March 10, 1989

Prof. R. J. Behnke,
Department of Fisheries and Wildlife Biology,
Colorado State University, Fort Collins,
Colorado 80523, U. S. A.

Dear Prof. R. J. Behnke:

By separate mail, I am sending you photo-prints (B & W) and a copy of morphometric data of 4 specimens of the cutthroat trout-like fish, which were caught from the Yuufutsu River in Hokkaido on last June 20. As the specimens are possessing tiny basibranchial teeth, I identified them tentatively as Salmo (Parasalmo) clarki. I am feeling a little anxiety about this identification, for I couldn't remark red slash on the throat of the frozen ones. The specimens have a possibility of anadromous one, for their habitat is near the sea. I am now checking the stomach contents whether marine or freshwater origin. How do you think about these specimens ?

If you don't mind, I hope to send a short paper by Kimura and Behnke to the Editorial Committee of Japan. J. Ichthyol. in near future. If you want to observe these cutthroat specimens in detail, I will send you the specimens of Nos. 1 and 2 by air post. Of course, I am supposing that the cutthroat trout may not be native in Hokkaido but introduced from United States or Canada.

It is very difficult for me to know the subspecific name of these specimens, because I have a few references of taxonomy of this species. I would like to receive and read the xerox copies of the followings papers. At the present, I am needing only the chapters related to the cutthroat trout and to their references.

Behnke, R. J. and M. Zarn. 1976. Biology and management of threatened and endangered western trout. U. S. For. Serv. Gen. Tech. Rep. RM-28, Rocky Mtn. For. Range Exp. Stn. Fort Collins, Colo. 45 pp.

Behnke, R. J. 1979. Monograph of the native trouts of the genus Salmo of western North America. U. S. DA Forest Service, Regional Forester. 11177 W. 8th Ave., Lakewood, CO 80225. 163 p.

Your kind cooperations will be very highly appreciated. Please excuse me for giving you such trouble.

Thanking you anticipation,

Sincerely yours,

S. Kimura

S. Kimura,
Department of Fisheries,
Kyushu University 46-04,
Fukuoka, 812, J A P A N

P. S. Dr. K. Maekawa (Hokkaido University) wants to receive your revised manuscript for 'Proceeding'.

OREGON STATE UNIVERSITY

FISHERIES & WILDLIFE

FACSIMILE TRANSMITTAL COVER SHEET

From: Jim Hall
Dept. of Fisheries & Wildlife
Oregon State University
104 Nash Hall
Corvallis OR 97331-3803

Fax Phone: (503) 737-3590
Voice Phone: (503) 737-4531

To: Bob Behnke
CSU, F+W

Date: 4/19/95
Time:

Fax Phone: (970) 491-5091
Voice Phone:

3 Page(s) Faxed (including this cover sheet)

Bob —

good to talk with you. I think the program is shaping up. Still a few holes to fill. Would be glad to have any suggestions on people or topics.

Jim

Draft Program 4/3/95

Sea-run Cutthroat Trout
Status, Management, and Future Conservation
(Alt. subtitle: Biology, Management and Future Conservation)
October 12-14, 1995

Reedsport, Oregon

Kamchatkan record 1994

Session 1: What is a sea-run cutthroat trout?

Evolution and systematics of sea-run cutthroat trout	Robert Behnke, CSU
Life history profile - the biological potential	Patrick Trotter, Seattle
Stock structure and separation - how many stocks are there?	
Population genetics coastwide	Tommy Williams, OSU
Ecological adaptation to specific habitats	??
The interface between residence and anadromy	Tom Northcote, UBC
The role of interspecific interaction	??
Migratory behavior of smolts and adults	Doug Jones, ADF&G
Estuarine and saltwater residence	??

Session 2: Status of the Stocks--A Coastwide Review

Overview of Anadromous Salmonid Stocks	Jack Williams, BLM
California	Eric Gerstung, CDF&G
Oregon	Bob Hooton, ODFW
Washington	Steve Leider, WDFW
British Columbia	Tim Slaney, NPIC
Alaska	Art Schmidt, ADF&G

Session 3: A Case Study of a Stock in Decline - Oregon's North Umpqua River

Status review and the case for listing	Orlay Johnson, NMFS
State agency perspective on the listing	??
Forest industry perspective on the listing	John Palmisano, consultant
The public stake in the listing	Willa Nehlsen, PRC
Current research on the stocks	Dave Loomis, ODFW
The coastwide status review: prospects and consequences	Garth Griffin, NMFS

Session 4: (Option 1) A Roundtable Discussion

Conservation Groups

Sport Anglers and Recreationists

Resource Managers

Industry

Federal Government

Session 4: (Option 2) Contributed Papers: Biology, Management, and Conservation

A series of 15-minute papers, with 5 minutes of discussion each, on topics volunteered

Session 5: Restoration and Recovery: What Do We Know, and What Do We Need to Know?

Where are we coming from: an historic perspective on cutthroat trout	??
The role of land management: past, present, and future	Gordon Reeves, USFS
Instream habitat enhancement	Ron Ptolemy, BC Min. of Env.
	Mario Solazzi, ODFW
What is the role for hatchery programs?	Eric Loudenslager, HSU
The role of angling regulation	??
Estuarine and ocean habitats: can they be managed?	??

Some Kind of a Wrap-up ??

* Kamchatka subsp. !

re Salvelinus – coastal cutts

Bernard, D.R., Hepler, K.R., Jones, J.D., M.E. Whalen and D.N. McBride. 1995. Some tests of the "migration hypothesis" for anadromous Dolly Varden (southern form). TAFS 124(3): 297-307.
– Prince William Sound – Cube Ck. – Feb... Mar catches 10-15 mi. along shore in sea – by sport anglers – overwinters in sea!
→ long migration – northern form. DeCicco, A.L. 1992. Long-distance movements of anadromous D.V. between Alaska and the USSR. Arctic 45: 120-123. – Open Ocean! – Tagged Wulik R. – recapture > 1000 mi. – [struck] in Anadyr B. – across Bering Sea near St. Lawrence Is. . * – overwinter * open ocean migration (Northern form).

. . Trotter. 1989. TAFS 118: 463-73

Johnston, J.M. 1982. Life history of anadromous cutthroat trout with emphasis on migratory behavior. Pages 123-127 in E.L. Brannon and E.O. Salo (eds.), Proc. of salmon and trout migratory behavior symp. Univ. Wash., Seattle.
(overwinter in ocean?)

S. Kimura,
Department of Fisheries
Faculty of Agriculture,
Kyushu University 46-04
Fukuoka, 812, JAPAN

Dr. Behnke –
Sent 5/6 AM
To Japan
airmail
Thanks,
Sodie

PAR AVION

8.12g

Prof. R. J. Behnke,
Department of Fisheries & Wildlife Biology,
Colorado State University, Ft. Collins,
Colorado 80523, U. S. A.

S. Kimura,
Department of Fisheries,
Faculty of Agriculture,
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8.12g

Prof. R. J. Behnke,
Department of Fisheries & Wildlife Biology,
Colorado State University, Ft. Collins,
Colorado 80523, U. S. A.

緘

Preface

1st ¶ ? should endangered species act ? be capitalized (first ¶)
ask Dryer
yes - capital.

- 2nd line 2nd colum - man'd (s)

p. 9 - mid summer one word.

p. 12 - remove period after scrap.

18 so = to
Aslo = Also

19 off-chenell = off-chanell

22 cutthroat (x) rainbow trout — replace w/ and

- good!

- Cutt. — Mon. graph. 215 p.
- book simplified - direct - action
instructive, guidebook.

Cutt - so much of trout in general, virtually
nothing (except coastal 2nd cutt, behavior sharply diff. steelhead as

* So much more genetic infl. behavior, feeding, preferred habitat

ex. - Trafeirn - Selnubie S. R. cutt -

Intra specif. dif. - subsp. . . .

Three of the sets of would vary in what on sp - Cover essentially all trout - brown, brook, rainbow

- strongest common denominator of all - flow -

~ some pt
10%

/

Dept. of Fish & Wildlife Biol.
Colorado State University
Fort Collins, CO. 80523
14 May 1981

Dr. Theodore Pietsch
College of Fisheries
Univ. of Washington
Seattle, WA. 98195

Dear Dr. Pietsch,

One of my graduate students, Bryan Pierce, will be working in Washington this summer. His research on the cutthroat native to Lake Crescent requires, among other things, that he compare the current population with specimens collected in the past in order to determine the degree of hybridization present. Thus, I would be pleased if you would allow him access to whatever museum specimens you may have from this lake. The use of microscope and lab facilities on the several occasions he would need them would obviate removal of specimens from the premises.

Thank you very much for your time and effort.

Sincerely,

Dr. Robert J. Behnke

16 May 81

Dear Dr. Behnke,

Please save my final till I get back. Here is your copy of Tomasson's M.S. thesis. There is a copy of a letter to the head taxonomist at the U. of W. It would have a lot more clout if you sent it & not me. If it needs changing, correct & send to:

310 Fogarty
Port Angeles, WA. 98362

Otherwise ~~please send~~ to the address given on it. Pietsch doesn't let anyone, but his grad students into the collection that I know of.

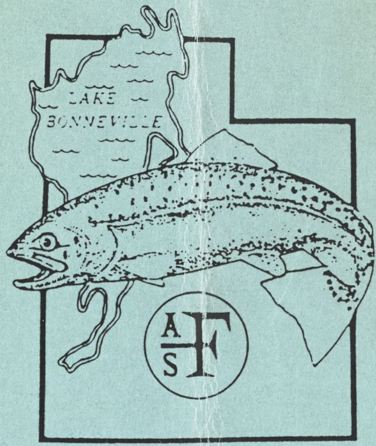
Thanks,

Bryan Pierce

BONNEVILLE CHAPTER

Of the

AMERICAN FISHERIES SOCIETY



20th ANNUAL MEETING

February 8 and 9, 1983

A. Ray Olpin Union Building
University of Utah
Salt Lake City, Utah

AGENDA

TUESDAY, FEBRUARY 8

8:00 Registration

9:00 Opening Remarks, Chuck McAda

9:15 Taxonomic Problems in *Chasmistes* and *Gila*. Dr. Gerald Smith, University of Michigan.

10:00 Cytogenetics of Bonneville Basin and Colorado River *Gila*. Mark Rosenfeld, U of U.

10:25 Spawning Ecology and Larval Development of the June Sucker. Dennis Shirley, UDWR. Springville.

10:50 Electrophoretic Analysis of Cutthroat Trout Subspecies in Selected Waters. Mark Martin, BYU.

11:15 Break

11:30 Recent Estimation Methods of Interest to Fisheries Biologists. Dr. Dave Anderson, USU.

11:55 Business Meeting

1:00 Social Hour

2:30 Banquet

Maynard Reece
Iowa Fish and Fishing

WEDNESDAY, FEBRUARY 9

8:30 Angler Satisfaction with Rainbow Trout Parasitized by Anchorworm. George J. Babey and Dr. Charles R. Berry Jr., USU.

8:55 IFG Data Analysis for Instream Flow Determination. Bill Geer, UDWR.

9:20 The Cutthroat Trout of Bear Lake, Utah-Idaho. Bryce Nielson, UDWR.

9:45 Niche Widths for Three Genera of Western Caddisflies: Parapsyche, Arctopsyche, and Hydropsyche. Dr. Fred A. Mangum, USFS, and Dr. Robert N. Winget, BYU.

10:10 Break

10:25 Population Dynamics of Threadfin Shad in Lake Powell, Utah-Arizona, 1977-82. Tom Pettengill and Wayne Gustaveson, UDWR.

10:50 Management of Winterkill Lakes with Artificial Aeration. Dr. Robert Summerfelt, Iowa State University.

11:15 Fisheries of the Provo River. Charles Thompson, UDWR.

11:40 Preference and Avoidance of TDS Concentrations by Endangered Colorado River Fishes. Richard Pimentel and Dr. Ross Bulkley, USU.

12:05 Lunch

1:05 Winter Losses of Trout in the Green River Below Flaming Gorge Dam. Bruce Bonebrake, UDWR.

1:30 Prey Selection by Intensively Reared Larval Walleye. Greg Raisanen, UDWR.

1:55 Response of a Trout Stream to Habitat Modifications. Dr. Robert N. Winget, BYU.

2:20 Ecology of Naturalized and Introduced Stocks of Brook Trout in Henrys Lake, Idaho. Bob Spateholts, Idaho State University.

2:45 Break

3:00 Short Term Results From Two Transplants of Bonneville Cutthroat Trout. Dale Hepworth, UDWR.

3:25 Alimentary Canal Development of Larval Walleye and Yellow Perch. Carrie Raisanen and Greg Raisanen.

3:45 Macroinvertebrate Drift Above and Below an Underground Culvert. Dean L. Sessions and Dr. Robert N. Winget, BYU.

4:10 Brown Trout Perception of Ultraviolet Radiation and Possible Influence on Distribution. Terrence Lee, USU.

COLLEGE OF NATURAL RESOURCES

UMC 52

Utah State University

Logan, Utah 84322

Department Wildlife Science
(801) 750-2459

5 March 1983

Dr. Robert J. Behnke
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, CO 80523

Dear Bob,

Sorry for not getting back to you sooner regarding some questions you asked in you letter to me in February. Enclosed is a program for the Bonneville Chapter meeting of the AFS. At this meeting I heard several very good papers regarding cutthroat trout (See papers by Mark Martin, Bryce Nielson, and Hepworth--separate papers). There will be a proceedings of the meeting that Chuck Berry will edit. I believe the papers are due in to him by mid-April and I would guess that they will be distributed by mid-summer. You can contact Chuck about that and request a copy as I am sure you will find much of interest in those papers.

My ichthyology class had no field trips and did no collecting. The ichthyology collection here is not a carefully cared for museum collection, mainly barely satisfactory for teaching, however, given its small size, it wouldn't take long to search through the collections for something--about one hour.

Utah is a gold mine for an ichthyologist. There is a dearth of publications on the native fishes of the state, other than the Gila. I'll send you a copy of the report that I organized from the students in Ichthyology class. We worked on 24 native fishes. That will be in the mail within a week.

Best wishes,

Bob

Bob Summerfelt

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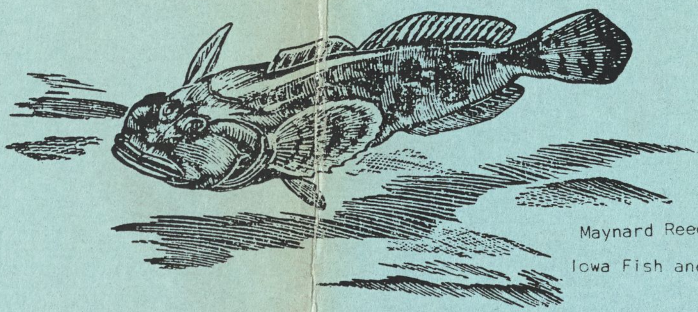

Maynard Reece

Iowa Fish and Fishing

Department of Fishery and Wildlife Biology

Colorado State University
Fort Collins, Colorado
80523

9 August 1978

Mr. Don Campton
Washington Cooperative Fishery Unit (WH-10)
University of Washington
Seattle, WA 98195

Dear Don:

Many of the questions you raised in your letter are frequently asked by fisheries people (but not so exhaustively) and to provide a source of information on western trout classification and biology I am currently writing a monograph on western Salmo for the USFWS. I was editing the section on the coastal cutthroat trout when your letter arrived. I will incorporate some of your observations into the manuscript. When my coastal cutthroat write-up is typed, I'll send you a copy along with the first section of the monograph which contains some arguments for better genetic management you might use to help sell your ideas.

The first point of taxonomic confusion, your work might settle concerns the two races of coastal cutthroat trout, observed by Leonard Schultz when he was at the University of Washington in the 1930's. Schultz frequently mentioned a coarse-scaled cutthroat trout (ca. 125-135 scales in lateral series) and a "normal" cutthroat trout (>150 scales), both inhabiting the Puget Sound drainages. I have never examined specimens of the "coarse-scaled" Puget Sound cutthroat, but I believe Schultz' specimens are in the University of Washington collection. Could Schultz' coarse-scaled cutthroat be the rainbow x cutthroat hybrid you are finding? If so, the hybridization has been going on for some time. Have you seen the specimens which Schultz considered as coarse-scaled cutthroat and compared them with the specimens you consider as hybrids?

My familiarity with coastal cutthroat trout is essentially limited to collections I made with the late P. R. Needham in 1957 from California to Alaska. I did come across occasional hybrid specimens, but "pure" cutthroats were always found in the same collection. That is, it appears that although hybridization does sometimes occur, natural selection favors the maintenance of two discrete groups rather than one intermediate hybrid swarm (as typically occurs in interior waters where rainbow trout have been introduced). In general, I would assume that where hybridization is more common between historically coexisting rainbow trout and coastal cutthroat trout, it has been stimulated by stocking of hatchery trout and/or environmental disturbances. Concerning fertility of hybrids, there is no published literature documenting rainbow x cutthroat fertility, but Gordon Hartman (now at Univ. Guelph) wrote his M.S. thesis at Univ. British Columbia (1958) on hybridization between coastal cutthroat trout and interior "Kamloops" rainbow trout (which is actually a redband trout according to my classification). Thus, it would be expected that the two parents differed by 10 chromosomes (2N = 58 and 68). Hartman only had time to study the F_1 generation for his thesis (hybrids actually had slightly better survival than pure parent crosses). He has since told me that F_2 and F_3 hybrid generations were produced with no observable loss of viability. I once had hatchery rainbow x interior cutthroat hybrids produced in Colorado and again we got slightly better hatch on the hybrids than with the pure parents. We made an F_2 hybrid generation but lost the fish due to water problems. From long experience with western trouts, I have no doubt that there is no significant reduction in fertility in hybrid combinations between rainbow trout, interior cutthroat trout, Gila trout and Aapche trout. If there was, there wouldn't be the problem of threatened and endangered western trout.

If you have some surplus specimens to send to me, you can preserve them in 10% formalin for about two weeks and then package them damp, sealed in plastic bags for mailing.

The area where steelhead trout (redband steelhead) and interior cutthroat trout have historically coexisted is the Salmon and Clearwater drainages (tributaries of the Snake River). Domestic hatchery rainbows have been stocked by the millions over the years in these drainages and they have hybridized with the native cutthroat trout in many streams.

I also recall a situation in tributaries to the Adriatic Sea in Yugoslavia and northern Italy where a species of trout, Salmo marmoratus, lived with a native S. trutta. When "non-native," hatchery brown trout were stocked, they initiated hybridization with S. marmoratus.

As I recall, the Washington Game Department maintained two broodstock lakes with interior cutthroat trout. The origin of one of the brood stocks was reputedly from Priest Lake, Idaho (a typical westslope cutthroat). The other, according to the letter from the person shipping the specimens, was of uncertain origin but they believed they originally came from Lake Chelan. When I saw the specimens I immediately recognized them as typical westslope cutthroat. When the ice dam of glacial Lake Missoula broke, a torrential flood swept across Washington, forming the present scablands. The westslope cutthroat trout, S. c. lewisi, could have been dispersed via the flood. The only native (?) cutthroat trout described from the scabland country is S. eremogenes and it appears to be the round-spotted, "Yellowstone" type of cutthroat trout which I recognize as S. c. bouvieri. I suspect that the specimens sent to me of reputed Lake Chelan origin are in reality the Priest Lake cutthroat. Have you ever seen the native cutthroat trout of Lake Chelan? Are there specimens in the University collection? If so, what do they look like?

