

Colorado
State
University

Sept. 23, 91

Department of Fishery and
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Dear Datus:

I'm a bit tardy in sending my sincere thanks and gratitude to you for the wonderful day on the W. Sollatin and the benchmark dinner exemplifying the ultimate in wild game gourmet fare. It's not that I've forgotten or simply lazy, but I left on my Siberian trip a few days after returning home from Montana, and then, after that, I had the opportunity to experience a fantasy-come-true fishing trip to Alaska. Now that I'm back to reality, I'm catching-up on odds & ends accumulated.

The Siberian trip worked out well, we left Moscow the day before all the excitement. Things have certainly changed in the USSR -- now, essentially Russia, but even ethnic groups of Russian republic such as the Yakutia of Siberia are asserting their independence. We caught both species of lenole I was looking for, some small (26-32", but juvenile) taimen, Arctic charr, etc. The trip was written-up for Fly Rod & Reel magazine - perhaps next issue. I just received the book that the

enclosed book mark announces. It probably is the "definitive" work on trout (especially compared with Schwiebert's book of some title), but I never was sent page proofs for final checking and saw several errors in my sections on first scan. Evidently, editorial revisionism occurred. My terms 'lumpers' and 'splitters' were reversed to give a contradictory meaning - 250 km (155 mi) became 155 km (250 mi). - interior subsp. of cathartes

trout became interior subsp. of california trout, Columbia River became the Colorado River.

Be sure that the 'definitive' work also reflects sloppy editing and careless rewriting.

I had expected this. The work before going to press, the editor was phoning and faxing me every day for advice and corrections - a rush job, that shows on careful reading.

When you next see Dennis Kavanaugh
please pass on my regards and thanks --
Dennis is top-notch, I would have loved to
have him as a guide on my Alaskan trip.

Regards,

Bob Behnke

Colorado
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April 12, 91

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Dear Datus:

The West. Div. Am. Fish. Soc. holds its annual meeting in mid July in Bozeman. I plan to attend and since it's in your neighborhood, if you're at home, perhaps we could get together for a day of fishing. One of my former students, now working for Utah Div. Wildlf., has inlaws who retained part of old family ranch which includes the ~~Axodotl~~ Lks., south of Bozeman (Madison R. valley near Ennis). Last time I fished there we caught grayling (lots of grayling) and cutthroat trout of 4-5 lbs.

I recall an interesting collection from Shields R. in 1972. George Holton (formerly MT. chief of fish mgt.-now runs souvenir store in Helena) and I were making collections of Yellowstone R. drainage cutthroat trout (subsp. bouvieri). We went to headwaters of Shields near small town of Willsow. There was Forest Service campground there that had been long stocked with catchable rainbow trout. We were there after Labor Day, after stocking ceased, and when little angling occurred. All we found from electrofishing were native cutthroats, many

quite large. How this population had persisted without being replaced or hybridized out of existence is a mystery. One can only make a broad generality that the native trout in its native, unperturbed environment, is much better adapted than is the rainbow to survive and thrive through all life history stages, at least in this small one - in its range.

These Yellowstone subsp. cutts do have a brownish-yellowish coloration that resembles brown trout when observed in the water. Sometimes, mature males will have pink tints, but this subsp. never develops the brilliant, gaudy colors of the upper Columbia, or upper Missouri subsp. (lewisii) -- but for lewisii specimens, they must take color pigment (carotenoids) in food -- mainly crustaceans. This is why lake fish, where crustaceans are typically more common, will have brighter colors than stream fish of same hereditary constituency.

Regards,
Bob Behnke

Float Salmonid 3/Deans

Colorado
State
University

May 6, 91

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Dear Deans:

The enclosed figure lets you know what you'll be in for if you bring up the subject of fish classification in my presence. You will note the char genus, Salvelinus (brook trout, Sal. fontinalis) is phyletically closer to taimen-huchen (genus Huxo) x lenok (Bachymystax) than it is to trout-salmon (Salmo x Oncorhynchus -- which now includes ~~rainbow~~ cutthroat trout).

