with Contingency)**				**$17,905,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.4. Estimate of Probable Costs (Summary)

Scenario 1 - 150,000 Fish - Intensive/Extensive with Cold Well Water

1.	Site Work	$604,820
2.	Utilities	$770,000
3.	Residences	$483,040
4.	Hatchery Building	$2,280,555
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$2,904,000
14.	Production Ponds (1/2 Acre)	$319,500
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$400,000
20.	Yard Piping	$668,000
21.	Oxygen System	$201,000
22.	Monitoring and Alarm System	$419,000
23.	Fish Rearing Equipment	$368,000
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$437,000
	Total	$14,324,175
	Contingency 25%	$3,581,044
	Total (with Contingency)	**$17,905,000**

Table C.5. Estimate of Probable Costs (Itemized)

Scenario 1 - 150,000 Fish - Intensive/Extensive with Surface Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	62.5 AC	$1,000.00	$62,500	
	Grading	90,700 SY	$0.50	$45,350	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	38,000 SY	$4.00	$152,000	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$55,000.00	$55,000	
	Stormwater Control	1 LS	$20,000.00	$20,000	
	Fencing	7,200 LF	$19.50	$140,400	
					$625,570
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$90,000.00	$90,000	
	Communications Systems	1 LS	$25,000.00	$25,000	
					$770,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	18,945 SF	$94.00	$1,780,830	
	Freezer	1 LS	$25,000.00	$25,000	
					$2,280,555
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.5. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	54 EA	$25,000.00	$1,350,000	
	Lining	54 EA	$16,000.00	$864,000	
	Outlet Structure (Kettle)	54 EA	$12,500.00	$675,000	
	Predation Control	54 EA	$7,000.00	$378,000	
					$3,267,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	4 EA	$50,000.00	$200,000	
	Lining	4 EA	$32,000.00	$128,000	
	Outlet Structure (Kettle)	4 EA	$12,500.00	$50,000	
	Predation Control	4 EA	$12,000.00	$48,000	
					$426,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.5. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Surface Water Supply				
	Microscreen max. 13 cfs	1 EA	$175,000.00	$175,000	
	Disinfection max. 13 cfs	1 EA	$464,000.00	$464,000	
	Pump Station and Intake Screening max. 15 cfs	1 EA	$522,000.00	$522,000	**$1,161,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$321,000.00	$321,000	
	Process Water Lines	1 LS	$338,000.00	$338,000	
	Process Water Hydrant System	1 LS	$27,000.00	$27,000	
					$686,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$54,000.00	$54,000	
					$204,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$68,000.00	$68,000	
	Instrumentation Package	1 LS	$365,000.00	$365,000	
	Levels, Oxygen, Temperature, Controller				**$433,000**

Table C.5. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	42 EA	$2,000.00	$84,000	
	4' Tanks	12 EA	$400.00	$4,800	
	4-1/2' X 1-1/2' Troughs	44 EA	$300.00	$13,200	
	Incubation	2 EA	$1,500.00	$3,000	
	Insect Prod	1 LS	$17,000.00	$17,000	
	Fish Prod	1 LS	$8,000.00	$8,000	
	Algae Prod	1 LS	$17,000.00	$17,000	
	Zooplankton	1 LS	$17,000.00	$17,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$38,000.00	$38,000	
	Feed Distribution - Ponds	58 EA	$5,000.00	$290,000	
					$528,000
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Heating Equipment	1 LS	$290,500.00	$290,500	
	Degassing Equipment	1 LS	$120,000.00	$120,000	
	Cooling Equipment	1 LS	$125,000.00	$125,000	
					$535,500
	Total				**$15,868,925**
	Contingency 25%*				$3,967,231
	Total (with Contingency)**				**$19,836,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.6. Estimate of Probable Costs (Summary)

Scenario 1 - 150,000 Fish - Intensive/Extensive with Surface Water

1.	Site Work	$625,570
2.	Utilities	$770,000
3.	Residences	$483,040
4.	Hatchery Building	$2,280,555
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$3,267,000
14.	Production Ponds (1/2 Acre)	$426,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$1,161,000
20.	Yard Piping	$686,000
21.	Oxygen System	$204,000
22.	Monitoring and Alarm System	$433,000
23.	Fish Rearing Equipment	$528,000
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$535,500
	Total	$15,868,925
	Contingency 25%	$3,967,231
	Total (with Contingency)	**$19,836,000**