Can you list the number of gene loci differences you have found in all of the different groups of trout you have examined and sketch a rough approximation of relationships (a "cladogram") based on your data? You mentioned differences at 4 loci between rainbow and coastal cutthroat (are all alleles species specific or are some shared at these loci?). Fred Allendorf recently wrote that he has assessed 50 loci and the most divergent group he found, with 8 distinct loci, is the Yellowstone cutthroat trout. He found very few (2-3?) unique loci between rainbow trout, westslope cutthroat trout and coastal cutthroat trout. Obviously, something is wrong here. The other tazonomic characters, karyotypes, and zoogeography all argue against the phylogeny indicated from Allendorf's data.

The following is a list of my graduate student's theses, written on trout:

Hickman, T. J. 1978. Systematic study of the native trout of the Bonneville basin. M.S. thesis: 122 p.

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Sekulich, P. T. 1974. Role of the Snake River cutthroat trout (Salmo clarki subsp.) in fishery management: 102 p.

Trojnar, J. R. 1972. Ecological evaluation of two sympatric strains of cutthroat trout: 59 p.

Wernsman, G. 1973. The native trouts of Colorado: 57 p.

You may have a problem finding a suitable job as a geneticist with a M.S. degree. Virtually all state and federal fishery positions which start with a M.S. degree are for general fisheries biology, fish management oriented jobs. Being with the Cooperative Unit program you should be in touch with federal jobs through the "green sheets." Gary Reinitz, who received a M.S. degree at the Univ. Montana a few years ago with an electrophoretic study of cutthroat trout did get a job with the fish genetics lab (USFWS) at Buelah, Wyoming, but he is now at Spearfish, South Dakota (nutritional lab), and is no longer involved with his original work.

I would advise that you try to "sell" yourself as a general fisheries biologist with special skills in genetics which could be useful to an agency.

Unfortunately, for almost all state fishery jobs and most federal jobs hiring at the M.S. level, to the people doing the hiring, very bright and specialized applicants are looked on as ivory tower academicians, out of touch with the real world. In my opinion, the "real world" of fisheries management is in need of change, but my opinion won't help you get a job.

I will keep alert to any possibilities that endangered species monies might be available in Colorado which could provide an opportunity for you to pursue your interests in a Ph.D. program.

I recently received an excellent M.S. thesis from Mr. Craig Busack of Univ. Calif., Davis, on Paiute trout. If you haven't seen it, I believe it would be of interest to you. Also, I believe, Eric Loudenslager, who just completed an M.S. thesis on cutthroat trout gene loci at the Univ. of Wyoming, is at Davis. You should find your visit to Davis a stimulating experience.

Give my regards to Fred Utter and show him the draft of my incomplete monograph.

Sincerely,

Robert Behnke

+ incl. copy
Col. R. paper
+ Lohnston
others

Mr. Don Campton
Washington Coop. Fish. Unit (WH-10)
University of Washington
Seattle, WA 98195

(address large envelope to contain ca. 75 p. ms.)

Dear Don:

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Schreck
Wernsman
Trojnar
Cerculins
Roscoe
Murphy
Hickman

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(7)

Sekulich, P. T. 1974. Role of the Snake River cutthroat trout (Salmo clarki subsp.) in fishery management; 102 p.

Trojnar, J. R. 1972. Ecological evaluation of two sympatric strains of cutthroat trout; 59p.

Wernsman, G. 1973. The native trouts of Colorado: 57 p.

You may have a problem finding a suitable job as a geneticist with a M.S. degree. Virtually all state and federal fishery positions which start with a M.S. degree are for general fisheries biology, fish management oriented jobs. Being with the Cooperative Unit program you should be in touch with federal jobs through the "green sheets". Gary Reinitz, who received a M.S. degree at the Univ. Montana a few years ago with an electrophoretic study of cutthroat trout did get a job with the fish genetics lab (USFWS) at Buelah, Wyoming, but he is now at Spearfish, South Dakota (nutritional lab), and is ~~not~~ no longer involved with his original work.

I would advise that you try to "sell" yourself as a general fisheries biologist with special skills in genetics which could be useful to an agency.

8

Unfortunately, for almost all state fishery jobs and most federal jobs ~~a~~ hiring at the M.S. level, ~~than~~ to the people doing the hiring, very bright and specialized applicants are looked on as ivory tower academicians, out of touch with the real world. In my opinion, the "real world" of fisheries management is in need of change, but my opinion wont help you get a job.

I will keep alert to any possibilities that endangered species monies might be available in Colorado which could provide an opportunity for you to pursue your interests in a Ph.D. program.

I recently received an excellent M.S. thesis from Mr. Craig Busack of Univ. Calif., Davis, on Paiute trout. If you haven't seen it, I believe it would be of interest to you. Also, I believe, Eric Loudenslager, who just completed an M.S. thesis on cutthroat trout gene loci at the Univ. of Wyoming, is at Davis. You should find ~~a stimulating~~ your visit to Davis a stimulating experience.

Give my regards to Fred Utter and show him the draft of my incomplete monograph.

Sincerely,

Robert Behnke

Washington Cooperative Fishery Research
Unit (WH-10)
University of Washington
Seattle, Washington 98195
July 31, 1978

Dr. Robert J. Behnke
Department of Fisheries and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80521

Dear Dr. Behnke:

I have wanted to write you for quite awhile but I am only now finding the time to compose a letter. I have read many of your papers and am very much interested in your work concerning the taxonomy, evolution and management of the threatened and endangered trouts native to western North America.

I first became aware of your work through my own research. I am currently working towards a master's degree in fisheries at the University of Washington. For my thesis, I am determining the genetic structure of "sea-run" cutthroat trout (Salmo clarki clarki) populations in the Puget Sound region. Starch-gel electrophoresis is the method by which I am collecting genetic data on these populations. Identifying genetically-distinct stocks of wild cutthroat and establishing their baseline allele frequencies are the primary purposes of my thesis. Future work will be concerned with estimating the genetic contribution made by hatchery-reared cutthroat to the natural production of wild fish. As you have probably already guessed, Dr. Fred Utter is my major professor.

Dr. Behnke, my work has revealed something quite surprising which I think will be of interest to you. Coastal ("sea-run") cutthroat trout and steelhead trout are apparently hybridizing in nature to a much greater extent than anyone has ever previously suspected; i.e., hybridization does not appear to be a "rare" event as the literature indicates. Salmo gairdneri and S. clarki clarki can be easily distinguished electrophoretically; the two species possess different common alleles at four of the 30 loci which I regularly assay. Consequently, I can unambiguously distinguish a coastal cutthroat from a steelhead trout. This electrophoretic identification is not limited by the size of the specimen; it works equally well for fry (25-75mm) as with juveniles and adults. My work would obviously have little merit if I could not electrophoretically distinguish these two species because they coinhabit the same streams in western Washington. Morphologically, the two species are indistinguishable at the fry level of development. I have, however, electrophoretically analyzed a substantial number of fish which I could not classify as belonging to one or the other species; these fish overwhelmingly appeared to possess a mixed steelhead-cutthroat ancestry. I have electrophoretically examined over 4000 cutthroat (coastal) and more than 1000 steelhead and am therefore well acquainted with the kinds of intraspecific genetic variation present at the molecular level in these two species. Those fish which electrophoretically appeared to be hybrids possessed unique genotypes which would be virtually impossible to produce by matings within one of the species alone. Furthermore, these "hybrid-looking" fish were most often collected from those stream areas where the cutthroat and steelhead spawning habitats appeared to intergrade and overlap. In virtually every trout sample in which I electrophoretically found hybrids, I also found "pure" fish of both species. In the upstream samples, however, I collected nothing but pure cutthroat. In the downstream samples, I collected nothing but pure steelhead. This finding agrees completely with our expectations; steelhead prefer to spawn in the larger, swifter flowing stream areas whereas cutthroat spawn almost exclusively in the smaller, tributary creeks. In addition, many field biologists in Washington have told me that the spawning habitats of the two species overlap considerably. Therefore, I do not believe that geographical segregation of preferred spawning habitat provides a complete barrier to hybridization between steelhead trout and coastal cutthroat trout. Furthermore, a large portion of these hybrid specimens appeared to be two or three generations removed from the initial hybrid mating; these "F2" or "F3" hybrids were genetically showing the effects of segregation and independent assortment of alleles.

In addition to the relatively large number of "age-zero" hybrids I have found, I have also collected some juveniles which I electrophoretically classified as hybrids. Dr. Behnke, would you be interested in examining the meristic characters of these juveniles? I freeze my samples rather than "pickle" them in order to preserve the biochemical activities of the enzymes which are assayed during electrophoresis. I could pull these juvenile carcasses out of the freezer and mail them to you in formalin. I would be very much interested in your findings.

Discovering these naturally-produced, steelhead-cutthroat hybrids has significant management implications. Steelhead trout and coastal cutthroat trout evolved different spawning times which originally did not overlap to any great extent; sea-run cutthroat spawn from late January to early March whereas coastal steelhead spawn from mid-March to mid-May. However, in an effort to produce hatchery stocks of steelhead which smolt in their first year, hatchery personnel have, for several years, been artificially selecting steelhead for early maturation. As a result, the spawning times of many steelhead stocks now overlap considerably with the natural spawning time of sea-run cutthroat trout. Furthermore, in an effort to increase steelhead run sizes, management agencies are now talking about stocking steelhead smolts into the small creeks and streams which have, in the past, been predominantly the domain of cutthroat. The literature asserts that only behavioral differences in spawning time and preferred spawning habitat have prevented mass hybridization between these two species; steelhead and coastal cutthroat are thought to be completely compatible genetically. If these assertions are, in fact, true, then I believe that our steelhead management practices could conceivably be stimulating natural hybridization. Although the possibility of Salmo clarki clarki becoming a threatened (or endangered) species seems extremely remote, it does seem possible that many pure cutthroat populations could be eliminated through interspecies hybridization with introduced steelhead. What are your thoughts on this matter, Dr. Behnke? I would greatly appreciate your comments.

You have mentioned in several papers, Dr. Behnke, that steelhead (or rainbow)-coastal cutthroat hybrids are completely fertile. I do not mean to challenge your statements, Dr. Behnke, but how do you know that hybrids are completely fertile? To my knowledge, no one has ever performed a controlled breeding experiment designed to measure the viability and fertility of hybrids relative to the pure parental species for any of the western trouts. Could you please provide me with any data or references you may have regarding the genetic compatabilities of the various species belonging to western North America Salmo

I have proposed to the Washington State Department of Game a series of experiments which would help us to understand the mechanisms which are preventing mass hybridization between steelhead trout and sea-run cutthroat trout. Performing a controlled hybridization breeding experiment is one of my proposals. Using many of the same arguments presented in this letter, I have had some difficulty convincing the Game Department of the necessity to perform these experiments. They have difficulty seeing how these academic experiments will help them to more effectively manage steelhead and cutthroat trout. Perhaps you could provide me with some additional arguments which are more persuasive.

In one of your papers, you mentioned that steelhead trout and one of the inland cutthroat subspecies naturally coexisted without hybridizing. However, mass hybridization occurred when hatchery rainbows were introduced. Could you please elaborate on this observation? I would very much like to see the documentation or a reference which describes hybridization occurring only after the hatchery rainbows were introduced. Were the introduced fish a domesticated rainbow stock or a hatchery-reared steelhead stock?

I read somewhere that you thought west-slope cutthroat may have occurred as far west as Lake Chelan and perhaps that Yellowstone cutthroat recently inhabited the eastern slopes of the Cascades. Perhaps some data I have may interest you. The Washington State Department of Game maintains a broodstock of our inland cutthroat subspecies for airplane stocking of "high lakes." The source of this brood is Twin Lakes, a pair of lakes about 20 miles northeast of Lake Wenatchee. The cutthroat residing there are natives; the lakes serve as a sanctuary and are closed to angling. Every year, biologists hike into the lake and trap mature adults heading upstream to spawn. The biologists hand-spawn the trapped adults and then pack out the water-hardened eggs. I electrophoretically compared a sample of this Twin Lakes broodstock to samples of west-slope and Yellowstone cutthroat provided to me by Fred Allendorf. I know that the west-slope sample came from the Jocko River hatchery and I believe the Yellowstone sample did also. In any event, the Twin Lakes stock <u>is definately</u> a west-slope cutthroat. West-slope cutthroat and Yellowstone cutthroat are electrophoretically as different from one another as either is from a coastal cutthroat and so subspecies identification is virtually without error. Perhaps cutthroat native to the subalpine areas in the Deschutes River drainage of eastern Oregon are of the Yellowstone variety.

My thesis work with coastal cutthroat and steelhead trout has "spawned" a great interest in all of the western trouts. I am particularly interested in the geographical distribution, systematics and management programs concerning all subspecies of the inland cutthroats. I would very much like to see a map which outlines the original (before man) and current geographical distributions of all inland cutthroats. I am not quite sure where one "draws the line" demarcating the distributions of west-slope, Yellowstone, "fine-spotted" Snake River, Colorado River and Bonnevile cutthroat. Is the Bonnevile cutthroat now extinct? Are west-slope cutthroat and Yellowstone cutthroat considered to be different subspecies? To which fish does the subspecies name <u>lewisi</u> refer? What is the scientific name for the other subspecies (the one that is not <u>lewisi</u>)? I've seen in the literature <u>S</u>.<u>c</u>. <u>lewisi</u> refer to both west-slope and Yellowstone cutthroat.

I would appreciate very much, Dr. Behnke, any information you could provide me regarding the biology and management of the inland cutthroats. Dr. Richard Wallace at the University of Idaho has informed me that you maintain a small library of unpublished mimeos which summarize our current knowledge about the trouts native to western North America. Do you have any spare copies of those √ check mimeos which you could send to me? Could you also send me a bibliographic list of Colorado State, graduate-student theses which have dealt with biology and management problems of the inland cutthroats?

Dr. Behnke, you may be wondering why I desire so much information regarding the inland cutthroats? Well, aside from my academic interests, I hope to eventually work with these fishes as a professional biologist. My career goal is to work as a "fisheries geneticist." I want to apply genetic principles and methodologies to fish management problems. I would particularly like to become involved with endangered species programs and work with the threatened and endangered trouts in the western United States. I believe that electrophoretic and karyological techniques (I will be learning the latter in the laboratory of Dr. Graham Gall at U.C. Davis later this summer) can be directly applied to identifying pure cutthroat populations and evaluating the genetic impacts which introduced species have had upon the native stocks. Unlike many students in fisheries, my interest in genetics is not a superficial one; I received my bachelor's degree in genetics from the University of California, Berkeley. I will be completing my master's thesis in fisheries by December of this year and will subsequently be seeking full-time employment. Although Dr. Utter wants me to continue my studies for a Ph.D., I would rather work for at least two years as a professional fisheries biologist/geneticist before I decide to pursue a doctoral degree. I am currently thinking in terms of employment with either a state fish and game agency or the U.S. Fish and Wildlife Service. Dr. Behnke, perhaps you can help me. Do you know of any future openings with either the U.S. Fish and Wildlife Service or the Colorado Division of Wildlife which might require somebody with my skills and background. Is the Colorado Division of Wildlife now using genetic techniques in its cutthroat restoration programs? If the C.D.W. is not using genetic techniques, do you personally think they could benefit by employing a biologist trained in electrophoretic and karyological methods? Alternatively, would the U.S.F.W.S. or C.D.W. be interested in supporting a graduate student to genetically identify pure cutthroat populations in the Rocky Mountain and intermountain regions? I am asking you this last question because you are one of three professors under whom I would want to study when and if I decide to pursue a Ph.D. degree. Dr. Behnke, would you be interested in supervising a student with my background? How do you think I would fit into a Ph.D. program in the Fisheries and Wildlife Department at Colorado State University? I realize that answering these questions is difficult without seeing my file and previous work, but your opinions would be greatly appreciated.

Thank you for taking the time to read this lengthy letter. I am hoping to receive answers to my many questions as soon as your time permits.

Sincerely yours,

Don Campton

Don Campton

Don Campton
Washington Cooperative Fishery Research Unit (WH-10)
University of Washington
Seattle, Washington 98195

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Coastal Cutts.

hybrids Puget Sound

Dr. Robert J. Behnke
Department of Fisheries and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80521

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High frequency of translocation heterozygotes in odd year populations of pink salmon (*Oncorhynchus gorbuscha*)

R.B. Phillips[1] and A.R. Kapuscinski[2]

[1] Department of Biological Sciences and Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, WI and
[2] Department of Fisheries and Wildlife, College of Forestry, University of Minnesota, St. Paul, MN

Abstract. The pink salmon (*Oncorhynchus gorbuscha*) has a rigid two year life cycle so that populations spawning on the even years do not hybridize with populations spawning on the odd years. Examination of the chromosomes of two populations from an even year (1986) and four populations from an odd year (1987) showed that all individuals from the even year populations had a diploid number of 52, considered the normal number for the species, while a high frequency of individuals in each of the odd year populations sampled from Washington State to Alaska were translocation heterozygotes with a diploid chromosome number of 53. The chromosome involved in the translocation was the seventh metacentric pair containing the NOR (nucleolus organizer region) adjacent to the centromere. In two populations a simple fission of this chromosome has produced individuals with 53 chromosomes with two acrocentrics replacing the metacentric chromosome, with the larger acrocentric having the NOR adjacent to the centromere on the long arm. In the other two populations individuals with 53 and 54 chromosomes were found in which the acrocentric with the NOR has undergone an inversion so that the NOR is now on the short arm of a small submetacentric chromosome. In one population all of the individuals with 53 and 54 chromosomes were of this type, while in the other case both forms were found. Because these two populations are adjacent to each other in the middle of the range sampled, the rearranged chromosome probably had a single origin.

Although it has been assumed that the normal diploid number of pink salmon (*Oncorhynchus gorbuscha*) from western North America and eastern Asia is 52 (Simon, 1963; Muramoto et al., 1974; Phillips et al., 1986), some individuals with 53 chromosomes were found in Lake Superior in 1985 and 1986 (Phillips and Kapuscinski, 1987) and in a population from Kamchatka, U.S.S.R., in 1979 (Gorshkov and Gorshkova, 1981). The extra chromosomes in these two populations were different, however, with one of the acrocentrics from the Lake Superior fish having undergone an additional rearrangement, producing a small submetacentric chromosome. The Lake Superior fish were derived from fish stocked in 1956 from a 1955 spawning of the Lakelse, British Columbia stock. Because pink salmon have a rigid two year life cycle, populations spawning on even years do not hybridize with those spawning on odd years. Electrophoretic studies have shown that odd year populations in Asia and North America are more alike than odd and even year populations from the same stream (Aspinwall, 1974). Because both cases of fish with 53 chromosomes were from odd year populations, we decided to investigate the chromosome number in several odd year Pacific Coast populations including the founder Lakelse stock. In this paper we report the results of karyotyping representatives from four odd year stocks and two even year stocks.

The translocation involves the chromosome pair with the nucleolar organizer region, which is the seventh largest metacentric chromosome pair (Phillips et al., 1986). This pair can be identified either with silver staining or with chromomycin A_3 (CMA_3) staining because CMA_3 stains the nucleolar organizer regions in many fish and amphibian species (Schmid, 1982; Phillips and Ihssen, 1985; Amemiya and Gold, 1986). Fish with 53 or 54 chromosomes are also readily identified with Giemsa staining, because there are no acrocentrics in the normal karyotype with 52 chromosomes, but fission of the metacentric results in two acrocentrics in some populations and one acrocentric and one submetacentric in the populations with the rearranged chromosome.

Materials and methods

Adult pink salmon were collected and gametes obtained from several different populations in 1986 and 1987 (Fig. 1). The even year populations sampled included Auke Bay and Indian River, Alaska. The odd year populations sampled included Hood Canal, Washington; Lakelse, British Columbia (founder stock for Lake Superior fish); Indian River, Alaska; and Prince William Sound, Alaska. Unfertilized gametes from each of these populations were collected and shipped to Milwaukee on ice where single crosses were made using gametes from each parent twice.