I have tentative schedule for July. I will be giving a cutthroat trout workshop for biologists of Utah Dept. of Wildlife, July 10-12 (the changing attitude on native cutthroat trout is apparent here--10 years ago, the old regime wanted nothing to do with native cutthroat or any fish which might be listed under End. Sp. Act--so an embargo was placed on shipping specimens to me for identification), July 12-16 vicinity of Ennis at Axolotl Lakes, July 16-19, Am. Fish. Soc. meeting Mont. St. campus, Bozeman, July 19-20 return Axolotl Lakes and end of trip.

There are society dinners on July 16 & 18, free Wed., July 17 evening--I haven't seen program yet but I suspect I could be free for some blocks of time on 17th-18th -- I'm sure we can arrange an interlude for an evening at Hyalite Res. ^{and} for your Spring Creek, and, hopefully, you might join us at Axolotl Lakes for a try at giant cutthroat and large grayling. A former

C.S.U. student, Donn Johnson (I was on his Ph.D. committee) may meet me in Bozeman. Donn is into deep fly fishing--all aspects, literature, tackle, techniques. I have often used Donn's expertise for my Trout articles. If you, Donn, & me go fishing, I would handle subject matter of ichthyology and Donn would discourse on any aspect of flyfishing--sort of a salmonid summit meeting. I must admit that, although I enjoy angling, I've never had the time to fully develop my potential to be an expert (I might categorize my level as semi-skilled).

I see where Lee Wolff was terminated last Sunday by plane crash while renewing his pilot license at age 86--all in-all, a rather nice way to exit. Last Friday I attended a "wake-farewell party for Steve Lundy in Denver. Steve was president of T.U. and died of AIDS couple months ago. He stipulated in his will that a great party would be held for all his old fishing friends--a great time was had by all.

Regards,
Bob Behnke

Answered
March
1991

#18:91

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Dear Dr. Durst:

Thanks for Field & Stream article. I recall seeing this last year and it suggested some points I attempted to bring out in my article.

Perhaps you also received fax mail on your article. Enclosed is one forwarded by Tom Perno. There are two basic problems concerning our disagreement. One concerns semantics. By 'know' or 'knowing' I assume knowledge, in-depth knowledge, vs. awareness. Columbus and Magellen would have had maps of the world available to them - but of not much use because so much was unknown - Custer was aware that the Indians were below him on the Little Bighorn, but if he had 'known' - he never would have made the charge.

To document how little was 'known' of western trout and salmon during late 19th century and how this lack of knowledge created myths on the origin of hatchery rainbow trout, I have article on subject in Fall, 1990, The Am. Fly Fisher (I just received advanced copy). I chose the museum's publication because I could detail the documentation, and cut-off any superficial know-it-all, who might cite Schwiebert to show my ignorance.

The other problem of Mr. Cohen is

the common cult worship mentality that believes any frailty or blemish that might become apparent on an heroic figure is blasphemy. Actually, I believe I would have admiration for such a dogmatic, omnipotent figure such as Hewitt. I don't think I would use the word "hubris" to explain mistakes made by any contemporary singling authority -- heroic figures have hubris. Done Whitlock was featured at our T.O. banquet Saturday. Done may pontificate on Big, about his singling feats, techniques and systems, but, in my mind, he doesn't have "hubris". He did define 'nymphs', however -- "any underwater form of insects, crustaceans, snails, or worms" -- and that settles that matter.