Table C.7. Estimate of Probable Costs (Itemized)

Scenario 2 - 300,000 Fish - Intensive/Extensive with Warm Well Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	67.1 AC	$1,000.00	$67,100	
	Grading	92,900 SY	$0.50	$46,450	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	34,100 SY	$4.00	$136,400	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$60,000.00	$60,000	
	Stormwater Control	1 LS	$25,000.00	$25,000	
	Fencing	7,700 LF	$19.50	$150,150	
					$635,420
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$100,000.00	$100,000	
	Communications Systems	1 LS	$30,000.00	$30,000	
					$785,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	30,795 SF	$94.00	$2,894,730	
	Freezer	1 LS	$35,000.00	$35,000	
					$3,404,455
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.7. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	60 EA	$25,000.00	$1,500,000	
	Lining	60 EA	$16,000.00	$960,000	
	Outlet Structure (Kettle)	60 EA	$12,500.00	$750,000	
	Predation Control	60 EA	$7,000.00	$420,000	
					$3,630,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	4 EA	$50,000.00	$200,000	
	Lining	4 EA	$32,000.00	$128,000	
	Outlet Structure (Kettle)	4 EA	$12,500.00	$50,000	
	Predation Control	4 EA	$12,000.00	$48,000	
					$426,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.7. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Well Supply				
	Well, Screens, Pump, Isolation Valve, Flow Meter and Vaults	6 EA	$150,000.00	$900,000	**$900,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$324,000.00	$324,000	
	Process Water Lines	1 LS	$341,000.00	$341,000	
	Process Water Hydrant System	1 LS	$27,000.00	$27,000	
					$692,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$57,000.00	$57,000	
					$207,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$70,000.00	$70,000	
	Instrumentation Package	1 LS	$375,000.00	$375,000	
	Levels, Oxygen, Temperature, Controller				**$445,000**

Table C.7. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	80 EA	$2,000.00	$160,000	
	4' Tanks	26 EA	$400.00	$10,400	
	4-1/2' X 1-1/2' Troughs	56 EA	$300.00	$16,800	
	Incubation	3 EA	$1,500.00	$4,500	
	Insect Prod	1 LS	$20,000.00	$20,000	
	Fish Prod	1 LS	$10,000.00	$10,000	
	Algae Prod	1 LS	$20,000.00	$20,000	
	Zooplankton	1 LS	$20,000.00	$20,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$50,000.00	$50,000	
	Feed Distribution - Ponds	64 EA	$5,000.00	$320,000	
					$667,700
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Cooling Equipment	1 LS	$200,000.00	$200,000	**$200,000**
	Total				**$16,944,875**
	Contingency 25%*				$4,236,219
	Total (with Contingency)**				**$21,181,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.8. Estimate of Probable Costs (Summary)

Scenario 2 - 300,000 Fish - Intensive/Extensive with Warm Well Water

1.	Site Work	$635,420
2.	Utilities	$785,000
3.	Residences	$483,040
4.	Hatchery Building	$3,404,455
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$3,630,000
14.	Production Ponds (1/2 Acre)	$426,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$900,000
20.	Yard Piping	$692,000
21.	Oxygen System	$207,000
22.	Monitoring and Alarm System	$445,000
23.	Fish Rearing Equipment	$667,700
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$200,000
	Total	$16,944,875
	Contingency 25%	$4,236,219
	Total (with Contingency)	**$21,181,000**

Table C.9. Estimate of Probable Costs (Itemized)