Embryos were dissected from fertilized eggs, incubated in culture media with 25 µg/ml colchicine, and fixed as described previously (Thorgaard et al., 1981; Phillips and Zajicek, 1982). Slides were made using the method of Kligerman and Bloom (1977). Slides were stained with silver nitrate using the method

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Request reprints from Dr. Ruth B. Phillips, Department of Biological Sciences and Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, WI 53201 (USA).

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Life Histories and Precocity of Chinook Salmon in the Mid-Columbia River

James W. Mullan

U.S. Fish and Wildlife Service
Fisheries Assistance Office
Leavenworth, Washington 98826, USA

Anne Rockhold

U.S. Fish and Wildlife Service
Leavenworth National Fish Hatchery
Leavenworth, Washington 98826, USA

Carol R. Chrisman

U.S. Fish and Wildlife Service
Fisheries Assistance Office
Leavenworth, Washington 98826, USA

Abstract.—We review available information on the phenomenon of precocious sexual development in stream-type (spring run) male chinook salmon (*Oncorhynchus tshawytscha*), provide some new data, and suggest implications. Females consistently outnumber males about 3:2 in adult returns of stream-type chinook salmon to the mid-Columbia River. No selective harvest occurs. Sex ratios of juveniles favor males. Precocious parr experience more deaths than nonmaturing juveniles, which leads to more females than males among returnees from the ocean. Precocious maturation of males is characteristic of both hatchery and wild stocks. Rapid growth in hatcheries may result in a large increase in precocious males. This could be one factor in the low survival (0.16–0.55%) of stream-type chinook salmon from mid-Columbia River hatcheries.

Two behavioral forms account for much of the diversity in the life history of chinook salmon (*Oncorhynchus tshawytscha*). Fish of the stream-type or spring run (Gilbert 1913), typical of Asian populations, northern-latitude populations, and headwater tributary populations in temperate North America, spend one or more years in fresh water before migrating to sea. These fish perform extensive offshore migrations and return to their natal stream in the spring or summer, several months before spawning. Ocean-type or summer–fall runs ("sea-type"; Gilbert 1913) typify populations on the North American coast south of 56°N. Ocean-type chinook salmon migrate to sea during their first year of life, spend most of their ocean life in coastal waters, and return to their natal stream in late summer or fall, a few days or weeks before spawning (Healey 1983, in press).

Precocious maturation of male stream-type chinook salmon is common, suggesting that it is characteristic of this behavioral form (Healey 1983, in press). Examination of 3,443 juveniles from the Lemhi River, Idaho, showed that precocious development existed in 2.6% of the sample (Gebhards 1960). Rich (1920) noted 10–12% precocious males in the McCloud River, California. Precocious males constituted about 1% of 20,000 wild chinook salmon examined in tributary streams of the mid-Columbia River 1983–1988 (J. W. Mullan, unpublished).

Sexual maturation of salmon is considered precocious when it occurs any time before normal maturation in the ocean. We review available information on the phenomenon in stream-type chinook salmon, provide some new data, and suggest implications, particularly with regard to hatchery propagation.

Methods

We examined for precocity 757 age-0 chinook salmon from Leavenworth (Washington) National Fish Hatchery (NFH), 1,033 age-0 naturally produced chinook salmon from nearby Icicle Creek, and 3,248 yearling chinook salmon studied for smoltification (W. Zaugg, National Marine Fisheries Service, personal communication) at Leavenworth NFH and other Columbia River hatcheries. Samples mostly were divided into males and females as well as precocious males. Precocious age-0 chinook salmon were identified by huge testes or (in summer) running sperm, or both; precocious yearlings were identified in spring by gonadal development, the presence of sperm, or both. During summer, we also examined 175 age-0 to age-2 chinook salmon that had not migrated to the ocean after release from Leavenworth NFH in spring.

Results

Females consistently outnumber males about 3:2 among adult stream-type chinook salmon returning to the mid-Columbia River (Mullan 1987). There is no selective harvest.

Our analysis shows sex ratios that favor males for stream-type chinook salmon juveniles at Leavenworth NFH (Table 1; chi-square tests, $P < 0.01$). Independent determinations of sex ratios in studies of smoltification confirm our observations that males predominate at Leavenworth NFH, but not necessarily at other Columbia River hatcheries (Table 1).

Although sample sizes were small, precocious males made up a greater percentage of the fish that died at Leavenworth NFH in September 1988 (5.7%) than they made up in the general population (1.4%) (Table 1). Mortality of hatchery fish is rarely explicitly documented. Thus, a yearling chinook salmon cohort examined in spring before release may have already sustained substantial mortality of precocious males the previous fall. Age-0 chinook salmon examined in fall at Leavenworth NFH included a higher percentage of males (56–63%) than the same brood-year fish examined in spring 1989 (55%) (Table 1).

Sex ratios (male : female) for 257 migrant fish from 27 June to 5 September 1989 (47:53) and 182 resident fish from Icicle Creek, 11 October 1989 (69:31) (Table 1) suggest that mostly males remained and females migrated by October. There was little migration of age-0 chinook salmon in Icicle Creek after June in 1988. Fifteen (24%) of 63 resident fish on 12 August, and 43 (77%) of 56 migrants from 8 August to 15 September were precocious males. However, none of the 67 resident fish from 20 September to 7 October were precocious, suggesting that precocious males were very numerous up until the time they either died or migrated (Table 1).

On 4 August 1989 we removed the following

TABLE 1.—Sex ratios and precocious males in groups of juvenile stream-type (spring-run) chinook salmon.

Location and stock[a]	Sample size	Type of sample[b]	Age	Date sampled	Males: Total	Males: Precocious	Females	Male : female ratios
Hatchery cultured								
Leavenworth NFH	121	Random	0	21 Sep 1988	71	1	50	59:41
	120	Random	0	21 Sep 1988	75	0	45	63:37
	120	Random	0	26 Sep 1988	67	2	53	56:44
	105	Mort	0	21–27 Sep 1988		6		
	120	Random	0	15 Apr 1989	66		54	55:45
	120	Random	0	31 May 1989	66		54	55:45
	51	Mort	0	24 Apr–31 May 1989	32		19	63:37
Hatchery cultured (Zaugg[c])								
Leavenworth NFH	805	Random	1	3 Mar–14 Apr 1989	443	106[d]	362	55:45
Carson NFH	273	Random	1	Spring 1978	137	31	136	50:50
	179	Random	1	Spring 1984	106	21	73	59:41
	210	Random	1	Spring 1985	90	16	120	43:57
	223	Random	1	Spring 1986	136	30	87	61:39
Marion Forks[e]								
Willamette stock	193	Random	1	Spring 1978	95	17	98	49:51
Carson stock	238	Random	1	Spring 1978	138	35	100	58:42
Dworshak NFH	456	Random	1	Spring 1989	233	67	223	51:49
	210	Random	1	Spring 1990	102	21	108	49:51
Warm Springs NFH	281	Random	1	Spring 1989	124	30	157	44:56
	180	Random	1	Spring 1990	87	10	93	48:52
Wild								
Icicle Creek	63	Resident	0	12 Aug 1988		15		
	56	Migrant	0	24 Aug–16 Sep 1988		43		
	67	Resident	0	20 Sep–7 Oct 1988		0		
	257	Migrant	0	27 Jun–5 Sep 1989	120	0	137	47:53
	240	Migrant	0	7 Sep–31 Oct 1989		7		
	168	Resident	0	10 Aug 1989		4		
	182	Resident	0	11 Oct 1989	125	14	57	69:31

[a] NFH = National Fish Hatchery.

[b] Sample types: random = random sample, 10 fish from 12 raceways selected by chance; mort = hatchery mortality; resident = fish from a controlled section of Icicle Creek; migrant = fish from a smolt trap below controlled section of Icicle Creek.

[c] Fish examined by W. Zaugg, National Marine Fisheries Service, in studies of smoltification.

[d] No huge testes typical of spawning season but gonadal development was obvious, sperm was present, or both.

[e] Oregon State Hatchery.

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RESEARCH SECTION

Oregon Department of Fish and Wildlife

A Review of Literature and Unpublished Information on
Cutthroat Trout **(Salmo clarki clarki)** of the Willamette Watershed

A Review of Literature and Unpublished Information on Cutthroat Trout *(Salmo clarki clarki)* of the Willamette Watershed

Jay W. Nicholas

Oregon Department of Fish and Wildlife

February 1978

This work was partially funded by the U. S. Fish and Wildlife Service, through Dingell-Johnson funds, Project F-94-R.

INTRODUCTION

"I am convinced that the management of a wildlife species must rest upon an adequate understanding of the biology of that species." This statement, referring to a proposed study of coastal cutthroat trout *(Salmo clarki clarki)*, is just as true today as when it was written over 30 years ago (Dimick, R. E. letter to J. P. Miller, March 13, 1943). Contemporary management of this species in the Willamette watershed is, however, still based largely on assumption and tradition, with a minimal amount of reliable documented information.

The Oregon Department of Fish and Wildlife is currently initiating a study to answer questions that will shift management options to a less speculative base. The purpose of this report is to document the current state of knowledge about cutthroat trout in the Willamette River watershed by summarizing known published and unpublished material on the subject.

Cutthroat trout in the Willamette watershed above the falls at Oregon City are apparently not anadromous. This conclusion is based on a belief that the falls originally were impassable during the typical upstream migration period for anadromous coastal cutthroat trout and the fact that they have not been observed passing through the fishway at the falls (William Day, personal communication). Some of these trout exhibit migration tendencies, however, and there is nothing to suggest that these (inland) coastal cutthroat differ markedly from their anadromous relatives. Thus it will be useful for the reader to review discussions of Dewitt (1954), Scott and Crossman (1973), Giger (1972), Johnston and Mercer (1976) and Sumner (1972, MS) for a broad overview of the anadromous stocks.

SOURCES OF INFORMATION

The following potential sources of published and unpublished information were investigated during the review:

1. Thesis Library, Oregon State University, Corvallis
2. District Fisheries Biologists, Oregon Department of Fish and Wildlife (ODFW)
3. Research Section, ODFW, Corvallis
4. Northwest Regional Office, ODFW, Corvallis
5. Environmental Management Section, ODFW, Portland
6. U. S. Bureau of Land Management Offices, Oregon
7. U. S. Forest Service offices, Oregon
8. R. E. Dimick, Professor Emeritus, Oregon State University, Corvallis
9. Dr. Carl E. Bond, Professor, Department of Fisheries and Wildlife, Oregon State University, Corvallis
10. Scientific literature published in national journals

RESULTS

Life History Characteristics

Spawning time

Various reports suggest that cutthroat trout in the Willamette system generally spawn between January and July; trout entering tributaries of the valley floor may spawn earlier than those entering higher elevation Cascade slope tributaries. Henry Reed reports (personal communication) that Long Tom stock cutthroat at Leaburg Hatchery normally spawn in mid-January. Hansen (1955) and Wetherbee (unpublished data) found cutthroat trout in Lewisburg (Mountain View, Berry and Soap creeks spawning from January through March. Nicholas (unpublished data) found spent cutthroat in low elevation tributaries of the North Fork of the Middle Fork Willamette in early April and gravid, unspawned trout in higher elevation tributaries in late May. Wyatt (1959) reported spawning activity of cutthroat trout in small tributaries of the McKenzie watershed from late March through early June. Wetherbee (unpublished data) observed a "large run" of cutthroat trout jumping at a dam on the lower Marys River on November 7, 1955. He trapped 32 upstream migrant cutthroat trout from November 8-10 and on the last day observed 65 trout attempting to leap over the dam in a 10-minute period.

Dr. C. E. Bond (personal communcation) believes that most cutthroat trout spawning in tributaries of the Luckiamute system move upstream in November and drop back to the Willamette River by late March. He relates that his students seined large spent cutthroat trout (up to 41 or 46 cm TL) from Oak Creek in early April in the 1940's. It is probable that the timing of cutthroat trout spawning in the Willamette watershed is dictated in individual tributaries by water temperatures and runoff patterns.

Spawning location

It is generally believed that cutthroat trout utilize many of the smallest tributaries for spawning. Dimick and Merryfield (1945), Wyatt (1959) and Wetherbee (unpublished data) have observed Willamette watershed cutthroat trout spawning in very small tributaries (14.2-28.3 l/sec). The absence of reports of cutthroat trout spawning in larger tributaries does not preclude their use of these sites.

Fecundity

There are few reports on the fecundity of cutthroat trout in the Willamette watershed. Nicholas (unpublished data) and Wetherbee (unpublished data) have documented the fecundity of several small trout (Table 1).

Table 1. Fecundities of Willamette watershed cutthroat trout, as reported on the North Fork of the Middle Fork Willamette River (Nicholas, unpublished data) and Lewisburg Creek (Wetherbee, unpublished data).

Length (cm)	Egg Number	Location
11.4	41	North Fork Middle Willamette
13.2	81	North Fork Middle Willamette
13.4	114	North Fork Middle Willamette
16.0	119	North Fork Middle Willamette
19.1	80	Lewisburg Creek (Mountain View Cr.)
22.8	157	Lewisburg Creek (Mountain View Cr.)

Egg retention has not been studied in detail but Nicholas (unpublished) data) reports that out of 66 spent female cutthroat trout examined from the North Fork of the Middle Fork of the Willamette River, only four had retained eggs and fewer than 10 eggs were retained by each trout. Although the fecundities of trout reported here are low, they represent females of small size. Larger females will logically have higher fecundities, but such information has not been documented for wild cutthroat trout in the Willamette watershed. Cutthroat trout (Long Tom) held at Leaburg Hatchery have an average fecundity of 500-700 eggs at age III and approximately 1,300 eggs at age IV. These trout are approximately 30 and 41 cm long, respectively (Henry Reed, personal communication).

Homing to small tributaries

Wyatt (1959) reported cutthroat trout moving into the same small tributary in two successive years. Johnston and Mercer (1976), in a review of sea-run cutthroat life history, found that cutthroat trout generally home to their parent stream, but that a variable amount of straying occurs. It is not known to what degree each tributary stock constitutes a discreet spawning population in the Willamette watershed.

Hybridization

There are no reported studies of hybridization between cutthroat trout and other salmonids in the Willamette watershed. Hybridization between cutthroat and rainbow trout *(S. gairdneri)* is possible here because both species are present (native or introduced) in many streams. The F_1 generation is viable (Needham and Gard 1959; Dimick, unpublished data) and might backcross with either parent species. However, it is believed that hybridization between *S. clarki clarki* and *S. gairdneri* is largely circumvented by spatial and/or temporal segregation of spawning; cutthroat trout in Oregon generally spawn earlier and in smaller tributaries than sympatric rainbow trout (Sumner 1972 MS; Dimick and Merryfield 1945).

Hybrids may be mistaken for rainbow trout. Experimental crosses of sea-run cutthroat and steelhead at the Alsea Hatchery in the early 1940's resulted in hybrid offspring that phenotypically resembled rainbow trout. The mean lateral line scale count was 124 (n = 14), cutthroat "slash" marks were absent in 81% (n = 16), hyoid teeth were absent in all (n = 16) and the maxillary extension was absent in 81% (n = 16) (Dimick, unpublished data).

Fry emergence and movement

Little work has been conducted on cutthroat trout fry in the Willamette watershed. Aho (1977) found that fry emerge earlier in an unshaded section of Mack Creek (McKenzie River) than in a shaded section, probably due to warmer water temperatures in the former location. Wyatt (1959) found small numbers of fry moving downstream in several small tributaries to Lookout Creek from June through November, although most movement took place early in the period. His trapping on small tributaries indicated that fry from the upper portions did not reach Lookout Creek and that fry entering Lookout Creek originated in the lower 91 m of the tributaries. No relationship was apparent between the number of gravid migrants in small study tributaries and its corresponding fry production in this study.

Age/length relationships

Cutthroat trout that reside in cool headwater tributaries are generally smaller than trout which are found in the lower elevation tributaries and the Willamette River. Much of this size difference may be related to slower growth due to cooler water temperatures, lower food availability and limited space. However, differences in longevity, downstream movement of large trout, age of maturity, and inherent growth rates may also be contributing factors. Most of the available age-length data in the Willamette watershed is for small tributary trout (Table 2). Preliminary interpretation of scales collected from Willamette River cutthroat trout indicates that growth accelerates when the fish enter the main stem from the tributaries. It is interesting to note that Nicholas (1977) found that cutthroat in the Upper North Fork of the

Middle Fork Willamette were smaller than similar age rainbow trout from the same part of the stream (Table 3).

Table 2. Age specific length (cm) of cutthroat trout collected from several locations in the Wilamette watershed.

Location	Mean fork length (cm) by age[a] Age II+		Age III+		Age IV+		Source
Tributary 8 (Blue R.)	10.4	(18)	12.3	(8)	13.6	(4)	Wyatt (1959)
Mack Creek	12.0	(20)	14.2	(22)	15.1	(4)	Wyatt (1959)
Lookout Creek	12.7	(16)	15.6	(28)	19.6	(6)	Wyatt (1959)
N. Fk. Willamette (upper)	12.8	(124)	15.5	(105)	19.8	(22)	Nicholas (1977)
Mack Creek (shaded)	9.7	--	13.5	--	--		Aho (1977)
Mack Creek (unshaded)	11.9	--	15.8	--	--		Aho (1977)

[a]*Numbers of fish measured are in parentheses.*

Table 3. Age specific length of cutthroat and rainbow trout collected above river km 32 on the North Fork of the Middle Fork Willamette River in 1975 and 1976.

Species	Mean fork length (cm) by age[a] Age II	Age III	Age IV
Rainbow trout	14.1 (124)	18.3 (55)	24.1 (12)
Cutthroat trout	12.8 (124)	15.5 (105)	19.8 (22)

[a]*Numbers of fish measured are in parentheses.*

Age at maturity

Several workers have independently reported that some female cutthroat trout mature at age II and most are mature by age III (Wyatt 1959; Nicholas 1977; Henry Reed, personal communication). Dimick (unpublished data) noted that 20 and 90%, respectively, of 2- and 3-year-old anadromous female cutthroat trout were mature in the first hatchery generation at Alsea, Oregon. His results are almost identical to those I found (Nicholas 1977) working on the North Fork of the Middle Fork Willamette River, where male cutthroat trout matured at a younger age than females and the latter matured at a younger age than female rainbow trout (Table 4).

Table 4. Percent of mature trout in the North Fork of the Middle Fork Willamette River at each age.

Sex and Species	Percent mature by age[a]			
	II	III	IV	V+
Male cutthroat	59 (22)	92 (24)	100 (8)	100 (2)
Female cutthroat	19 (31)	86 (28)	90 (10)	-- (0)
Female rainbow	0 (47)	2 (42)	50 (14)	100 (3)

[a] *Numbers of trout examined are in parentheses.*

Migrations

It is certain that some cutthroat trout move upstream from larger streams into smaller tributaries from late fall through early summer. These movements are probably influenced by local water flow and temperature, and not all of these upstream migrants are maturing fish on a spawning run (Wyatt 1959; Wetherbee unpublished data). Immature upstream migrants have previously been noted in anadromous cutthroat trout populations (Jones 1975; Johnston personal communication).

Roy Sams (personal communication) noted a number of large (46-51 cm) cutthroat trout in a pool on East Dairy Creek (lower Willamette Valley) in late fall in the early 1960's. The pool had been seined weekly throughout the summer and had not previously contained large trout.