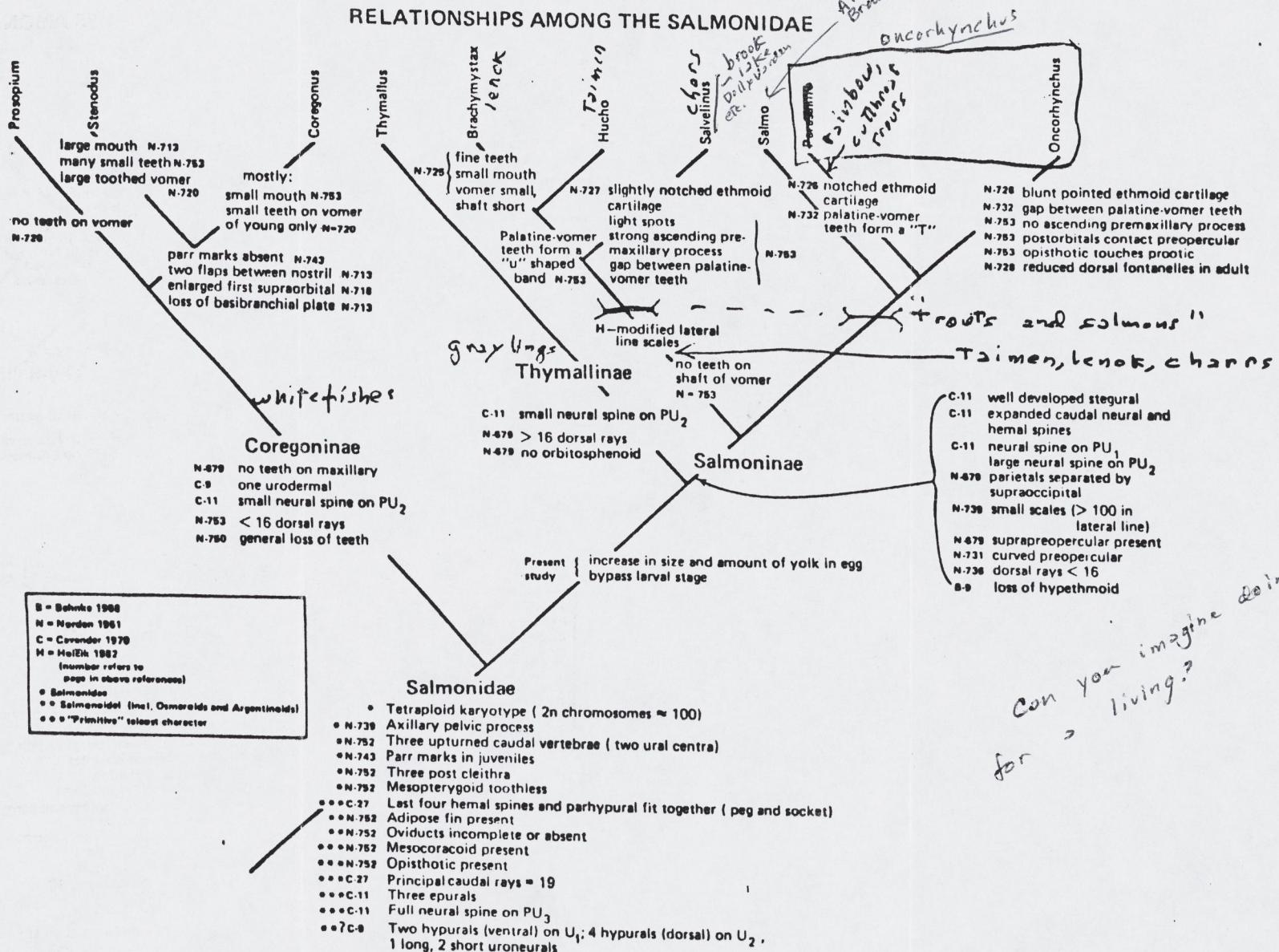
No Every year or two someone brings in a natural brook x brown hybrid (tiger trout). Both species spawn at same time in essentially similar habitat. Males are very unselective in whom they try to mate with (male guppies in aquaria may try to insert their gonopodia into goldfish). I suspect a small brook trout male struck onto a brown trout redd and released sperm during the mating act. I assume you are netted. I recall Bob Behnke referring to you in the D.C. area.

Have you fished Sixteen Mile Crk., just to the north of you? The only stream I know where the native "lewisii" subsp. of cutterthroat trout coexists with rainbow trout & brown trout. Best regards,

Bob Behnke

Salmon (DRW)
 Coregonus (DRW)
 Salmoninac (DRW)
 Species (both)

Kendall & Betinke 1984



Colorado
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June 3, 91

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Dear Datus:

I'll plan to phone you, probably evening of July 16 and see what we can work out for the 17th-18th - and I accept your dinner invitation for the 17th.

I'll be away most of the time after next week (June 10) attending meetings in N.Y., ID, WA, & Salt Lake City till I arrive in Bozeman on July 16th.

Enclosed is copy of response to one of the antagonistic letters received by Trout magazine. Editor asked me to pick one for response. I believe he's looking for ways to fill up pages to meet budget restrictions. I'm still amazed at the workings (or nonworking) of human mind. The writers all make point of being factual, critical, rational, etc. and then contradict themselves as they blather on in attempt to make a point. This letter writer cited the fact that salmon from the McCloud R. sent by Livingston Stone were stocked in Great Salt Lake (if they didn't know their salmon in the 1870's, why would

They be stocked in G.S.L., -- or Mississippi R.?)