Scenario 2 - 300,000 Fish - Intensive/Extensive with Cold Well Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	81.2 AC	$1,000.00	$81,200	
	Grading	112,550 SY	$0.50	$56,275	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	50,300 SY	$4.00	$201,200	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$60,000.00	$60,000	
	Stormwater Control	1 LS	$25,000.00	$25,000	
	Fencing	8,700 LF	$19.50	$169,650	
					$743,645
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$100,000.00	$100,000	
	Communications Systems	1 LS	$30,000.00	$30,000	
					$785,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	30,795 SF	$94.00	$2,894,730	
	Freezer	1 LS	$35,000.00	$35,000	
					$3,404,455
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.9. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	96 EA	$25,000.00	$2,400,000	
	Lining	96 EA	$16,000.00	$1,536,000	
	Outlet Structure (Kettle)	96 EA	$12,500.00	$1,200,000	
	Predation Control	96 EA	$7,000.00	$672,000	
					$5,808,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	6 EA	$50,000.00	$300,000	
	Lining	6 EA	$32,000.00	$192,000	
	Outlet Structure (Kettle)	6 EA	$12,500.00	$75,000	
	Predation Control	6 EA	$12,000.00	$72,000	
					$639,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.9. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Well Supply				
	Well, Screens, Pump, Isolation Valve, Flow Meters, and Vaults	7 EA	$100,000.00	$700,000	**$700,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$402,000.00	$402,000	
	Process Water Lines	1 LS	$423,000.00	$423,000	
	Process Water Hydrant System	1 LS	$33,000.00	$33,000	
					$858,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$76,000.00	$76,000	
					$226,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$82,000.00	$82,000	
	Instrumentation Package	1 LS	$439,000.00	$439,000	
	Levels, Oxygen, Temperature, Controller				**$521,000**

Table C.9. (Continued)

ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23. Fish Rearing Equipment				
14' Tanks	4 EA	$2,500.00	$10,000	
12' Tanks	80 EA	$2,000.00	$160,000	
4' Tanks	26 EA	$400.00	$10,400	
4-1/2' X 1-1/2' Troughs	56 EA	$300.00	$16,800	
Incubation	3 EA	$1,500.00	$4,500	
Insect Prod	1 LS	$20,000.00	$20,000	
Fish Prod	1 LS	$10,000.00	$10,000	
Algae Prod	1 LS	$20,000.00	$20,000	
Zooplankton	1 LS	$20,000.00	$20,000	
Pathological Incinerator	1 LS	$10,000.00	$10,000	
Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
Feed Distribution - Hatchery	1 LS	$50,000.00	$50,000	
Feed Distribution - Ponds	102 EA	$5,000.00	$510,000	
				$857,700
24. Laboratory Equipment				
Pathology	1 LS	$70,000.00	$70,000	
Genetics	1 LS	$250,000.00	$250,000	
Darkroom	1 LS	$5,000.00	$5,000	
Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
				$445,000
25. Process Water Conditioning Equipment				
Heating Equipment	1 LS	$395,000.00	$395,000	
Degassing Equipment	1 LS	$220,000.00	$220,000	
Cooling Equipment	1 LS	$70,000.00	$70,000	
				$685,000
Total				**$20,180,100**
Contingency 25%*				$5,045,025
Total (with Contingency)**				**$25,225,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.10. Estimate of Probable Costs (Summary)

Scenario 2 - 300,000 Fish - Intensive/Extensive with Cold Well Water

1.	Site Work	$743,645
2.	Utilities	$785,000
3.	Residences	$483,040
4.	Hatchery Building	$3,404,455
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$5,808,000
14.	Production Ponds (1/2 Acre)	$639,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$700,000
20.	Yard Piping	$858,000
21.	Oxygen System	$226,000
22.	Monitoring and Alarm System	$521,000
23.	Fish Rearing Equipment	$857,700
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$685,000
	Total	$20,180,100
	Contingency 25%	$5,045,025
	Total (with Contingency)	**$25,225,000**

Table C.11. Estimate of Probable Costs (Itemized)