Wetherbee (unpublished data) tagged cutthroat trout in Marys River, Lewisburg Creek (Mountain View Creek), Berry Creek, and a tributary to Soap Creek. He noted that upstream migrants on the smaller tributaries were generally smaller than migrants on the lower portion of Marys River (Table 5). He surmised that most of the Marys River migrants had been rearing in the Willamette River while many of the migrants in small tributaries had reared in a larger tributary to the Willamette. There were subsequently five reported tag recoveries by anglers from these trout (Table 6).

Table 5. Number of upstream migrant cutthroat trout (by size group) trapped in four Willamette Valley streams (Wetherbee, unpublished data)[a].

	Number of trout by fork length (in.)											
Stream	6	7	8	9	10	11	12	13	14	15	16	17
Marys River	-	-	-	-	1	-	4	5	8	9	3	2
Lewisburg Creek[b]	-	2	2	6	4	5	1	1	-	-	-	-
Berry Creek	2	12	23	16	13	3	2	2	-	-	-	-
Soap Creek	-	2	8	-	-	2	-	1	-	-	-	-

[a] *Original data were recorded in inches (1 inch = 2.54 cm).*
[b] *Mountain View Creek.*

Table 6. Angler recoveries of upstream migrant cutthroat trout tagged in Willamette tributaries by Wetherbee (unpublished data).

Tagging		Recovery	
Location	Date	Location	Date
Lewisburg Creek[a]	1/25/55	Lewisburg Creek[a]	5/8/55
Berry Creek	1/31/55	Berry Creek	5/13/55
Lewisburg Creek[a]	3/28/55	Santiam River	Unknown
Marys River	11/9/56	Willamette River at Harrisburg	May 1957
Marys River	1/14/57	Willamette River at Harrisburg	4/14/57

[a] *Mountain View Creek.*

These limited observations suggest that upstream migrant cutthroat trout in Willamette tributaries may have reared in that same tributary, in the main stem Willamette, or in a major tributary on the other side of the valley.

Wyatt (1959) captured cutthroat trout moving in and out of small tributaries from November through June, although movements ceased when water temperatures fell below 3.3 C. He felt that cutthroat trout in

Lookout Creek were essentially non-migratory. He recovered about 15% of over 1,000 marked trout and found that 64.6% had moved less than 167 m. Aho (1977) reported similar results from a tagging study in Mack Creek where only 1% of 871 recovered trout had moved more than 100 m from the point of initial capture.

Disease resistance

It is suspected that there may be differences in resistance to diseases such as *Ceratomyxa shasta* among Willamette watershed cutthroat trout, but no experimental work has been done to test this hypothesis. Inherant differences in disease resistance, if any exist, could help define the genetic discreetness of cutthroat trout from various parts of the watershed. Such differences would have important implications in the potential use of cutthroat trout in hatchery programs. Baldwin et al. (1967) found that coastal cutthroat trout obtained from Cedar Creek Hatchery ranked relatively high in resistance to the salmon poisoning fluke *Nanophytus salmincola* when compared to several other salmonids.

Hatchery biology

Wild cutthroat trout were captured in the Long Tom River in 1966 for use as an egg source in hatchery programs. They were seined from the spill basin below Fern Ridge Reservoir, but probably originated from above the dam and were flushed out as the reservoir was drawn down in the fall. The trout, ranging from about 30.5 to 40.6 cm would not accept prepared food, were extremely excitable and injured themselves on the pond wall (Ralph Swan, personal communication).

A cutthroat trout brood stock from this source is currently maintained at Leaburg Hatchery, Leaburg, Oregon. Some females mature at age 2, but spawning of these fish was discontinued because of suspected low egg quality (fragility, low fertility, small size). The potential for use of eggs from 2-year-old females should not be ignored in the future, however. One group of fry from 2-year-old parents, which was ponded at extremely low densities, exhibited such remarkably improved growth, survival, and disease resistance that they were held for use as brood stock. Under current practices, however, eggs are presently stripped and discarded from 2-year-old females. Most females mature at age 3. Mortalities are approximately 10-12% as eggs, 10-12% as fry, and 25-30% as fingerlings. Overall, mortalities from egg to maturity are approximately 60-90%. Highest losses occur after the fish begin to feed and these result from bacterial gill disease, furunculosis, and adverse reactions to therapeutic treatments. Cutthroat trout appear to experience high mortalities when exposed to treatment concentrations which are routinely used with rainbow trout and chinook salmon (Henry Reed, personal communication).

Cutthroat trout also seem to require lower ponding densities than rainbow trout; they grow larger and have fewer disease problems when reared at relatively low densities. Cutthroat trout eggs have been hatched and the fry reared at Roaring River and Wizard Falls hatcheries with similar results. Fingerling cutthroat trout from this stock are currently being utilized in high lake and some reservoir stocking programs, but yearlings are not being used as a catchable product.

Approximately 5,000 brood fish are kept on hand at present. They are normally spawned in mid-January and the young hatch in May and are about 38 gr by the following May. There has not been a systematic selective breeding program on these trout.

Distribution

Cutthroat trout are found throughout the entire Willamette watershed (Willis, Collins and Sams 1960; Wetherbee 1976). They are the only native trout in tributaries draining the coast range but are found in sympatry with resident or anadromous rainbow trout in many tributaries draining the Cascades (Dimick, personal communication). There was a good sport fishery for cutthroat trout on the main stem of the Willamette River above Independence in the 1920's and early 1930's, but this fishery was later destroyed by pollution upstream as far as Eugene (Bond, personal communication). Water quality in the Willamette has improved since that time (Gleason, 1972), and cutthroat trout have since repopulated much of their former range. There is now a sport fishery of unknown magnitude upstream from Corvallis. It is not known how the present abundance of cutthroat trout in the Willamette compares with prepollution population levels.

In east side tributaries, where cutthroat reside with rainbow trout the former are generally most abundant in headwater and tributary areas. Nicholas (unpublished data) found that while rainbow and cutthroat trout were found together in the lower 63 km of the North Fork of the Middle Fork of the Willamette River, rainbow were numerically dominant in the lower river and cutthroat trout were more abundant in the upper river.

Detailed esimates of the distribution and abundance (actual or relative) of cutthroat trout in specific tributaries have not been made. However, ODFW district fisheries biologists are currently updating planning forms that describe the approximate distribution and abundance of resident trout in the

Willamette watershed (James Griggs, personal communication). In addition, various stream surveys have been conducted by U. S. Forest Service personnel and these provide some information on distribution and abundance of cutthroat trout.

Some of the stream surveys used an undefined combination of hook, net, and observation to estimate the abundance and size of cutthroat trout at, for example, between six and 50 trout from 2.5 to 30.5 cm long in a 30.5 m section of stream (stream surveys on file, Bureau of Land Management office, Eugene). On the other hand, the U. S. Forest Service surveyed a few Cascade streams (Willamette National Forest) from 1973-77, employing backpack shockers, mark and recapture population estimates, snd some standing crop weight estimates.

Abundance and Production

ODFW district biologists would like to have estimates of the abundance of cutthroat trout in Willamette watershed streams, expressed primarily as the number of legal sized (15 cm) trout per km. Sample data currently available (Table 7) reveals a range in the abundance of legal sized cutthroat trout from 6 to 197/km, with an average of 73/km (n = 15; 95% CI = 40/km - 105/km). The average per surface area is 0.009/m^2 (n = 11; 95% CI = .005/m^2 - .013/m^2). These values do not represent an unbiased estimate of the abundance of cutthroat trout in Willamette watershed tributaries. It would be more desirable and correspondingly more difficult to estimate population abundance in terms of biomass per unit of stream volume or surface area. This would permit comparison of productivities between different sized streams.

Table 7. Examples of the abundance of cutthroat trout larger than 15 cm in sections of several Willamette watershed tributaries[a].

Tributary (watershed)	Year	Length of stream sampled (m)	Abundance of trout larger than 15 cm: Per stream length no./m	Abundance of trout larger than 15 cm: Per stream area no./m^2	Sample method	Source
Elk Creek (Quartzville)	1975	91.5	0.164	--	Rotenone	Wetherbee (unpublished data)
Big Creek (Little N. Fk. Santiam)	1975	61.0	0.164	--	Rotenone	Wetherbee (unpublished data)
S. Tally Creek (M. Fk. Santiam)	1975	30.5	0.197	--	Rotenone	Wetherbee (unpublished data)
Tally Creek (M. Fk. Santiam)	1975	30.5	0.033	--	Rotenone	Wetherbee (unpublished data)
Budworm Creek (McKenzie)	1974	71.0	37/acre*	--	Shocker	Heller and Baker (1974)
Tidbits Creek (Blue River)	1974	234.7	151/acre*	--	Shocker	Heller and Baker (1974)
Rebel Creek (McKenzie)	1974	78.0	230/acre*	--	Shocker	Heller and Baker (1974)
Oliver Creek (Muddy)	1977	198.8	0.101	0.021	Shocker	Nickelson, T. E. (unpublished)
Ferguson Creek (Long Tom)	1977	266.6	0.026	0.007	Shocker	Nickelson, T. E. (unpublished)
Rock Creek (Marys)	1977	192.5	0.047	0.006	Shocker	Nickelson, T. E. (unpublished)
S. Fk. Rock Creek (Marys)	1977	156.8	0.006	0.001	Shocker	Nickelson, T. E. (unpublished)
Galena Creek (Quartzville)	1977	171.8	0.058	0.012	Shocker	Nickelson, T. E. (unpublished)
Elk Creek (Quartzville)[b]	1977	33.0	0.120	0.019	Shocker	Nickelson, T. E. (unpublished)
Elk Creek (Quartzville)[c]	1977	221.7	0.045	0.007	Shocker	Nickelson, T. E. (unpublished)
Mill Creek (McKenzie)	1977	270.3	0.067	0.009	Shocker	Nickelson, T. E. (unpublished)
Portland Creek (M. Fk. Willamette)[b]	1977	121.6	0.057	0.009	Shocker	Nickelson, T. E. (unpublished)
Portland Creek (M. Fk. Willamette)[c]	1977	57.0	0.088	0.008	Shocker	Nickelson, T. E. (unpublished)
Hehe Creek (M. Fk. Willamette)	1977	169.9	0.024	0.004	Shocker	Nickelson, T. E. (unpublished)

a *Values represent raw sample data except for expanded estimates which are indicated by *.*

b *Above falls.*

c *Below falls.*

Total annual production of cutthroat trout in Berry Creek was 0.49 g/m2, although younger age classes had higher values and older fish had negative production values (Nickelson, 1974). Warren et al. (1964) found that production in sucrose enriched sections of Berry Creek increased seven fold over values in unenriched sections.

Taxonomy

There are no reported studies on the taxonomic relationships between various stocks of cutthroat trout in the Willamette watershed. I x-rayed cutthroat and rainbow trout from the North Fork of the Middle Fork Willamette River and found little overlap in vertebral counts of the two species (Nicholas, unpublished data). Rainbow trout (n = 37) had an average of 63.7 vertebrae, with a range of 61 to 66. Cutthroat trout (n = 41), however, had an average of 61.1 vertebrae, with a range of 58 to 64. The only work identified on the taxonomic aspects of Willamette watershed cutthroat trout was by Dimick (unpublished data, Table 8).

Table 8. Characters typical of cutthroat trout in the Willamette system[a].

Character	Mean	Range	Standard deviation	n	Percent which exhibit characteristic
Laterial line scales	119.3	111-126	3.2	60	--
Scales above lateral line	35.5	30-43	3.0	59	--
Gill raker count	17.2	14-22	1.6	54	--
Pyloric ceca	36.4	25-52	5.6	46	--
Maxillary extension past posterior margin of eye	--	--	--	59	98
Hyoid teeth	--	--	--	61	100
External cutthroat markings	--	--	--	61	100

[a]*Samples were collected from Marys, Luckiamute, Pudding and Molalla rivers, the Coast Fork of the Willamette River and the main Willamette River (Dimick unpublished data).*

Scale analysis

Giger (1972) and Sumner (1972 MS) report the results of scale analysis on coastal cutthroat trout, which largely involved sea-run trout in coastal streams. Wyatt (1959), Aho (1977) and Nicholas (1977) aged cutthroat trout from Cascade tributaries and calculated mean age specific lengths of those fish (see section on "Age-length relationships"). Hansen (1955) found both "stream" and "river" circuli on the scales of cutthroat trout over 25 cm in Berry and Lewisburg creeks. Preliminary viewing of scales from cutthroat trout collected in the McKenzie, Santiam, and Willamette rivers revealed that many individuals had 2 or 3 years of closely spaced circuli followed by 1 or more years of widely spaced circuli. This pattern may be caused by migration of cutthroat trout from small nursery tributaries into larger streams.

Cutthroat scales are more difficult to handle and read than those from rainbow trout because they are smaller and have fewer circuli in each yearly increment. Rainbow trout in the North Fork of the Middle Fork Willamette River generally had from 12-20 circuli per year, while cutthroat trout had from four to nine circuli. The annulus was also more easily distinguishable on the rainbow trout scale (Nicholas, unpublished data). Future studies which age cutthroat trout by scale analysis should describe the quantitative and subjective criteria by which age determinations are made.

Contribution to sport fisheries

Systematic sampling of angler catches has generally only been conducted on streams which receive large plants of legal size hatchery trout. The results of non-systematic creel checks by district field personnel and State Police game officers are summarized annually and available, by district, as a computer printout from the ODFW Portland office. However, they are not useful to monitor catch trends or make comparisons among streams. District planning forms contain largely unsubstantiated estimates of angler use and harvest on many tributaries. The vast majority of streams in the Willamette watershed which are not stocked support sport fisheries of variable magnitude on natural populations of cutthroat trout. Nicholas (1977) conducted a systematic creel survey (opening day through September 1976) on the North Fork of the Middle Fork Willamette and estimated that native cutthroat and rainbow trout provided a catch rate of 0.229 and 0.257 trout/hr respectively. Many native cutthroat trout streams contain numbers of fish which are less than the present 15 cm (6 in) minimum size limit, that are mature 3-year-old fish. ODFW fishery managers are interested in determining if the health of these populations would be adversely affected by removing the minimum size limit.

Effects of stocking other species

There are no reported investigations on the effect of stocking other species on native populations of cutthroat trout in the Willamette watershed. Theoretically, the effects will vary depending on such variables as stock characteristics and developmental history of native and introduced fish, physical characteristics of the stream and stimulation of the sport fishery. Potential effects include the following: no effect, competition for some environmental requisite, hybridization (which may increase or decrease fitness), predation, introduction of disease, and increased angler harvest.

There is circumstantial evidence of a negative impact from coho salmon and steelhead trout because cutthroat populations are more abundant in some stream areas above falls which exclude these species (Nickelson, personal communication). McIntyre (1970) compared the production in an experimental section of Berry Creek, of juvenile coho salmon, cutthroat trout, and both species combined. He found that cutthroat trout production was lower when they were together with coho, but that total production was higher in the dual species section. He also found that cutthroat trout in the dual species section occupied riffle areas that were vacant when coho were absent, thus suggesting that competitive interactions resulted in more complete habitat utilization.

DISCUSSION

It is likely that there are at least three general life history patterns exhibited by cutthroat trout in the Willamette watershed (Table 9). Averett and MacPhee (1971) demonstrated that fluvial and adfluvial cutthroat trout in the St. Joe River, Idaho could be differentiated on the basis of scale patterns and it is probable that type 2 and type 3 cutthroat trout in the Willamette system can be distinguished in the same manner. It is uncertain, however, whether spatial, temporal, or behavioral reproductive mechanisms keep these two types genetically distinct.

Man's activities frequently represent obstacles to the conservation of viable stocks of wild trout. These activities may be characterized in three basic categories: habitat alterations, depletion of stocks by angling, and introduction or enhancement of selected fish species. A basic understanding of the life history of cutthroat trout in the Willamette watershed will enable us to rationally evaluate the consequences of these activities in the future, and plan for effective fishery management.

Table 9. Description of three potential life history patterns of cutthroat trout in the Willamette watershed.

Type	Description
1.	Trout which are above impassable barriers and therefore constitute reproductively isolated populations. Any individuals which emigrate downstream past these barriers are removed from the population.
2.	Trout which are largely resident in the middle or upper sections of tributaries but are not isolated above barriers. The opportunity exists for some individuals to move downstream to rear and then return to spawn with individuals who did not move.
3.	Trout which are largely migratory. They emerge and rear for an undetermined length of time in small to medium sized tributaries, move downstream to the Willamette River or its largest tributaries (eg. Santiam, McKenzie) to mature, and then return to smaller tributaries to spawn.

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A SURVEY OF THE COAST CUTTHROAT TROUT, *SALMO CLARKI CLARKI* RICHARDSON, IN CALIFORNIA[1]

JOHN W. DeWITT, JR.
Humboldt State College
Arcata, California

INTRODUCTION

Although of restricted distribution and one of the least known trout of California, the Coast Cutthroat Trout, *Salmo clarki clarki* Richardson, occupies an environmental niche that has not yet been filled by any other fish. Probably because of its relative unimportance numerically, no general scientific studies have previously been made of this fish in California. Sumner (1948) has conducted intensive research into the life history of the coast cutthroat in Oregon. Very little has been published concerning it in the State of Washington, but Dymond (1928, 1932), Haig-Brown (1947), and Neave (1949), have contributed considerably to the knowledge of the fish in British Columbia.

With an allegedly declining population of coast cutthroat in California there is a need for definite information on this subspecies. The present paper is based on a study made during 1951 to determine its general distribution and status in the State, as the first step in the search for information on which to base its management.

DISTRIBUTION IN CALIFORNIA

In California the coast cutthroat is restricted mainly to the area bounded by the Eel River, the Oregon state boundary line, the Pacific Ocean, and the summit of the Coast Range (Figure 1). It has also been reported from tributaries of the Rogue River in California's Siskiyou County. Murphy and DeWitt (1951) established what appears to be the first definitive record of the cutthroat in the Eel River system. In that river system cutthroat have been found only in the main river, in tidewater, and in six small tributaries, all within 10 miles of the ocean.

From Eel River northward the distribution extends gradually farther inland. In the Klamath River drainage cutthroat have been taken about 20 miles inland. In the Smith River system they are common even in the headwaters, some 50 to 60 miles from the ocean.

The Smith River system is the most important coast cutthroat area. Virtually all sections of the river and its tributaries are known to contain or are reported to contain cutthroat (see Table 1).

[1] Submitted for publication January, 1954.

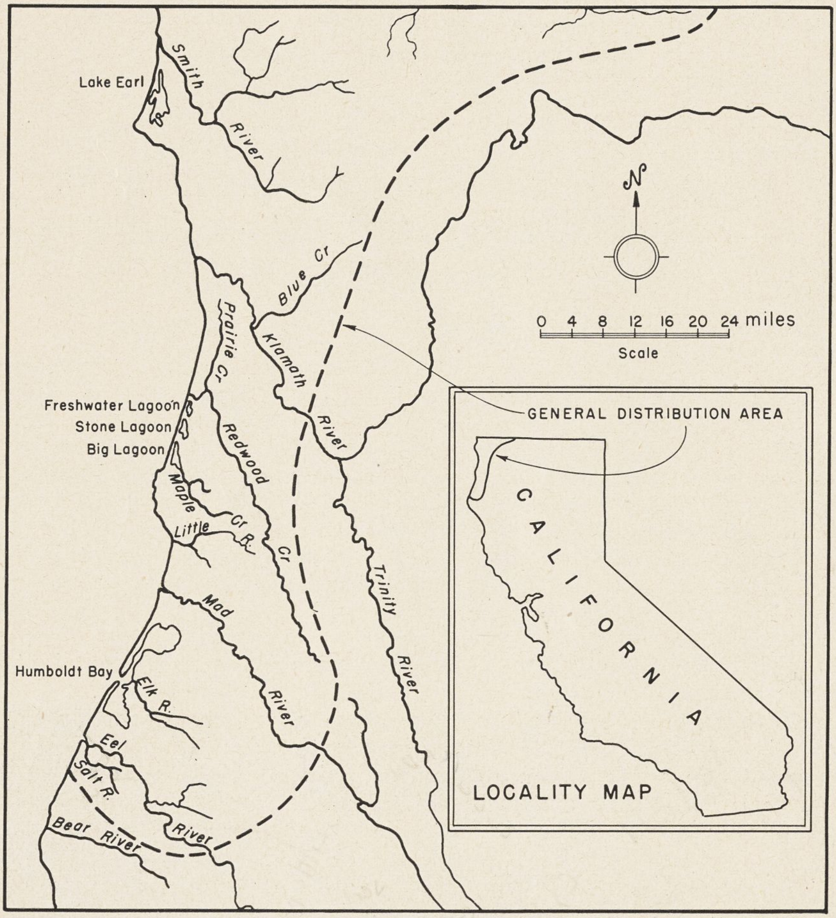

FIGURE 1. Map showing the range of the coast cutthroat trout in California.

DISTINCTIVE FEATURES OF THE COAST CUTTHROAT

The coast cutthroat in California is a slender fish (Figure 2), generally not as deep-bodied nor as large as its cousin, the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*), in the same waters. Few specimens weighing more than three or four pounds are taken, while the sea-going rainbow frequently exceeds 10 pounds.

The cutthroat may generally be distinguished from steelhead and other trout of the rainbow series by the presence of hyoid teeth and reddish or orange dashes on the throat, as well as by differences in body coloration.

The presence of hyoid teeth is one of the most reliable characters for distinguishing cutthroat from trout of the rainbow series. Rainbows lack these teeth. However, not all cutthroats possess them, as shown

TABLE 1

Waters Containing Coast Cutthroat Trout in California [1]

- Eel River—C
  - Salt River
    - Russ Creek—C
    - Reas Creek—C
    - Francis Creek—C
    - Williams Creek—C
  - Strongs Creek—C
  - Barber Creek—C
- Elk River—C
- Mad River—C
  - Mill Creek—C
  - Warren Creek—C
  - Lindsay Creek—C
  - North Fork Mad River—C
- Widow White Creek—R
- Clam Beach Lagoons—C
- Little River—C
- Luffenholtz Creek—R
- McNeil Creek—C
- Patrick Creek—R - Penn Ck.
- Big Lagoon—C
  - Maple Creek—C
- Stone Lagoon—C
  - McDonald Creek—C
- Freshwater Lagoon—C
- Redwood Creek—C
  - Prairie Creek—C
    - Lost Man Creek—C
- Klamath River—C
  - Panther Creek—R
  - Hunter Creek—C
  - Turwar Creek—R
  - Ah Pah Creek—C
  - Tectah Creek—C
- Wilson Creek—R
- Lake Earl—R
- Smith River—C
  - Rowdy Creek—R
  - Little Mill Creek—R
  - Mill Creek—C
  - South Fork Smith River—C
    - Goose Creek—C
    - Hurdygurdy Creek—R
    - Jones Creek—C
    - Fall Creek—C
  - Middle Fork Smith River—R
    - Patrick Creek—R
    - Jones Creek—C
    - Monkey Creek—C
    - Siskiyou Fork—R
  - North Fork Smith River—R
    - Diamond Creek—R
- South Fork Winchuck River—R

[1] C = Cutthroat trout collected during course of study; R = Cutthroat trout reported but not collected during study.

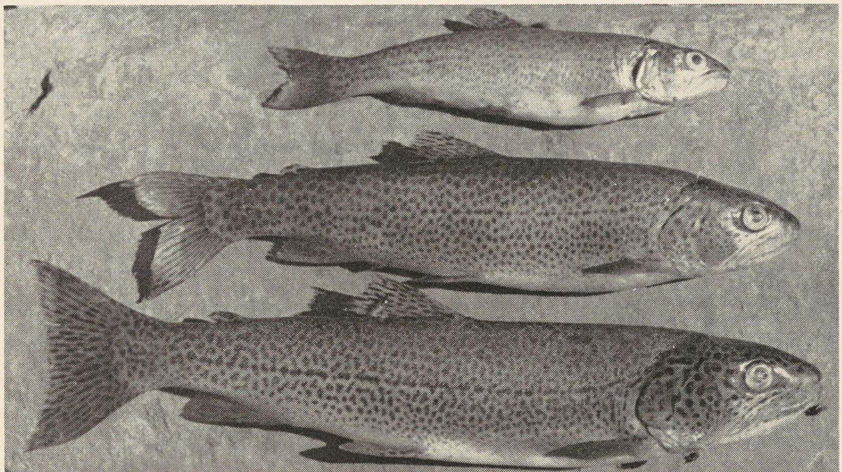

FIGURE 2. Three coast cutthroat trout from Monkey Creek, tributary to the Middle Fork of Smith River, Del Norte County, California. Largest specimen about 12½ inches long, fork length. *Photograph by John W. Westgate, August, 1951.*

by Dymond (1928) and others; and, as Miller (1950) points out, all trout having hyoid teeth are not pure cutthroat, for hybrids may have as many as six teeth.

Generally, the hyoid teeth are arranged in two rows meeting at either end, to form a boat-shaped pattern. Frequently, several more are located inside the two outer rows. The teeth are located on the basibranchial bones approximately between the first and second gill arches. They are deciduous and thus very easily scraped away or broken. The teeth are fang-shaped and usually point toward the back of the throat. In large specimens they may be seen easily with the naked eye or felt with the finger; in small individuals (two to three inches long) they may be readily located with the use of a microscope.

Seventy-nine specimens from nearly all sections of the range were examined. In 73 of these fish the number of hyoid teeth varied from 1 to 34. Most of the counts fell between three and nine, and the average number was 8.8. The counts were made with a binocular microscope under a bright blue light, using a very fine dissecting needle. The usual procedure, which required considerable care, was to count all teeth visible without disturbing the mucus covering over the tooth area. Then, after carefully removing the mucus, a second count was made. Often several teeth would be hidden by the mucus, giving an initial count lower than the actual number present. On occasion, however, during the removal of the mucus one or more teeth were lost, giving a higher initial count.

Nearly all cutthroat observed in this study possessed red, orange, or red-orange throat dashes. Several small specimens under four inches in length and one large tidewater fish did not have the dash. Dymond (1928) and Sumner (1948) also noted that at certain stages cutthroat may not have the red dash. A number of specimens, from Tectah Creek especially, had the general appearance of cutthroat, but instead of the red or orange dash possessed faint yellow or bronze streaks. These fish possessed other somewhat intermediate features and may have been cutthroat-rainbow hybrids.

There was great variation in coloration and an even greater variation in spotting. It was impossible to select any one specimen as a truly "typical" coast cutthroat which would represent all others in its general appearance.

Fish taken in or near tidewater areas were the most uniform in appearance. The most marked diversity occurred among those in small streams and in headwater areas.

The tidewater fish examined were usually more faintly spotted than specimens from other waters. They were often silvery in coloration. Among the upstream fish the spotting varied from profuse to scarce, and the spots ranged from rounded to irregular in shape. Even fish from the same part of a single stream sometimes differed strikingly in the spotting.

General coloration ranged from washed-out brown to brilliant blues and greens. Every specimen examined from the Eel River tributaries was a dirty-white color. In these the jaw dash was a faded orange or red-orange and the spotting on the back was indistinct. A number of Prairie Creek specimens possessed the same general features.

The most strikingly colored fish were those from several very small, clear creeks flowing directly into the ocean. These, as well as many from other areas, characteristically displayed predominantly red-orange pectoral, ventral, and anal fins. The bases of these fins were ordinarily greyish-white and the free margins milky-white. In other specimens, the pectoral fins were yellow, the ventrals red-orange, and the anals yellow and orange. The characteristic pattern among fish taken from murky waters was grey-white pectoral, ventral, and anal fins.

Diagonal rows of scales were counted along the second row above the lateral line within the standard length (measured from tip of snout to base of the center caudal fin rays) on 78 of the cutthroat examined. The mean count was 151.7. The range of the counts was 122 to 188. Approximately 80 percent of the values fell between 137 and 165. In referring to the coast form, Snyder (1908) stated that the scales in the lateral series of *Salmo clarki* vary generally from 140 to 170. In a later paper (Snyder, 1940), he listed the range as 160 to 200.

Pyloric caecum counts were made on 71 of the specimens examined. The mean number was 40.3. The extreme range of the counts was from 23 to 60; however, the majority were between 30 and 50. These values vary rather widely, thus extending the range given by Miller (1950), who gives the limits as 27 to 45.

LIFE HISTORY NOTES

In the fall and winter fresh sea-run cutthroat are taken in varying numbers from Redwood Creek and the Mad, Klamath, and Smith Rivers. Most of the fish are caught in September or October, usually after the first substantial rain. Only a few are taken from Mad River, with larger numbers from Redwood Creek and tributaries, and the Klamath. Very good catches of apparently sea-run fish are made in tidewater areas of the Smith, especially in the fall, winter, and early spring, but occasionally also in the summer.

Female cutthroat containing ripe or nearly ripe eggs have been taken from September to April. Spawning thus evidently occurs over a relatively long period. Small, newly emerged fry have been seen from March to June. In British Columbia, according to Dymond (1932), spawning occurs from February to May in the small streams. Dimick and Merryfield (1945) say that the migratory phase spawns in January and February in Oregon.

During the summer and early fall the cutthroat populations in coastal California streams consist ordinarily of fish of the year class 1 to and including mature fish that have spawned but have never gone to the ocean, plus a few sea-run individuals landlocked by receding water levels after spawning.

Log jams and natural falls block many streams at different points, preventing, at least in part, the migration of steelhead and salmon into the waters above. Almost pure or predominantly cutthroat populations exist in the sections above these barriers on a number of streams, while almost none are found below the barriers in the summer and early fall. Some of the fish above barriers are sexually mature although relatively small, usually under 10 inches in length.

Fish-of-the-year were taken only in the very smallest tributaries, usually in those with summer flows less than one cubic foot per second. Most of the cutthroat brood streams examined were too small to be named. Large cutthroat occur in many streams throughout the year; life histories of such individuals vary considerably.

In September of 1951 a 779-foot section of Prairie Creek was cut off by diverting the flow into an artificial channel. The cut-off section was seined, treated with rotenone, and reseined. The fish population collected was composed of sculpins (*Cottus* sp.) (72.7 percent), silver salmon (*Oncorhynchus kisutch*) (15.0 percent), steelhead (*Salmo gairdneri gairdneri*) (8.7 percent), stickleback (*Gasterosteus aculeatus*) (2.2 percent), cutthroat trout (*Salmo clarki clarki*) (0.9 percent), and king salmon (*Oncorhynchus tshawytscha*) (0.3 percent). The total number of fish of all kinds taken was 674. Scale readings of the nine cutthroat collected indicated that none had undergone any ocean or tidal growth. The ages of these fish varied from two to six years (Table 2). No cutthroat-of-the-year were found in the cut-off section.

TABLE 2

Length, Age, and Residence of Coast Cutthroat Trout From Prairie Creek Cutoff[1]

Fork length in inches	Number of stream annuli[2]	Calculated length at each annulus						Ocean or tidal growth
		1	2	3	4	5	6	
15.0	6	3.2	4.8	6.1	8.2	11.1[3]	13.4[3]	None
10.1	4	3.2	4.9	7.5	8.9	----	----	None
8.6	3	2.4	4.3	6.0	----	----	----	None
8.1	3	2.8	4.6	7.0	----	----	----	None
6.1	2	2.0	4.4	----	----	----	----	None
5.7	2	2.8	4.7	----	----	----	----	None
5.3	2	3.1	4.3	----	----	----	----	None
5.4	2	2.0	4.1	----	----	----	----	None
4.7	2	1.7	3.8	----	----	----	----	None

[1] Determinations by F. H. Sumner of the Oregon Game Commission.
[2] Not counting edge where annulus is partly formed in some samples.
[3] Spawning check.

SUMMARY

In California the Coast Cutthroat Trout (*Salmo clarki clarki*) is restricted mainly to the area bounded by the Eel River, the Oregon state boundary line, the Pacific Ocean, and the summit of the Coast Range. The Smith River system is the most important cutthroat area.

The cutthroat may generally be distinguished from steelhead and other trout of the rainbow series by the presence of hyoid teeth and reddish or orange dashes on the throat, as well as by differences in body coloration.

This form is extremely variable in California. Pyloric caecum counts range from 23 to 60; scale rows along the lateral line vary from 122 to 188; hyoid teeth vary from 1 to 34.

Fresh sea-run cutthroat are taken in varying numbers from the main streams within their California range during the fall and winter.

There are indications that some coast cutthroat do not migrate to sea and constitute resident, breeding populations.

Fish-of-the-year were found only in the very smallest tributary streams, usually those with summer flows less than one cubic foot per second.

ACKNOWLEDGMENTS

Thanks are extended to Leo Shapovalov of the California Department of Fish and Game and to Dr. Donald E. Wohlschlag of Stanford University for reading the manuscript critically and offering valuable suggestions during the course of study. John W. Westgate assisted the writer in making many trout collections.

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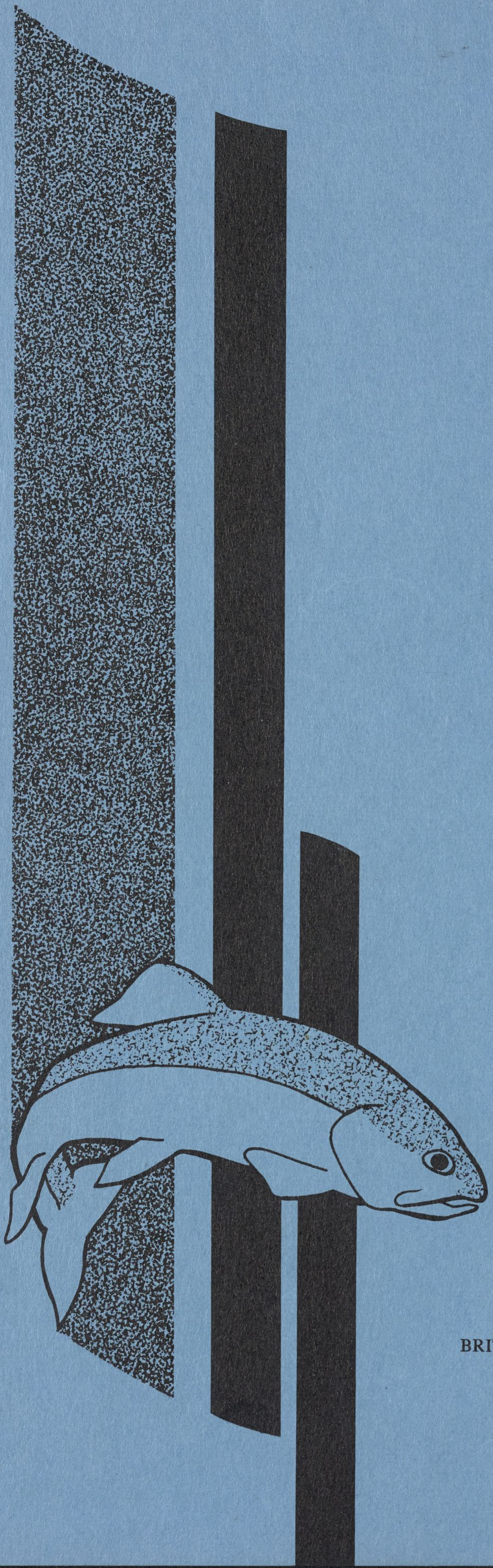

THE CUTTHROAT TROUT

by

Nils-Arvid Nilsson

Fisheries Technical Circular No. 7

1971

BRITISH COLUMBIA FISH AND WILDLIFE BRANCH

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PREFACE

This is the second in a series of publications resulting from a reciprocal exchange of fishery biologists arranged between the British Columbia Fish and Wildlife Branch and the Swedish Fishery Board during 1968 and 1969. Dr. Nils-Arvid Nilsson from the Institute of Freshwater Research at Drottningholm, Sweden joined our group for the spring and summer of 1969 to study the interactive ecology of cutthroat and rainbow trout in coastal lakes of British Columbia.

Shortly after his return to Sweden he gave a lecture to Swedish fishery managers, describing some interesting features of cutthroat trout ecology and reporting briefly on aspects of his research in British Columbia. Because his lecture is so delightfully instructive in an area which lacks information, it has been made available in our technical circular series. A more extensive account of his research on interaction between cutthroat and rainbow trout will be available shortly in an appropriate scientific journal.

T. G. Northcote

October, 1971

For some years there have been a couple of small stocks of the North American salmonid, the cutthroat (Salmo clarki) in Sweden. This species is closely related to the rainbow trout, but has many distinctive features, which can make it an interesting alternative in rotenone treated or other angling waters. At first sight the cutthroat bears a striking similarity to the rainbow trout, but closer inspection will disclose a number of distinctive differences.

In general the dark spots are more evenly distributed over the whole body than in the rainbow. The red band along the sides of the body, to which the rainbow trout owes its name, is also discernible on the cutthroat but is less clearly marked. The mouth is large, the upper jaw extending posteriorly some distance beyond the eyes, whereas in the rainbow trout it often does not go past them.

The cutthroat derives its name from a pair of red streaks along the throat on the under side of the head. On dead fish they are frequently not visible until the mouth is pryed open, when they shine like fresh knife wounds. These red streaks are thus a distinctive feature of the cutthroat (Fig. 1); in some cases, however, they are quite weak, or even absent altogether, and then one must rely on other identifying characteristics. One of the best is the teeth, which are larger and more complete in the cutthroat than in the rainbow trout. A simple check is to insert the index finger behind the tongue where, in the larger fish, several teeth can be felt, while in the small fish the surface feels like rough sandpaper.

Confusion in the identification of the cutthroat may arise because it can hybridize with the rainbow trout, with the result that one can find

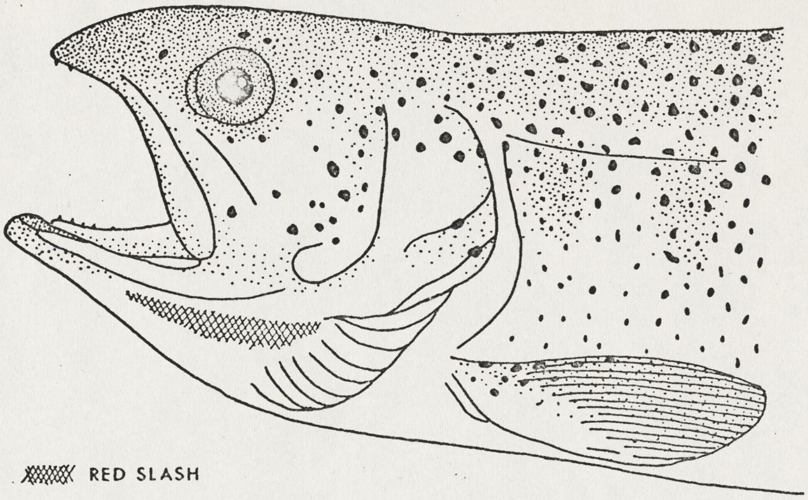

Fig. 1 The head region of a cutthroat trout with the mouth opened to expose the red slash area on its throat.