Scenario 2 - 300,000 Fish - Intensive/Extensive with Surface Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	86.8 AC	$1,000.00	$86,800	
	Grading	120,200 SY	$0.50	$60,100	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	56,300 SY	$4.00	$225,200	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$60,000.00	$60,000	
	Stormwater Control	1 LS	$25,000.00	$25,000	
	Fencing	9,100 LF	$19.50	$177,450	
					$784,870
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$100,000.00	$100,000	
	Communications Systems	1 LS	$30,000.00	$30,000	
					$785,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	30,795 SF	$94.00	$2,894,730	
	Freezer	1 LS	$35,000.00	$35,000	
					$3,404,455
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.11. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	108 EA	$25,000.00	$2,700,000	
	Lining	108 EA	$16,000.00	$1,728,000	
	Outlet Structure (Kettle)	108 EA	$12,500.00	$1,350,000	
	Predation Control	108 EA	$7,000.00	$756,000	
					$6,534,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	8 EA	$50,000.00	$400,000	
	Lining	8 EA	$32,000.00	$256,000	
	Outlet Structure (Kettle)	8 EA	$12,500.00	$100,000	
	Predation Control	8 EA	$12,000.00	$96,000	
					$852,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.11. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Surface Water Supply				
	Microscreen max. 15 cfs	1 EA	$200,000.00	$200,000	
	Disinfection max. 15 cfs	1 EA	$540,000.00	$540,000	
	Pump Station and Intake Screening max. 17 cfs	1 EA	$600,000.00	$600,000	
				$1,340,000	**$1,340,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$415,000.00	$415,000	
	Process Water Lines	1 LS	$436,000.00	$436,000	
	Process Water Hydrant System	1 LS	$35,000.00	$35,000	
					$886,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$83,000.00	$83,000	
					$233,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$86,000.00	$86,000	
	Instrumentation Package	1 LS	$463,000.00	$463,000	
	Levels, Oxygen, Temperature, Controller				**$549,000**

Table C.11. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	80 EA	$2,000.00	$160,000	
	4' Tanks	26 EA	$400.00	$10,400	
	4-1/2' X 1-1/2' Troughs	56 EA	$300.00	$16,800	
	Incubation	3 EA	$1,500.00	$4,500	
	Insect Prod	1 LS	$20,000.00	$20,000	
	Fish Prod	1 LS	$10,000.00	$10,000	
	Algae Prod	1 LS	$20,000.00	$20,000	
	Zooplankton	1 LS	$20,000.00	$20,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$50,000.00	$50,000	
	Feed Distribution - Ponds	116 EA	$5,000.00	$580,000	
					$927,700
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Heating Equipment	1 LS	$588,500.00	$588,500	
	Degassing Equipment	1 LS	$220,000.00	$220,000	
	Cooling Equipment	1 LS	$220,000.00	$220,000	
					$1,028,500
	Total				**$22,276,825**
	Contingency 25%*				$5,569,206
	Total (with Contingency)**				**$27,846,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.12. Estimate of Probable Costs (Summary)

Scenario 2 - 300,000 Fish - Intensive/Extensive with Surface Water

1.	Site Work	$784,870
2.	Utilities	$785,000
3.	Residences	$483,040
4.	Hatchery Building	$3,404,455
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$6,534,000
14.	Production Ponds (1/2 Acre)	$852,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$1,340,000
20.	Yard Piping	$886,000
21.	Oxygen System	$233,000
22.	Monitoring and Alarm System	$549,000
23.	Fish Rearing Equipment	$927,700
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$1,028,500
	Total	$22,276,825
	Contingency 25%	$5,569,206
	Total (with Contingency)	**$27,846,000**

Table C.13. Estimate of Probable Costs (Itemized)