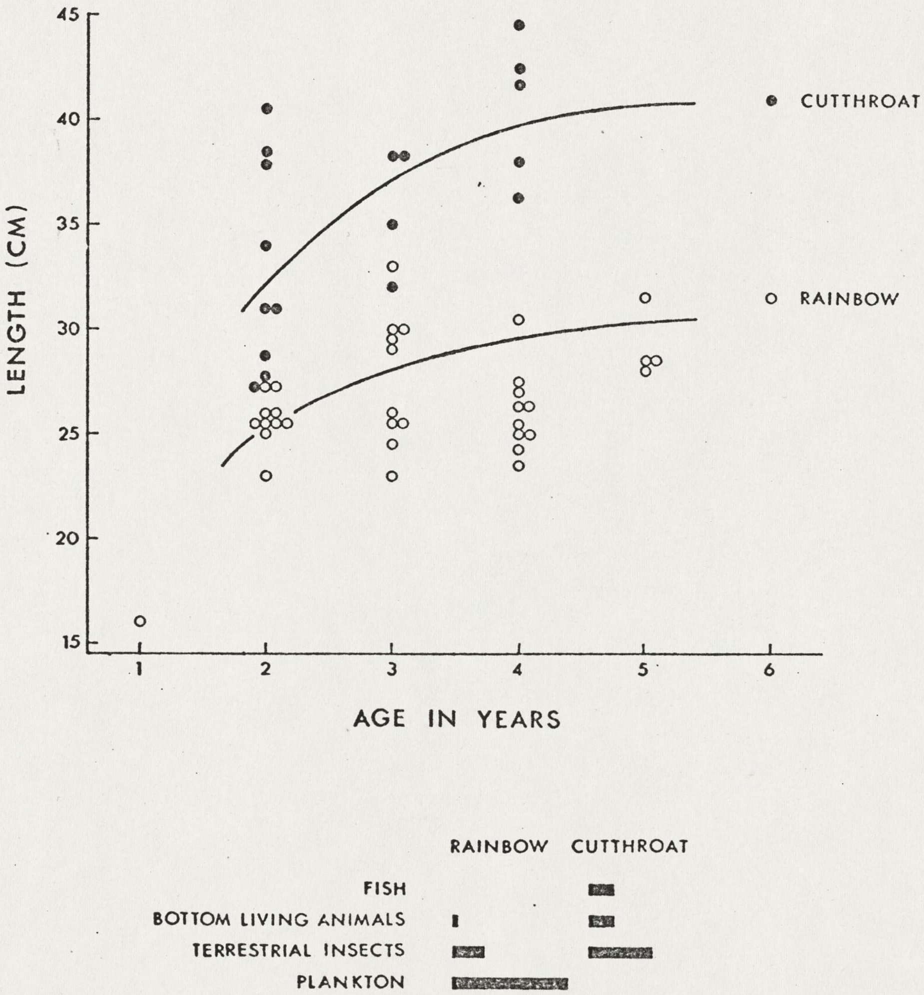

Fig. 2 Comparison of growth rate and food habits (relative contribution of major items, June 1951) of cohabiting coastal cutthroat and rainbow trout.

fish in which the red streaks are absent but with teeth behind the tongue, and vice versa.

Like the rainbow trout, the cutthroat can be both sea run and landlocked, but the two types are not distinguished by separate names. It is generally accepted that we are here concerned with a single species which, like the rainbow trout and the European brown trout, can migrate or remain in the river. The type of sea run or landlocked cutthroat found along the coast is usually distinguished from a different sub-species found deeper in the North American continent and known as the Yellowstone cutthroat. It is more densely spotted than the coastal sub-species, and has its centre in Montana along the Columbia and Missouri river systems, in southern Alberta and southeastern British Columbia. The coastal sub-species is found from northern California to southeastern Alaska. It is thought that the coastal sub-species survived the Ice Age in rivers of the Washington and Californian coastal region, while the Yellowstone sub-species was found in fresh water of the Montana area. When the ice receded they both spread northwards, but never came into contact with each other. They constitute typical examples of what are referred to as geographical races or sub-species. Other sub-species or species, have been identified in more southerly parts of western North America.

The cutthroat, like the rainbow trout, has long been cultured in America. It would appear to have been mainly the Yellowstone sub-species that were the ancestors of the vast numbers of cultured fish that have been released into the lakes and rivers over the years.

One of the first to conduct a scientific study of the profitability of planting cultured fish was the fishery biologist R. B. Miller, who carried out a most elegant series of experiments. In a small stream known as Gorge Creek, which contained a stock of wild cutthroat, Miller closed off certain reaches with nets so as to control the stock in them. He then planted three different categories of individually tagged and weighed cutthroat - some reared in ponds, some partly reared in running water, and the others wild. One stretch was also cleared first of native wild fish.

It was found that the planted wild fish survived best. It is true that they lost some weight at first, but only 10 per cent or so died. The second group (those partly reared in running water) did not fare so well, losing weight, if not actually dying, as 18 per cent of them did. The pond-reared group managed worst of all, losing greatly in weight while 35-85 per cent died (depending on their size when planted).

In the cleared stretch of the stream Miller obtained quite different results. Of the cutthroat bred in ponds and planted there, only about 15 per cent died, 10 per cent of them in the first 10 days. They did not lose weight but grew steadily throughout the period of the study.

Miller concluded from his study that it is rarely worth planting hatchery-reared fingerlings in streams already populated with a wild stock. By natural selection the latter are well adapted to the environment where they live and they will therefore defend their territory most effectively against encroachment.

Though the cutthroat is sometimes found alone in small lakes, they are more often in the company of one or more other species, commonly with the Dolly Varden char. This is an American west coast char which, when it lives together with the cutthroat, is often of a small size and spends the whole year in deep water. The cutthroat also is frequently found with the rainbow trout, and these two species likewise share the resources in a characteristic manner.

The two species are found together in both streams and lakes. Examining the distribution of young fish in 66 rivers on the coast of British Columbia, the two Vancouver biologists Hartman and Gill observed that the rainbow trout - in this case the sea run steelhead - claimed the large rivers while the cutthroat had to be content with small tributaries or streams with a catchment area of less than 15 km^2. Rivers dropping steeply to the sea generally contained rainbow trout, while the cutthroat dominated the rivers where a steep upper reach was followed by slow-moving stretches through marshland. Where the two species were found in the same river it was always the cutthroat that was predominant in the uppermost reaches. In general, the evidence indicates that in streams the rainbow trout dominates the cutthroat. Because the latter is found mainly in small streams, it is more sensitive to the incursions of man. Perhaps the most serious threat to the cutthroat at the present time comes from the often fairly ruthless forestry measures in British Columbia, which lead to severe erosion of the small and easily affected streams; clear-cutting of the formerly dense rain forest results in dramatic modifications of the conditions of light and temperature in the water.

Even when the cutthroat and rainbow trout live together in lakes some dominance of the latter is evident, anglers usually catching more rainbow trout than cutthroat. It is, however, also remarkable that the cutthroat on the average grow larger than the rainbow trout. The difference in size is due to the more rapid growth of the cutthroat (Fig. 2). Since sexual maturity of the two species occurs at about the same age there will be a difference in size, especially at the time of spawning. It should not, however, be considered that the more rapid growth of the cutthroat is a general rule, for if this were the case it would long since have displaced the rainbow trout for fish cultural uses. In fact, when living alone in lakes cutthroat readily form stunted populations where the individual fish display poor growth. It seems, instead, as if the presence of the rainbow trout in some way stimulates the development of the cutthroat.

This is by no means a unique phenomenon. Where two related species are sharing waters and competing for the resources one of them often grows rapidly and large while the other grows slowly, remaining small. This difference can occur because they live on different kinds of food of different size and accessability. Beneath the graph in Fig. 2 is a diagram showing the food in a British Columbia lake, where the cutthroat feeds on fish (mostly sculpins and sticklebacks) and bottom-living animals while the rainbow trout feeds on plankton. In this connection the larger mouth of the cutthroat is certainly an important factor. In any case, the differences in size solves two problems of co-habitation: (1) by sharing the food resources the two species can live together without one forcing out the other; and (2) the difference in size of the spawning fish of the two species mitigates against hybridization.

Of interest in this connection is the fact that a large number of lakes where the cutthroat and rainbow trout are found are dammed and regulated. The system is generally similar to that in Sweden, the water level being lowered in winter and raised in the summer. Often the large evergreens are left in the submerged shore zones; some topple and remain floating around and others lean over the water. While net fishing in such lakes tries ones patience, to say the least, the fish thrive surprisingly well. Perhaps it is these trees with their rotting root systems and trunks that afford the fish nourishment in the form of the small creatures that they harbour. In any case, the cutthroat manages extremely well, better than the brown trout in our regulated lakes - and in spite of the fact that in many respects it is the brown trout's counterpart in the western hemisphere.

Surprisingly little has been written on the cutthroat as a game fish. This may be due to descriptions stating that its distribution is largely the same as for the rainbow trout. A comparison of the behaviour of the two species shows that the cutthroat is to a greater extent a "bottom fish". Rather like our brown trout, it feeds mostly on various kinds of bottom-living animals. When it takes food at the surface it snaps cautiously rather like the char. The rainbow trout, on the other hand, makes a powerful leap, breaking the water. On the hook the cutthroat strives persistently to get to deep water. It seldom makes the spectacular leaps in the air typical of the wild rainbow trout. In short, it is rather phlegmatic, but strong and stubborn.

This view is borne out by comparison of the two species in tanks. Both prefer to take food from the surface, as they do in their natural habitat; the rainbow trout makes a powerful rush as soon as the food lands on the surface, while the cutthroat approaches cautiously and nibbles, with only its nose above the surface.

Both the rainbow and the cutthroat are aggressive, defending their territory against individuals both of their own species and others. In the aquarium a day is sufficient for the dominant and subordinant fish to establish their rank. The ones that have gained ascendancy pursue the others, biting and making threatening approaches. Sometimes the adoption of particularly threatening postures suffices to frighten their rivals into submission. In this context, too, the rainbow trout would seem to be more active than the cutthroat. A group of the two species kept in aquaria at the University of British Columbia in the summer of 1969 was observed for many hours and the frequency of aggressive behaviour in different situations was noted. Altogether some 2000 attacks were counted, and these were distributed between the two species as follows:

	Number of attacks per 5 minutes		
	Before feeding	During feeding	After feeding
Rainbow, mean	8	9	15
Cutthroat, mean	4	4	5
Rainbow, maximum	35	35	40
Cutthroat, maximum	15	17	15

It is clear that aggressiveness of both species increased after feeding, but throughout the experiment it was the rainbow trout that was the more aggressive. The dominant rainbows attacked their competitors by making powerful rushes and biting. In an attempt to escape the pursued fish sometimes leapt high out of the water. Two rainbow trout of equal rank that had recently come into contact sometimes threatened each other by swimming side by side with fins stretched out and the body vibrating in a lateral threat display.

The cutthroat were calmer; their attacks were carried out more "deliberately" and the subordinate fish appeared to swim away only so far as was necessary. The cutthroat, but never the rainbow, exhibited frontal threat display, with arching of the back, lowering of the dorsal fin, opening of the gills wide, and lowering of the throat part so that the red streaks could be seen. This behaviour presumably served as a social signal, warning the subordinate individuals against a futile battle with an opponent of the same species.

When, towards the end of the study, the rainbow trout were released into the same aquarium as the cutthroat, they reacted to each others' presence in the same way as to individuals of their own species, chasing, biting and threatening each other. This time it was invariably the rainbow that was dominant over cutthroat of the same size. In one case it took only a night for a rainbow trout to stress to death a cutthroat that for a couple of months had been a sovereign despot over fish of its own species. Large cutthroat, however, gained dominance over small rainbow trout, and perhaps we find here a clue to the problem of how the presence of rainbow trout in lakes can stimulate the growth of the cutthroat. If it is supposed that also in their natural habitat young rainbow trout are more aggressive than cutthroat of the same size, natural selection would rapidly favour growth of the latter. One would then obtain numerous small rainbow trout and large but fewer cutthroat; this, however, is at present no more than an unconfirmed hypothesis.

Age, Food, and Migration of Sea-run Cutthroat Trout, *Salmo clarki*, at Eva Lake, Southeastern Alaska

ROBERT H. ARMSTRONG

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Age, Food, and Migration of Sea-run Cutthroat Trout, *Salmo clarki*, at Eva Lake, Southeastern Alaska[1]

ROBERT H. ARMSTRONG

Alaska Department of Fish and Game
Sport Fish Division
Juneau, Alaska 99801

ABSTRACT

Information was collected on sea-run cutthroat trout (*Salmo clarki*) from the Eva Lake system on Baranof Island, Southeastern Alaska.

Migrations of 1,210 to 1,594 out-migrants and 1,203 to 1,682 in-migrants were recorded at a weir across the outlet of Eva Lake. Migration peaks occurred in mid-May (out-migrants) and mid-September to early October (in-migrants). No movement of cutthroat was noted at the weir from December through February. Ages of out-migrant cutthroat ranged from 3 to 10, with the majority showing 5, 6, and 7 annuli on their otoliths. The numbers of annuli considered to be formed prior to smolt migration were 2 (3%), 3 (80%) and 4 (17%). Stomach contents consisted primarily of salmon young and insects during the summer and stickleback and insects during the winter in Eva Lake. The fish fed mostly on insects during their out-migration and amphipods and salmon young in salt water. Results of the Eva Lake study and other studies on sea-run cutthroat are compared.

INTRODUCTION

This paper presents information collected on sea-run cutthroat trout (*Salmo clarki*) from the Eva Lake system on Baranof Island, Southeastern Alaska, during 1962, 1963 and 1964. The data were collected incidental to a life history study on the sea-run Dolly Varden (*Salvelinus malma*).

Little is known about the sea-run cutthroat trout (*Salmo clarki*) in Alaska. Cope (1964) lists only four references for Alaska (Bean, 1894; Evermann and Goldsborough, 1907; Jordan, 1907; and Reed, 1963). However, these references are indicated to be on the non-migratory form. Baade (1957) presents some information on the timing and food of sea-run cutthroat entering and leaving Helm Lake near Ketchikan.

Information on sea-run cutthroat trout from other areas is presented by DeWitt (1954) for California; Bulkley (1966), Cramer (1940), Lowry (1965), and Sumner (1948, 1953 and 1962) for Oregon; and Hartman and Gill (1968), Neave (1949) and Qadri (1959) for British Columbia.

METHODS

Sea-run cutthroat trout were enumerated at a weir located across the outlet to Eva Lake about 250 yards (229 meters) above tidewater. The weir was capable of stopping and trapping all migrating cutthroat. A description of the weir and its effectiveness is given by Armstrong (1965). Blackett (1968) describes the study area. The Eva Lake watershed is located in a virgin wilderness area, and the population of cutthroat trout receives very little fishing pressure.

On occasion, the weir screens had to be removed during periods of flooding. Fortunately, these periods were not during major migration times of cutthroat. Estimated numbers of cutthroat missed, based on an average of the number captured the day before and the day after the screens were removed, ranged from 16 to 26 fish for a given in- or out-migration. These estimated counts are included in the monthly totals.

Samples of out-migrant cutthroat trout were taken from the weir traps for age, fork length and stomach content. Approx[illegible] mately 20 fish were sampled every other d[illegible] from May 27 to June 18, 1964. The [illegible] were not selected, and either the firs[illegible] captured or if less than 20, the entire n[illegible] captured, was sampled.

Otoliths were obtained for age dete[illegible] tion. Age was determined from the n[illegible] of hyaline rings (annuli) formed o[illegible] otoliths. Annuli were easily counted o[illegible]

[1] This investigation was conducted with Federal Aid in Fish Restoration funds.

Tȯmasson X

Tȯmasson, Tumi. 1978. Age and growth of cutthroat trout, _Salmo clarki clarki_ Richardson, in the Rogue River, Oregon. M. S. Thesis. Oregon State Univ. Corvallis. 75pp.

Cope Bibliog.

DRAFT

OCT 05 1979

CUTTHROAT TROUT

Introd - Because cutthroat comparable to "trout" in general (B & Z. 76) - lit. not available - use other species - Thus, - optimum suitability curves "generalized" w/ exceptions -

General Ecology

Distribution. Cutthroat trout, Salmo clarki, are a polytypic species consisting of several geographically distinct forms with a broad distribution and a great amount of genetic diversity (Hickman 1978; Behnke in press). Behnke (1979 in press) recognizes 13 extant subspecies: Coastal cutthroat (S. c. clarki) in coastal streams from Prince William Sound, Alaska to the Eel River in California; mountain cutthroat (S. c. alpestris), upper Columbia and Frazer River drainages of British Columbia; west slope cutthroat (S. c. lewisi) in the upper Columbia, Salmon, Clearwater, south Saskatchewan and upper Missouri drainages of Alberta Montana and Idaho; an undescribed subspecies in the Alvord basin, Oregon; Lahonton cutthroat (S. c. henshawi), Pauite cutthroat (S. c. seleniris), and an undescribed subspecies in the Humboldt River drainage of the Lahontan basin of Nevada and California; Yellowstone cutthroat (S. c. bouvieri) of the Yellowstone drainage of Montana and the Snake River drainage of Wyoming, Idaho and Nevada; an undescribed subspecies (fine spotted) from the upper Snake River, Wyoming; Bonneville cutthroat (S. c. utah) of the Bonneville basin in Utah, Nevada, Idaho and Wyoming; Colorado River cutthroat (S. c. pleuriticus) of the Colorado River drainage in Wyoming, Utah and Colorado; greenback cutthroat (S. c. stomias) of the South Platte and Arkansas River systems; and Rio Grande cutthroat (S. c. virginalis) of the Rio Grande River drainage of

Colorado and New Mexico. Many of these 13 subspecies are included on Federal or State endangered or threatened species lists.

Variation in temperature and chemical preferences, migration, and other ecological and life history attributes exists among cutthroat subspecies (Behnke in press). Differences in growth rate (Carlander 1969; Scott and Crossman 1973; Behnke in press) and food preferences (Trojnar and Behnke 1974) between some subspecies have also been reported. To a large extent stream trout are territorial, they need a certain territory for their shelter and foraging, and the more aggressive individuals will defend these territories. Stream salmonids are able to reduce agression and tolerate crowded conditions if food is abundant (Chapman 1966).

in general * Humboldt, Bear R.-

Habitat. Cutthroat trout prefer clear, cold, rocky bottom streams and clear, deep lakes that may vary in size and chemical quality. These trout tend to occupy headwater stream areas, especially when other trout species are present in the same river system.

Several studies have demonstrated the importance of cover to salmonid densities but few have involved research during the winter (Bustard and Narver 1975b). In some streams the major factor limiting salmonid densities may be the amount of adequate overwintering habitat rather than summer rearing habitat (Bustard and Narver 1975a). Everest (1969) suggested that some salmonid population levels were regulated by the availability of suitable hibernating areas. The major advantages in seeking winter cover are: prevention of physical damage from ice scouring (Chapman and Bjornn 1969; Hartman 1965) and conservation of energy (Chapman and Bjornn 1969; Everest 1969). The main advantage of summer cover is probably predator avoidance. During high water velocity periods cover may also provide resting areas and help prevent downstream displacement. Very few salmonids are found in areas lacking cover (Bustard and Narver 1975a). Winter hiding behavior in salmonids is triggered by low temperatures (Chapman and Bjornn 1969; Everest 1969; Bustard and Narver 1975a,b). Bustard and Narver (1975a) indicated that as water temperatures dropped to 4 to 8^{o} C feeding was reduced in young salmonids and most were found within or near cover, few were found more than 1 m from potential cover. Cutthroat trout were found under boulders, log jams, upturned roots and debris when temperatures neared 4 to 8^{o} C, depending on velocity (Bustard and Narver 1975a). Salmonids use instream structures, substrate, deep water and undercut banks for cover. Bjornn (1971) observed that nearly all the rainbow trout in his study lived in or near rock piles during the winter. Lewis (1967) reported that rainbow trout tended to move into deeper water during winter. Bustard and Narver (1975a) reported that the streambank environment was very important to overwintering steelhead trout.

Headwater trout streams tend to be relatively unproductive. Most energy inputs to the stream are in the form of allochthonous materials; leaves and other terrestrial vegetation and terrestrial insects. About 40 to 50% or more of the food trout in headwater streams eat during the summer is comprised of terrestrial insects. Aquatic invertebrates are most abundant and diverse in stream riffle areas with cobble or greater

Binns, Eiserman

size substrate and on submerged aquatic vegetation. In headwater streams the invertebrate fauna is much more abundant and diverse in riffles than pools (Hynes 1970). Canopy cover is important in maintaining shade for stream temperature control and to provide allochthonous materials to the stream. Too much shade can, however, restrict primary productivity in a stream. Shading becomes increasingly important as stream gradients decrease.

Cutthroat trout fry exhibit three distinctly different genetically controlled patterns when moving from natal gravels to rearing areas: 1) Downstream to a larger river or lake; 2) upstream from an outlet river to a lake; or 3) local dispersion within a common spawning and rearing area to areas of low velocity and cover (Raleigh and Chapman 1971). The latter type of movement pattern is the most common. Fry of lake resident fish may either move into the lake from natal streams during the first growing season or overwinter in the spawning stream and move into the lake during the second growing season (Raleigh 1971; Raleigh and Chapman 1971). Some Salmo clarki lewisi spend one to four years in the stream (average two) before migrating back to the lake (Roscoe 1974).

Coastal cutthroat trout, Salmo clarki clarki, appear to be less prone to saltwater rearing than steelhead trout or salmon. ~~Some~~ Many coastal cutthroat live their entire lives without entering saltwater (Behnke in press), and those that enter the sea return to overwinter in freshwater streams and lakes each year (Armstrong 1971; Johnston and Mercer 1976). The majority of coastal cutthroat that smolt and migrate to the sea for the first time do so at III or IV years old. Some smolt at age I while others may not migrate to saltwater until age VI. In Washington the smallest cutthroat smolt entering saltwater weigh about 40 to 45 gms and are 160 to 170 mm in length. Physiological adaptation to saltwater appears to be more related to size than to age (Johnston and Mercer 1976).

In Washington and Oregon smolt movement to saltwater occurs as early as March, peaks in mid-May and is completed by mid-June (Johnston and Mercer 1976). In Alaska migration begins in April (Armstrong 1971; Johnston and Mercer 1976), peaks at the end of May (Johnston and Mercer 1976) and continues into August (Armstrong 1971). Armstrong (1971) indicated that most seasonal migrations occurred during the dark. Once in saltwater coastal cutthroat usually remain near shore in bays, estuaries and along the coastal area with little or no offshore movement (Behnke in press). Re-entry into freshwater in Washington and Oregon begins in July, peaks in September and October and lasts until the end of October. In smaller streams draining directly into saltwater re-entry begins in October, peaks in December and January and lasts until March. Migrations into small stream-lake systems in Alaska begins as early as mid-May, peaks in September and lasts until October (Johnston and Mercer 1976).

<u>Age and Growth</u>. Most male cutthroat trout mature at ages two to three while females usually mature a year later (Irving 1954; Drummond and McKinney 1965). Size of cutthroat trout at maturity is variable and depends on environmental conditions. Maximum life expectancy for

Sumner
Armstrong

coastal cutthroat is about 10 years of age (Johnston and Mercer 1976). Cutthroat tend to mature at a smaller size in small headwater streams (Behnke and Zarn 1976).

Trout are opportunistic feeders (Behnke and Zarn 1976). Aquatic insects, generally the most available food in streams, are the dominant item of most cutthroat trout diets (Allen 1969; Carlander 1969; Baxter and Simon 1970; Scott and Crossman 1973; Griffith 1974). Other foods, such as zooplankton (McAfee 1966; Carlander 1969; Trojnar and Behnke 1974), terrestrial insects (Carlander 1969; Trojnar and Behnke 1974; Hickman 1977), and fish (Carlander 1969) are important locally or seasonally. Cutthroat trout usually become more piscivorous as they increase in size (McAfee 1966; Carlander 1969; Baxter and Simon 1970).

Difference * Subsp. dif. most superior higher predaceous coastal (Idler -- but Ore. --Willamette R.-- w/ rainbow) — Lahontan highest predator - lewisi - seldom eats fish - evol. imprinting-programming.

Reproductive Behavior. Cutthroat trout are stream spawners. The fertilized ova are deposited in redds constructed primarily by the female in the stream gravels (Smith 1941, 1947). Resident populations of cutthroat in lakes spawn in both outlet and inlet streams (Raleigh 1971; Raleigh and Chapman 1971).

— sometimes in lakes - R.M.P. - Mullen, Rosenlund - but if too cold - eggs not hatch —

Spawning begins as early as March (Behnke and Zarn 1976; Fleener 1951) and as late as August (Juday 1907; Fleener 1951). The time of spawning depends on water temperature, runoff (Lea 1968), ice melt (Calhoun 1944), elevation and latitude (Behnke and Zarn 1976). Specific information on optimal velocity for cutthroat trout spawning was not found in the literature. Post-spawning mortality of adults is high in most populations (Irving 1954; Carlander 1969; Scott and Crossman 1973).

Specific Habitat Requirements

Habitat Parameters. In general sand is the poorest habitat for invertebrate production. The fact that rubble supports more organisms than sand is correlated with the amount of available stable living space. Larger and more irregular stones support a more diverse invertebrate fauna. Optimum substrate for invertebrate production consists of a mosaic of sand, gravel, rubble and boulder with rubble being dominant. On stony substrate the presence of silt reduces and changes the invertebrate fauna. The presence of vegetation increases the diversity and abundance of invertebrate fauna. In several studies vegetated areas were more heavily colonized than the non-vegetated areas of substrate (Hynes 1970). A ratio of 50% pool area to 50% riffle area is generally regarded as the best overall habitat for stream resident trout (Needham 1940).

Hartman and Gill (1968) studied 66 streams in British Columbia and those streams containing cutthroat trout had a pH range of 6.0 to 8.8. Thirteen streams in Wyoming containing populations of Colorado River cutthroat trout had pH levels ranging from 7.1 to 8.3 (Binns 1977). Sekulich (1974) reported that the pH in three reservoirs containing cutthroat trout ranged from 7.8 to 8.5. Platts (1974) analyzed three streams in Idaho containing cutthroat trout where the pH ranged from 7.3 to 7.9. Some isolated populations of cutthroat trout in the Great Basin area have developed a unique tolerance to high alkalinity and temperature conditions. The largest cutthroat trout ever recorded came from

Pyramid Lake, which has a pH of over 9.0 (LaRivers 1962). The pH range for cutthroat trout appears to be about 6.0 to 9.0 with more restricted optimal ranges regionally.

Bachmann (1958) reported that cutthroat trout stopped feeding and moved to cover at turbidities above 35 ppm. Total dissolved solids from 38 to 544 mg/l and turbidities of less than 25 JTU characterized 13 Wyoming streams containing cutthroat trout (Binns 1977). Platts (1974) recorded total dissolved solids ranging from 41 to 63 mg/l in three Idaho streams. The Lahontan basin cutthroat trout persist in waters where total dissolved solids may exceed 7,000 mg/l (Johnson 1974).

Adult. Dissolved oxygen requirements vary with the species, age of fish, prior acclimation temperature, water velocity and concentration of substances in the water (McKee and Wolf 1963). As temperatures increase the dissolved oxygen level in the water decreases while the dissolved oxygen requirement for the fish increases. As a result, an increase in temperature resulting in a decrease in dissolved oxygen can be detrimental to the fish. Doudoroff and Shumway (1970) demonstrated that swimming speed and growth rates for salmonids declined with decreasing dissolved oxygen levels. Cutthroat trout generally avoid water with dissolved oxygen level in the summer of less than 5 mg/l (Trojnar 1972; Sekulich 1974).

Cutthroat trout usually do not persist in waters where maximum temperatures consistently exceed 22^{o} C, although they may be able to withstand brief periods of daytime water temperature as high as 26^{o} C if considerable cooling takes place at night (Behnke and Zarn 1976). The Humboldt River cutthroat trout, however, occupy waters where temperatures may reach a summer maximal level of 25° C (Behnke in press). Needham and Jones (1959) reported cutthroat trout actively feeding at a temperature of 0° C. Bell (1973) reported a preferred temperature of 9 to 12° C for cutthroat trout. As temperatures neared 7° C adult steelhead trout in Idaho moved downstream to larger and deeper rivers (Everest 1969).

Embryo. The length of the incubation time varies indirectly with temperature. Eggs usually hatch within 28 to 40 days (Cope 1957), but may take as long as 49 days (Scott and Crossman 1973). The optimum temperature for incubation is approximately 10° C (Snyder and Tanner 1960). The combined effects of temperature, dissolved oxygen levels, water velocity, and gravel permeability are important for successful incubation. Suitable incubation substrate is gravel 3 to 80 mm in diameter (Duff in press). Suspended sediment levels greater than 130 ppm, combined with dissolved oxygen concentrations less than 6.9 mg/l and velocities in the redd of less than 55 cm/hr, can reduce egg survival to below 10% (Bianchi 1963). Coble (1961), working with steelhead trout embryos, demonstrated that velocities and dissolved oxygen concentrations were closely related in their effect on embryo survival. Doudoroff and Shumway (1970) reported that salmonids that hatched at low dissolved oxygen levels were weak and small; their development was slower and there were more abnormalities.

Fry. Cutthroat trout remain in the gravel for about two weeks after hatching (Scott and Crossman 1973), and emerge from the gravel 45 to 75 days after egg fertilization depending on water temperature (Calhoun 1944; Lea 1968).

Fry residing in stream environments prefer shallower water and slower velocities than other life stages (Miller 1957; Horner and Bjornn 1976). Velocities of less than 30 cm/sec are preferred with less than 8.0 cm/sec optimum (Horner and Bjornn 1976). Fry survival decreases with increased velocities after some optimal velocity has been reached (Bulkley and Benson 1962; Drummond and McKinney 1965). A pool area of 40% to 60% of the total stream area is optimal fry habitat. Cover in the form of aquatic vegetation, debris piles, and the interstitial spaces between rocks is critical.

Chapman and Bjornn (1969) demonstrated that the number of fry steelhead trout hiding in rubble cover was directly related to water temperature, none were observed above the substrate when water temperatures were below 4° C. Trout fry usually overwinter in shallow areas of low velocity near the stream margin, with rubble being the principle cover (Bustard and Narver 1975a). As these young trout mature they move to deeper, faster water. Everest (1969) suggested that one reason for this movement was the need for cover which is fulfilled by increased water depth, turbulence and larger substrate. Optimum size of substrate, used as winter cover for steelhead fry, ranges from 20 to 40 cm in diameter (Everest 1969; Hartman 1965). Bustard and Narver (1975a) reported that the majority of steelhead fry in their study were found in substrate less than 20 cm in diameter, but suggested that this was because few rocks larger than 15 cm were available. Using smaller diameter rocks for cover may result in increased mortalities because of shifting substrate (Bustard and Narver 1975a).

Juvenile. Juvenile cutthroat trout in southwestern British Columbia were generally in streams with drainage areas of less than 13 km^2 (Hartman and Gill 1968). The streams had a range of total dissolved solids between 20 and 190 ppm.

Juvenile cutthroat trout in streams are most often found in water depths of 45 to 75 cm and velocities of 25 to 50 cm/sec (Nickelson unpublished data). Metabolic rates are highest between 11 and 21^{o} C (Dwyer and Kramer 1975). The optimal temperature for growth of juvenile cutthroat trout is 15^{o} C and equilibrium is lost between 28 and 30^{o} C (Heath 1963).

Bustard and Narver (1975b) demonstrated that juvenile cutthroat trout used rubble and overhanging banks as cover. When given a choice between areas containing overhanging bank cover and areas without cover the cutthroat choose the overhanging bank cover areas, they also showed a preference for clean rubble as opposed to areas of silted rubble for cover. Common types of cover for juvenile steelhead are upturned roots, logs, debris piles, overhanging banks and boulders (Bustard and Narver 1975a). They also reported that young salmonids occupy different habitats in the winter than in the summer, log jams and rubble were the most important winter cover. Edmundson and Everest (1968) reported that juvenile steelhead were primarily under or between rubble particles in the winter. Everest (1969) demonstrated that juvenile steelhead actively seek suitable overwintering areas in the fall and they entered the substrate at temperatues below 7^{o} C, none were found above the substrate when temperatures reached 5^{o} C. These fish were found 15 to 30 cm deep in the substrate and were often covered by 5 to 10 cm of anchor ice. Everest (1969) indicated that juvenile steelhead do not feed during this winter hibernation and once in the substrate they do not come out until the temperature is above 7^{o} C.

Table 1. Data Summary

Model	Rating	Analysis Method	Data Source
I_{1A} - Temperature (Adult)	Good	Ocular Estimation	Behnke (in press) (CT) Bell 1973 (CT) McKee & Wolf 1963 (RB) Mottley 1933 (RB) Needham & Jones 1959 (CT) Purkett 1951 (CT)
I_{1E} - Temperature (Embryo)	Good	Ocular Estimation	Ball & Cope 1961 (CT) Brungs & Jones 1977 (RB) Dwyer & Kramer? Kwain 1975 (RB) Leitritz 1960 (RB)
I_{1F} - Temperature (Fry)	Good	Ocular Estimation	Same as Adult
I_{1J} - Temperature (Juvenile)	Good	Ocular Estimation	Same as Adult
I_{2A} - Dissolved Oxygen (Adult)	Good	Ocular Estimation	Davis 1975 (RB) Doudoroff & Shumway 1970 (RB) McKee & Wolf 1963 (RB)
I_{2E} - Dissolved Oxygen (Embryo)	Good	Ocular Estimation	Coble 1961 (RB) Davis 1975 (RB) Doudoroff & Shumway 1970 (RB) Garside 1966 (RB)

Table 1. (Continued)

Model	Rating	Analysis Method	Data Source
I_{2F} - Dissolved Oxygen (Fry)	Good	Ocular Estimation	Same as Adult
I_{2J} - Dissolved Oxygen (Juvenile)	Good	Ocular Estimation	Same as Adult
I_{3A} - Velocity (Adult)	Good	Ocular Estimation	Griffith 1972 (CT) Hanson 1977 (CT)
I_{3E} - Velocity (Embryo)	Good	Ocular Estimation	Coble 1961 (RB) Cooper 1965 (SAL) Pyper & Vernon 1975 (SAL) Shumway et al. 1964 (RB) Smith 1973 (RB)
I_{3F} - Velocity (Fry)	Good	Ocular Estimation	Everest 1969 (RB) Horner & Bjornn 1976 (CT) Miller 1957 (CT)
I_{3J} - Velocity (Juvenile)	Good	Ocular Estimation	Everest 1969 (RB) Nickelson unpubl. (CT)
I_{4A} - Percent Cover (Adult)	Good	Ocular Estimation	Boussu 1954 (RB) Elser 1968 (RB BN) Gunderson 1968 (BN) Lewis 1969 (RB BN) Marcuson 1977 (BN)

Table 1. (Continued)

Model	Rating	Analysis Method	Data Source
I_{4E} - Substrate (Spawning) (Embryo)	Good	Ocular Estimation	Bjornn 1969 (RB) Cope 1957 (CT) Duff (in press) (CT) Hall & Lanta 1969 (RB) Kiefling 1978 (CT) Koski 1966 (SAL) Lantz 1967 (CT) McCuddin 1977 (CT) Mills 1966 (CT) Phillips 1964 (RB) Phillips et al. 1966 (RB) Phillips et al. 1975 (RB)
I_{4F} - Substrate (Cover) (Fry)	Good	Ocular Estimation	Bustard & Narver 1975a,b (CT RB) Hartman 1965 (RB)
I_{4J} - Percent Cover (Juvenile)	Good	Ocular Estimation	Bustard & Narver 1975a,b (CT RB) Everest 1969 (RB)
I_{1H} - Substrate (Invert. Prod.) (Habitat)	Good	Ocular Estimation	Binns & Eiserman 1976 Hynes 1970 Pennak & Van Gerpen 1947

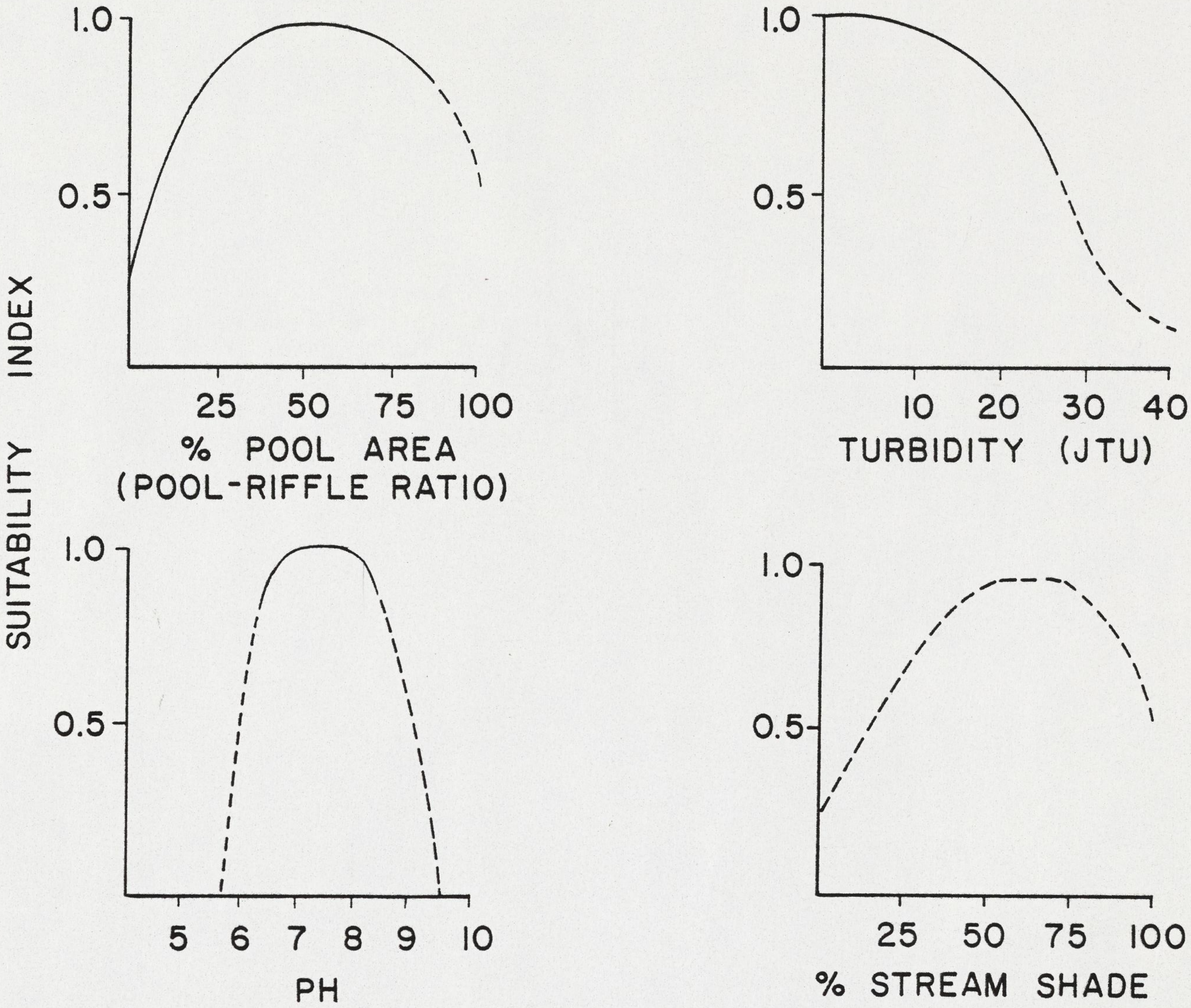
Table 1. (Continued)

Model	Rating	Analysis Method	Data Source
I_{2H} - % Pool Area (Pool/Riffle) (Habitat)	Good	Ocular Estimation	Elser 1968 (RB BN) Horner & Bjornn 1976 (CT) Hunt 1971 (BK) Jester & McKirdy 1966 (CT) Needham 1940 (CT RB BN BK)
I_{3H} - Turbidity (Habitat)	Good	Ocular Estimation	Binns 1977 (CT) Cordone & Kelly 1961 (CT)
I_{4H} - pH (Habitat)	Good	Ocular Estimation	Binns 1977 (CT) Hartman & Gill 1968 (CT) Kiefling 1978 (CT) LaRivers 1962 (CT) Platts 1974 (CT) Sekulich 1974 (CT)

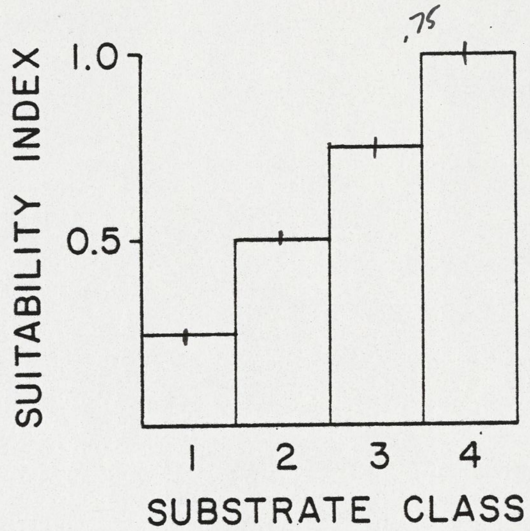
Key: CT Cutthroat; RB Rainbow; BN Brown; BK Brook; SAL Salmon

The suitability curves are a compilation of published and unpublished information on cutthroat trout. Information from another life stage or species or expert opinion was used to formulate curves when the data for a particular habitat parameter or life stage was insufficient. Data are not sufficient at this time to refine the habitat suitability curves that accompany this narrative to reflect subspecific or regional differences. Local knowledge should be used to regionalize the suitability curves if that information will yield a more precise suitability index score. Additional information on this species that can be used to improve and regionalize the suitability curves should be forwarded to the Project Impact Evaluation Group, U.S.D.I. Fish and Wildlife Service, 2625 Redwing Road, Ft. Collins, Colorado 80526.