Scenario 3 - 600,000 Fish - Intensive/Extensive with Warm Well Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	91.6 AC	$1,000.00	$91,600	
	Grading	132,100 SY	$0.50	$66,050	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	46,600 SY	$4.00	$186,400	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$60,000.00	$60,000	
	Stormwater Control	1 LS	$25,000.00	$25,000	
	Fencing	8,500 LF	$19.50	$165,750	
					$745,120
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$100,000.00	$100,000	
	Communications Systems	1 LS	$30,000.00	$30,000	
					$785,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	58,036 SF	$94.00	$5,455,384	
	Freezer	1 LS	$35,000.00	$35,000	
					$5,965,109
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.13. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	120 EA	$25,000.00	$3,000,000	
	Lining	120 EA	$16,000.00	$1,920,000	
	Outlet Structure (Kettle)	120 EA	$12,500.00	$1,500,000	
	Predation Control	120 EA	$7,000.00	$840,000	
					$7,260,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	8 EA	$50,000.00	$400,000	
	Lining	8 EA	$32,000.00	$256,000	
	Outlet Structure (Kettle)	8 EA	$12,500.00	$100,000	
	Predation Control	8 EA	$12,000.00	$96,000	
					$852,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.13. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Well Supply				
	Well, Screens, Pump, Isolation Valve, Flow Meters and Vaults	7 EA	$150,000.00	$1,050,000	**$1,050,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$426,000.00	$426,000	
	Process Water Lines	1 LS	$448,000.00	$448,000	
	Process Water Hydrant System	1 LS	$36,000.00	$36,000	
					$910,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$89,000.00	$89,000	
					$239,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$90,000.00	$90,000	
	Instrumentation Package	1 LS	$483,000.00	$483,000	
	Levels, Oxygen, Temperature, Controller				**$573,000**

Table C.13. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	146 EA	$2,000.00	$292,000	
	4' Tanks	30 EA	$400.00	$12,000	
	4-1/2' X 1-1/2' Troughs	82 EA	$300.00	$24,600	
	Incubation	5 EA	$1,500.00	$7,500	
	Insect Prod	1 LS	$20,000.00	$20,000	
	Fish Prod	1 LS	$10,000.00	$10,000	
	Algae Prod	1 LS	$20,000.00	$20,000	
	Zooplankton	1 LS	$20,000.00	$20,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$50,000.00	$50,000	
	Feed Distribution - Ponds	128 EA	$5,000.00	$640,000	
					$1,132,100
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Cooling Equipment	1 LS	$400,000.00	$400,000	**$400,000**
	Total				**$24,863,629**
	Contingency 25%*				$6,215,907
	Total (with Contingency)**				**$31,080,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.14. Estimate of Probable Costs (Summary)

Scenario 3 - 600,000 Fish - Intensive/Extensive with Warm Well Water

1.	Site Work	$745,120
2.	Utilities	$785,000
3.	Residences	$483,040
4.	Hatchery Building	$5,965,109
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$7,260,000
14.	Production Ponds (1/2 Acre)	$852,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$1,050,000
20.	Yard Piping	$910,000
21.	Oxygen System	$239,000
22.	Monitoring and Alarm System	$573,000
23.	Fish Rearing Equipment	$1,132,100
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$400,000
	Total	$24,863,629
	Contingency 25%	$6,215,907
	Total (with Contingency)	**$31,080,000**

Table C.15. Estimate of Probable Costs (Itemized)

Scenario 3 - 600,000 Fish - Intensive/Extensive with Cold Well Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	119.8 AC	$1,000.00	$119,800	
	Grading	172,900 SY	$0.50	$86,450	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	77,200 SY	$4.00	$308,800	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$60,000.00	$60,000	
	Stormwater Control	1 LS	$25,000.00	$25,000	
	Fencing	10,500 LF	$19.50	$204,750	
					$955,120
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$100,000.00	$100,000	
	Communications Systems	1 LS	$30,000.00	$30,000	
					$785,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	58,036 SF	$94.00	$5,455,384	
	Freezer	1 LS	$35,000.00	$35,000	
					$5,965,109
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.15. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	192 EA	$25,000.00	$4,800,000	
	Lining	192 EA	$16,000.00	$3,072,000	
	Outlet Structure (Kettle)	192 EA	$12,500.00	$2,400,000	
	Predation Control	192 EA	$7,000.00	$1,344,000	
					$11,616,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	12 EA	$50,000.00	$600,000	
	Lining	12 EA	$32,000.00	$384,000	
	Outlet Structure (Kettle)	12 EA	$12,500.00	$150,000	
	Predation Control	12 EA	$12,000.00	$144,000	
					$1,278,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.15. (Continued)

ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16. Brood Ponds (0.25 acre)				
Pond	20 EA	$25,000.00	$500,000	
Lining	20 EA	$32,500.00	$650,000	
Predation Control	20 EA	$7,000.00	$140,000	
				$1,290,000
17. Outside Research				
12' Circulars	4 EA	$2,500.00	$10,000	
4' Circulars	8 EA	$500.00	$4,000	
Experimental Channels	2 EA	$50,000.00	$100,000	
Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
				$163,000
18. Hatchery Effluent Treatment				
1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
Effluent Screening	1 LS	$32,000.00	$32,000	
				$140,000
19. Hatchery Rearing Water Supply				
Well Supply				
Well, Screens, Pumps, Isolation Valve, Flow Meters and Vaults	8 EA	$100,000.00	$800,000	**$800,000**
20. Yard Piping				
Pond Drains & Laterals	1 LS	$540,000.00	$540,000	
Process Water Lines	1 LS	$567,000.00	$567,000	
Process Water Hydrant System	1 LS	$45,000.00	$45,000	
				$1,152,000
21. Oxygen System				
Bulk Storage Tank	1 LS	$150,000.00	$150,000	
Piping System	1 LS	$127,000.00	$127,000	
				$277,000
22. Monitoring and Alarm System				
Intrusion	1 LS	$114,000.00	$114,000	
Instrumentation Package	1 LS	$611,000.00	$611,000	
Levels, Oxygen, Temperature, Controller				**$725,000**

Table C.15. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	146 EA	$2,000.00	$292,000	
	4' Tanks	30 EA	$400.00	$12,000	
	4-1/2' X 1-1/2' Troughs	82 EA	$300.00	$24,600	
	Incubation	5 EA	$1,500.00	$7,500	
	Insect Prod	1 LS	$20,000.00	$20,000	
	Fish Prod	1 LS	$10,000.00	$10,000	
	Algae Prod	1 LS	$20,000.00	$20,000	
	Zooplankton	1 LS	$20,000.00	$20,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$50,000.00	$50,000	
	Feed Distribution - Ponds	204 EA	$5,000.00	$1,020,000	
					$1,512,100
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Heating Equipment	1 LS	$776,000.00	$776,000	
	Degassing Equipment	1 LS	$400,000.00	$400,000	
	Cooling Equipment	1 LS	$140,000.00	$140,000	
					$1,316,000
	Total				**$31,333,629**
	Contingency 25%*				**$7,833,407**
	Total (with Contingency)**				**$39,167,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.16. Estimate of Probable Costs (Summary)

Scenario 3 - 600,000 Fish - Intensive/Extensive with Cold Well Water

1.	Site Work	$955,120
2.	Utilities	$785,000
3.	Residences	$483,040
4.	Hatchery Building	$5,965,109
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$11,616,000
14.	Production Ponds (1/2 Acre)	$1,278,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$800,000
20.	Yard Piping	$1,152,000
21.	Oxygen System	$277,000
22.	Monitoring and Alarm System	$725,000
23.	Fish Rearing Equipment	$1,512,100
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$1,316,000
	Total	$31,333,629
	Contingency 25%	$7,833,407
	Total (with Contingency)	$39,167,000

Table C.17. Estimate of Probable Costs (Itemized)

Scenario 3 - 600,000 Fish - Intensive/Extensive with Surface Water

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
1.	**Site Work**				
	Strip Clear Grub	131.0 AC	$1,000.00	$131,000	
	Grading	189,000 SY	$0.50	$94,500	
	Walkways	1,775 SY	$9.00	$15,975	
	Asphalt Road and Parking	10,890 SY	$10.50	$114,345	
	Gravel Roads	88,800 SY	$4.00	$355,200	
	Signage/Flag Pole	1 LS	$20,000.00	$20,000	
	Landscaping	1 LS	$60,000.00	$60,000	
	Stormwater Control	1 LS	$25,000.00	$25,000	
	Fencing	11,300 LF	$19.50	$220,350	
					$1,036,370
2.	**Utilities**				
	Potable Water System	1 LS	$90,000.00	$90,000	
	Domestic Wastewater Tmnt Sys	1 LS	$55,000.00	$55,000	
	Sewerage	1 LS	$140,000.00	$140,000	
	Site Electricity				
	Primary Power	1 LS	$30,000.00	$30,000	
	Secondary Power	1 LS	$340,000.00	$340,000	
	Yard Lighting	1 LS	$100,000.00	$100,000	
	Communications Systems	1 LS	$30,000.00	$30,000	
					$785,000
3.	**Residences**				
	Building	4 EA	$117,000.00	$468,000	
	Landscaping/Fence	4 EA	$3,760.00	$15,040	
					$483,040
4.	**Hatchery Building**				
	Administrative Area	5,585 SF	$85.00	$474,725	
	Production Area	58,036 SF	$94.00	$5,455,384	
	Freezer	1 LS	$35,000.00	$35,000	
					$5,965,109
5.	**Research Building**				
	General Use Area	12,688 SF	$90.00	$1,141,920	
	Laboratories	2,250 SF	$110.00	$247,500	
					$1,389,420
6.	**Broodstock Building**				
	Administrative	460 SF	$75.00	$34,500	
	Production Area	2,208 SF	$55.00	$121,440	
					$155,940