CUTTHROAT TROUT
(HABITAT)



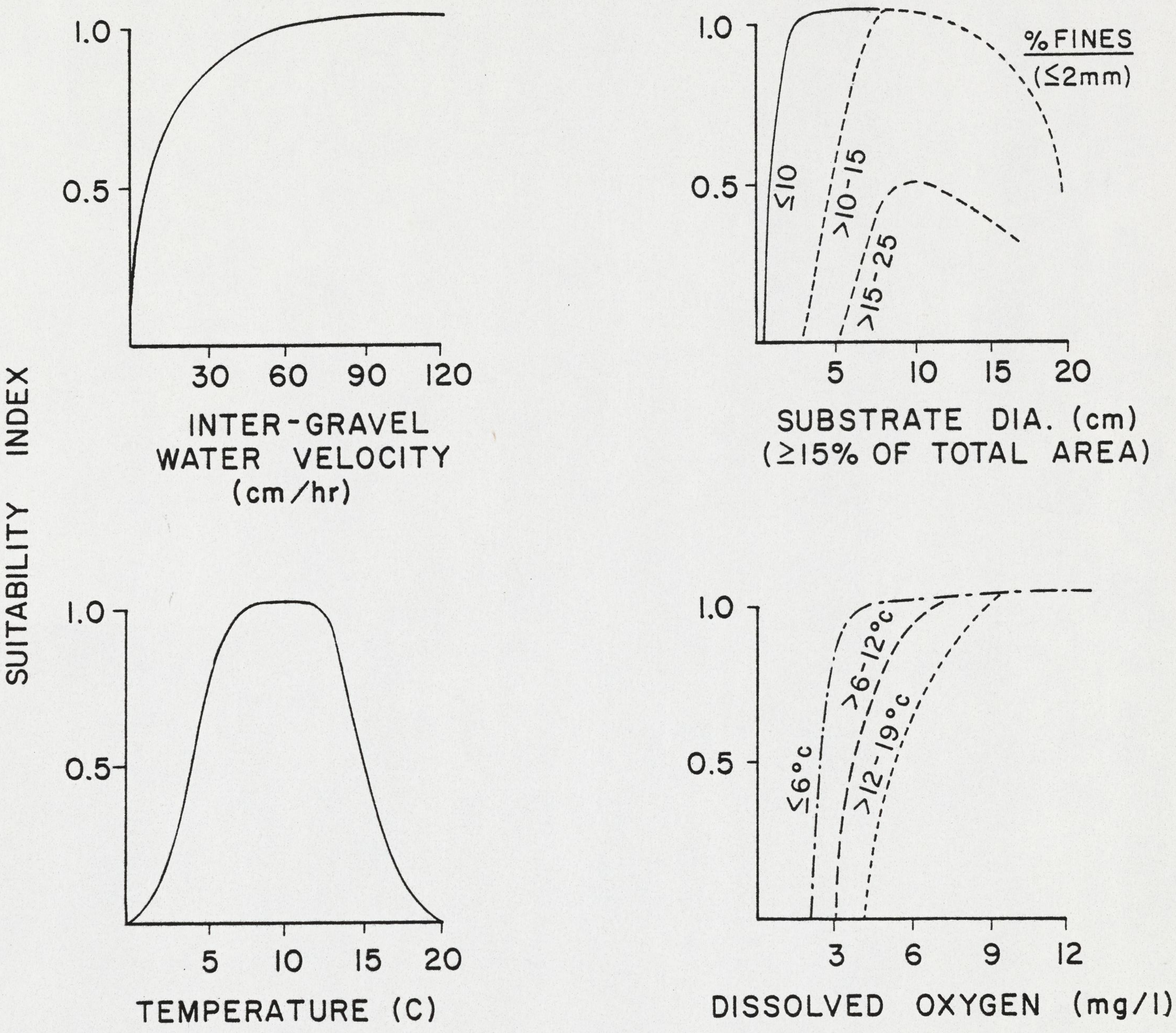
CUTTHROAT TROUT
(INVERTEBRATE PRODUCTION)

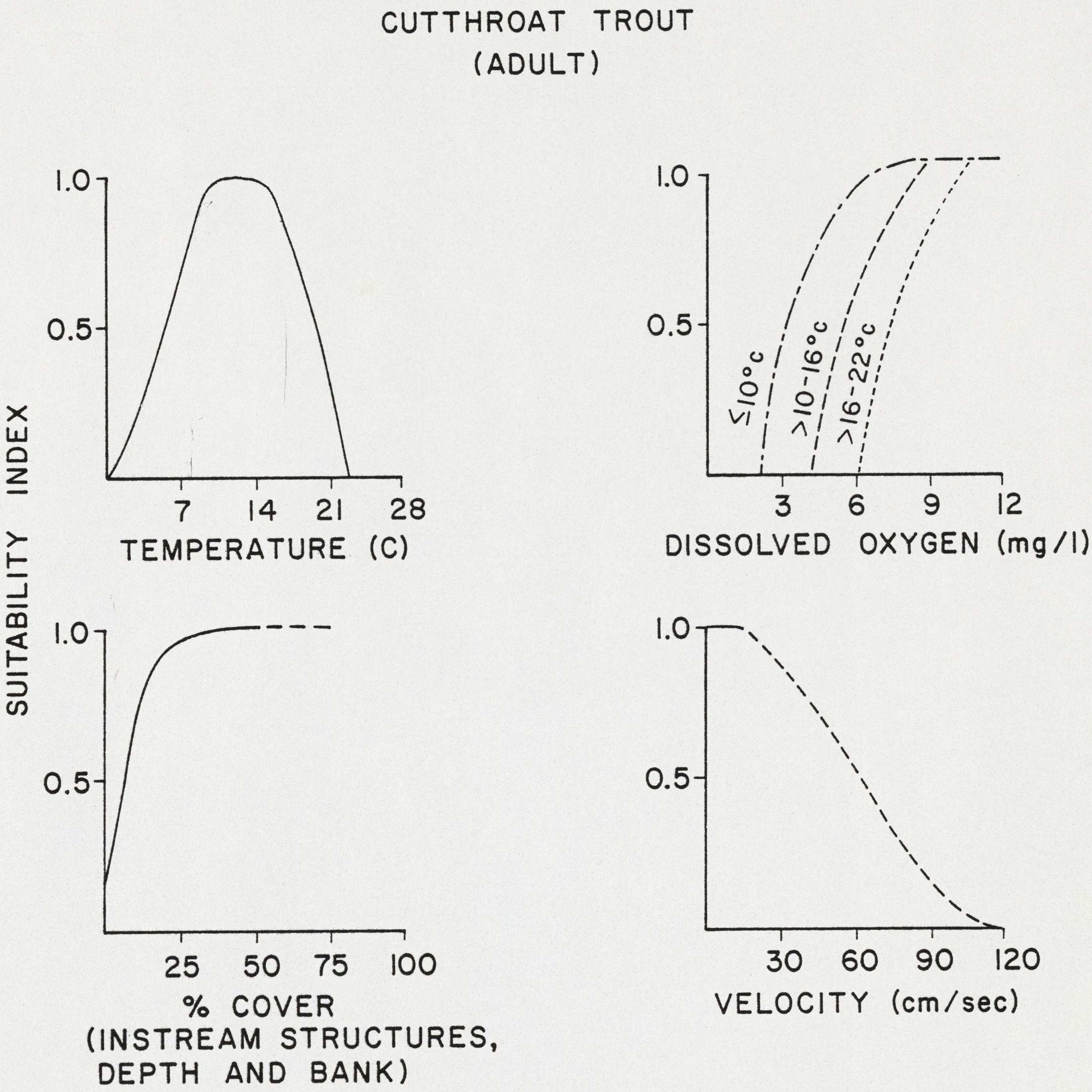


1. FINES, BEDROCK, OR BOULDERS ARE THE DOMINANT BOTTOM MATERIAL. RUBBLE AND GRAVEL ARE INSIGNIFICANT, IF PRESENT AT ALL (≤10%).
2. RUBBLE AND GRAVEL NOTICABLE (≤25%), BUT FINES OR BOULDERS ARE DOMINANT.
3. RUBBLE, GRAVEL, BOULDERS AND FINES OCCUR IN APPROXIMATELY EQUAL AMOUNTS.
4. RUBBLE DOMINANT (≥40%) WITH LIMITED AMOUNTS OF GRAVEL. BOULDERS AND FINES NOT COMMON.

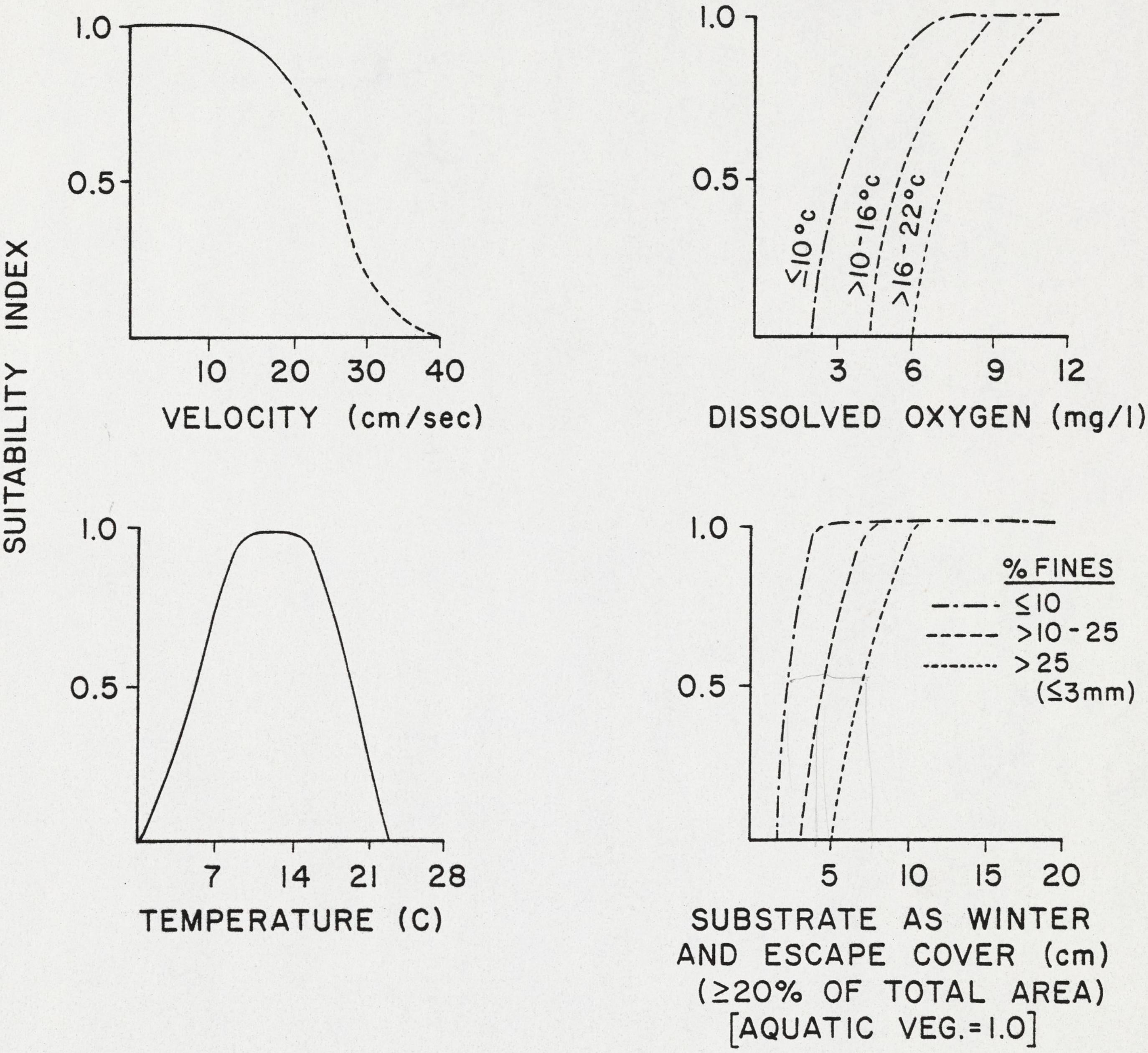
CUTTHROAT TROUT

(EMBRYO)

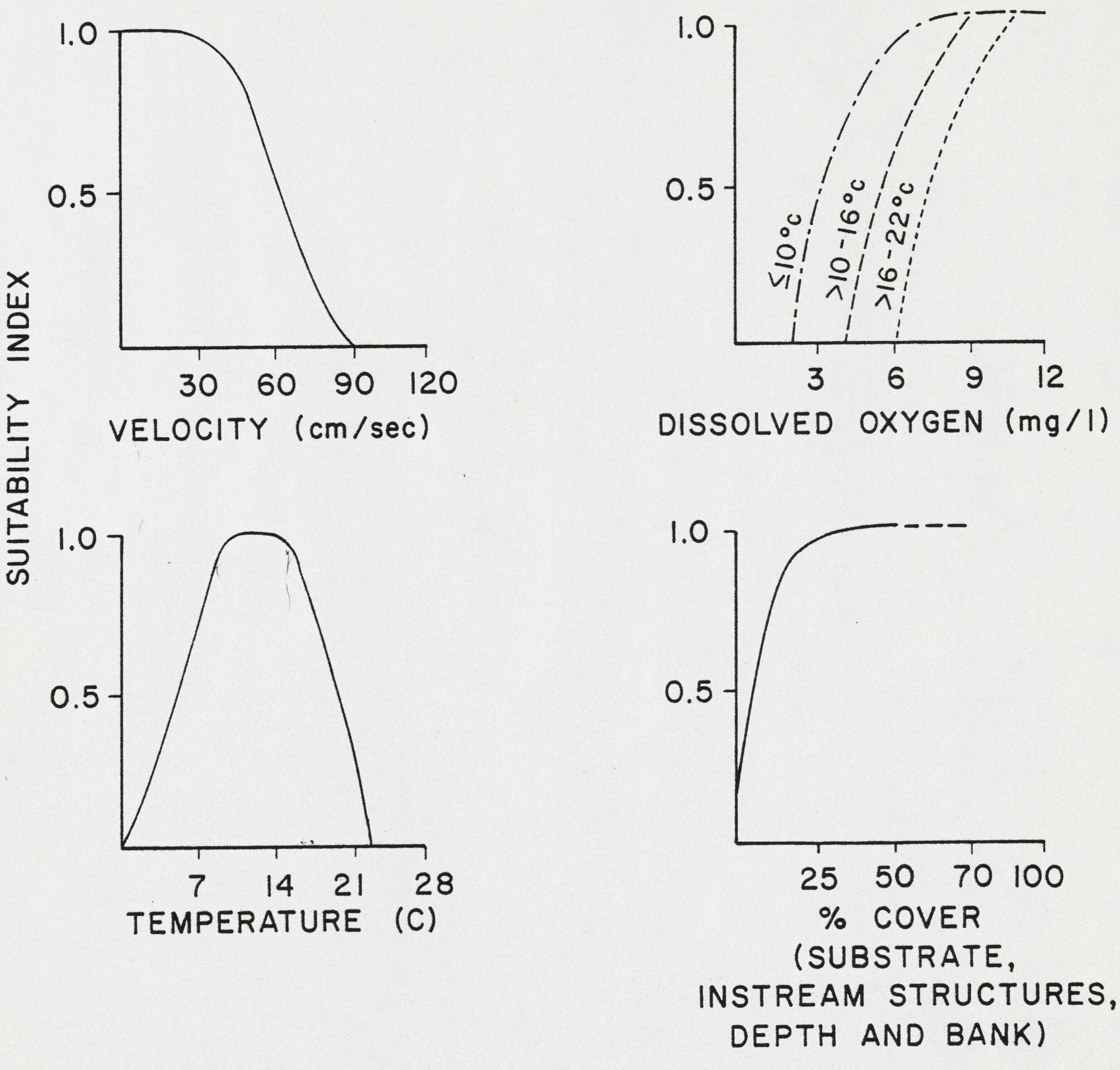



CUTTHROAT TROUT
(ADULT)
SUITABILITY INDEX
1.0
0.5
7
14
21
28
TEMPERATURE (C)
1.0
0.5
≤10°c
>10-16°c
>16-22°c
3
6
9
12
DISSOLVED OXYGEN (mg/l)
1.0
0.5
25
50
75
100
% COVER
(INSTREAM STRUCTURES,
DEPTH AND BANK)
1.0
0.5
30
60
90
120
VELOCITY (cm/sec)

CUTTHROAT TROUT
(FRY)



CUTTHROAT TROUT
(JUVENILE)



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- gradient - flushing flows

varying seasonal

Turbidity - prob - best indicator tons/km watershed - see

- logging
- livestock gr
x accelerated erosion -

Welch, et. al, 77 - Fish & Wild. Serv. Bull - 745

- Bjorn, et. al 74 - Sediment in Stream

- spawning ~ factors affecting - - Biblig. - Alderdice, et. al, 77 - Rept. 743

- Flows - POE.
Nehring. - Wesche - 30-25% - drops fast - love cover

Wyo. water Res. Inst, 78 - depths, velocity, subst. pref. - spawning trout

- [illegible]