Table C.17. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
7.	**Quarantine Building**				
	Building	2,300 SF	$55.00	$126,500	**$126,500**
8.	**Maintenance/Storage Building**				
	Building	2,880 SF	$55.00	$158,400	**$158,400**
9.	**Visitor/Aquarium Facility**				
	Building	1,900 SF	$75.00	$142,500	
	Display Equipment	1 LS	$30,000.00	$30,000	
					$172,500
10.	**Emergency Power Generator**				
	Building	900 SF	$60.00	$54,000	
	Generator	1 LS	$55,000.00	$55,000	
	Electrical	1 LS	$40,000.00	$40,000	
					$149,000
11.	**Gas Stabilization Tower**	1 LS	$125,000.00	$125,000	**$125,000**
12.	**Miscellaneous Structures**				
	Truck Fill Station	1 EA	$11,000.00	$11,000	
	Disinfection Station	1 EA	$12,000.00	$12,000	
	Sumps (Misc.)	5 EA	$1,500.00	$7,500	
					$30,500
13.	**Production Ponds (1/4 Acre)**				
	Pond	216 EA	$25,000.00	$5,400,000	
	Lining	216 EA	$16,000.00	$3,456,000	
	Outlet Structure (Kettle)	216 EA	$12,500.00	$2,700,000	
	Predation Control	216 EA	$7,000.00	$1,512,000	
					$13,068,000
14.	**Production Ponds (1/2 Acre)**				
	Pond	16 EA	$50,000.00	$800,000	
	Lining	16 EA	$32,000.00	$512,000	
	Outlet Structure (Kettle)	16 EA	$12,500.00	$200,000	
	Predation Control	16 EA	$12,000.00	$192,000	
					$1,704,000
15.	**Brood Ponds (0.1 Acre)**				
	Pond	4 EA	$12,000.00	$48,000	
	Lining	4 EA	$13,000.00	$52,000	
	Predation Control	4 EA	$6,000.00	$24,000	
					$124,000

Table C.17. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
16.	**Brood Ponds (0.25 acre)**				
	Pond	20 EA	$25,000.00	$500,000	
	Lining	20 EA	$32,500.00	$650,000	
	Predation Control	20 EA	$7,000.00	$140,000	
					$1,290,000
17.	**Outside Research**				
	12' Circulars	4 EA	$2,500.00	$10,000	
	4' Circulars	8 EA	$500.00	$4,000	
	Experimental Channels	2 EA	$50,000.00	$100,000	
	Experimental Ponds (.10 Acre)	2 EA	$24,500.00	$49,000	
					$163,000
18.	**Hatchery Effluent Treatment**				
	1/4 Acre Pre-Treatment Pond (Lined)	1 EA	$18,000.00	$18,000	
	1/2 Acre Effleunt Ponds (Lined)	3 EA	$30,000.00	$90,000	
	Effluent Screening	1 LS	$32,000.00	$32,000	
					$140,000
19.	**Hatchery Rearing Water Supply**				
	Surface Water Supply				
	Microscreen max. 17 cfs	1 EA	$227,000.00	$227,000	
	Disinfection max. 17 cfs	1 EA	$608,000.00	$608,000	
	Pump Station and Intake	1 EA	$684,000.00	$684,000	
	Screening max. 20 cfs			$1,519,000	**$1,519,000**
20.	**Yard Piping**				
	Pond Drains & Laterals	1 LS	$564,000.00	$564,000	
	Process Water Lines	1 LS	$591,000.00	$591,000	
	Process Water Hydrant System	1 LS	$47,000.00	$47,000	
					$1,202,000
21.	**Oxygen System**				
	Bulk Storage Tank	1 LS	$150,000.00	$150,000	
	Piping System	1 LS	$141,000.00	$141,000	
					$291,000
22.	**Monitoring and Alarm System**				
	Intrusion	1 LS	$123,000.00	$123,000	
	Instrumentation Package	1 LS	$658,000.00	$658,000	
	Levels, Oxygen, Temperature, Controller				**$781,000**

Table C.17. (Continued)

	ITEM	QUANTITY	UNIT COST	EXTENSION	TOTALS
23.	**Fish Rearing Equipment**				
	14' Tanks	4 EA	$2,500.00	$10,000	
	12' Tanks	146 EA	$2,000.00	$292,000	
	4' Tanks	30 EA	$400.00	$12,000	
	4-1/2' X 1-1/2' Troughs	82 EA	$300.00	$24,600	
	Incubation	5 EA	$1,500.00	$7,500	
	Insect Prod	1 LS	$20,000.00	$20,000	
	Fish Prod	1 LS	$10,000.00	$10,000	
	Algae Prod	1 LS	$20,000.00	$20,000	
	Zooplankton	1 LS	$20,000.00	$20,000	
	Pathological Incinerator	1 LS	$10,000.00	$10,000	
	Misc. Tanks, Tables, & Troughs	2 LS	$8,000.00	$16,000	
	Feed Distribution - Hatchery	1 LS	$50,000.00	$50,000	
	Feed Distribution - Ponds	232 EA	$5,000.00	$1,160,000	
					$1,652,100
24.	**Laboratory Equipment**				
	Pathology	1 LS	$70,000.00	$70,000	
	Genetics	1 LS	$250,000.00	$250,000	
	Darkroom	1 LS	$5,000.00	$5,000	
	Mini Computer with Terminals	1 LS	$120,000.00	$120,000	
					$445,000
25.	**Process Water Conditioning Equipment**				
	Heating Equipment	1 LS	$1,152,000.00	$1,152,000	
	Degassing Equipment	1 LS	$400,000.00	$400,000	
	Cooling Equipment	1 LS	$440,000.00	$440,000	
					$1,992,000
	Total				**$34,947,879**
	Contingency 25%*				$8,736,970
	Total (with Contingency)**				**$43,685,000**

* Includes 9.5% A/E fees and .5% for permits

** Rounded to nearest thousand

Table C.18. Estimate of Probable Costs (Summary)

Scenario 3 - 600,000 Fish - Intensive/Extensive with Surface Water

1.	Site Work	$1,036,370
2.	Utilities	$785,000
3.	Residences	$483,040
4.	Hatchery Building	$5,965,109
5.	Research Building	$1,389,420
6.	Broodstock Building	$155,940
7.	Quarantine Building	$126,500
8.	Maintenance/Storage Building	$158,400
9.	Visitor/Aquarium Facility	$172,500
10.	Emergency Power Generator	$149,000
11.	Gas Stabilization Tower	$125,000
12.	Miscellaneous Structures	$30,500
13.	Production Ponds (1/4 Acre)	$13,068,000
14.	Production Ponds (1/2 Acre)	$1,704,000
15.	Brood Ponds (0.1 Acre)	$124,000
16.	Brood Ponds (0.25 acre)	$1,290,000
17.	Outside Research	$163,000
18.	Hatchery Effluent Treatment	$140,000
19.	Hatchery Rearing Water Supply	$1,519,000
20.	Yard Piping	$1,202,000
21.	Oxygen System	$291,000
22.	Monitoring and Alarm System	$781,000
23.	Fish Rearing Equipment	$1,652,100
24.	Laboratory Equipment	$445,000
25.	Process Water Conditioning Equipment	$1,992,000
	Total	$34,947,879
	Contingency 25%	$8,736,970
	Total (with Contingency)	$43,685,000