Another letter writer scolded me for using example of Hewitt's claim that a pair of heron cleaned all the brook trout out of a stream (without presenting any factual data). Halford himself had already made such a pronouncement -- forever establishing the scientific basis for heron cleansing out a stream -- so there! Can't really argue with such logic -- known as 'appeal to authority'.

Regards,
Bob

Colorado
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July 14, 93

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Dear Datus:

Enclosed is copy of Hewitt article and copy of A.F.S. order form. To date, A.F.S. is sole source. They want to maximize profits so I, as author, receive no royalties and must purchase copies at very small discount. My price (\$25 soft, \$32 hard) is a \$8-9 saving over nonmember price, so if you want to save a few bucks, I can get you one at 'discount' price.

Regarding original sources for authenticity, I believe I sent you copy of my note on Livingston stone in Fall 1990 Am. Fly Fisher (Mus. Am. Fly Fishing) showing that the original hatchery rainbow trout did not come from McCloud R. For 100 years all authors repeated D.S. Jordan on matter and no one looked at original sources of information.

I'd love opportunity for another Mont. trip. I thoroughly enjoyed the 1991 trip. Bob Hunt (Wisconsin) told me he fished your

spring creek last year. He was also impressed.
Joe Urbani (Interflue) tells me it's better than
ever.

Sincerely,

Bob

VII : 21 : 92

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Dear Drs.:

Last week I saw Frank Richardson at West. A.F.S. meetings and he reminded me of your inquiries on the 'evolution' of trout habitat, as the basis for understanding why different rivers draining different watersheds of different landscape types, have different habitat characteristics - which, in turn, influence invent. diversity, trout feeding, etc. - Basically, what terrestrial components -- large boulders, trees, - are 'recruited' into river channel.

I think you're on to some interesting phenomena that should make for some genuine, keystone type angling literature landmarks (if you can tie it all together and interpret it in my anglers, at least, believe they will catch more fish if they understand this new info.).

I don't want to overload your circuits, but I'll enclose some pages from my trout monograph (Am. Zool. Soc. sched. to publish in Sept.) which raise a few fascinating phenomena that you might

consider for popular, educational articles;
One concerns Allen's Paradox and how do trout
get enough to eat when sampling of
stream substrate often shows not enough
food to support numbers/biomass of trout
there - most fisheries biologists are not
sure of hypotheric fauna.

Another paradox is 'optimal foraging
theory' - why don't trout select for
largest items as predicted by the theory?

Also items on large woody debris,
evolution of stream & habitat, and the
stream continuum theory + USFWS publ.
on stream type & invent. sp. --

These should keep you occupied
for a while. I hope you pursue
your interests and come up with
the keystone-landmark articles. Currently,
Leonard Wright and few other writers
dabble in 'scientific' explanations for
anglers, but I really haven't seen
much improvement over E.R. Heavitree's
stage of thinking of 50-70 years ago.

Good luck,

Bob Behnke

— Behnke, R. J., 1992 (in press) — Native Trout
of western N. Am. — A. F. S. monogr. ser.

temperatures, 60–70 years (about 20 generations) seem to have been too few for rainbow trout to expand its functional temperature range in the Firehole River.

Feeding and growth are stimulated more by a fluctuating temperature than by a constant temperature. Spigarelli et al. (1982) compared the feeding and growth rates of three groups of adult brown trout in three different temperature regimes during a 57-day period. One group was reared with a daily regular cycle of 9–18°C (mean, 12.5°C), the second group was reared at a constant temperature of 13°C, and the third group was maintained in an arrhythmic temperature regime of daily fluctuations and a gradual increase of daily mean temperatures (range, 4–11°C; 57-day mean, 7.7°C). The trout were fed alewives to satiety twice a day. At the end of 57 days, the mean food consumption and weight gain per individual reared in the daily 9–18°C cycle were by far the best: 752 g and 163 g, respectively. Fish reared at a constant 13°C consumed 459 g and gained 104 g, on average, while fish in the arrhythmic temperature regime consumed 476 g and gained 94 g. In constant-temperature trials at the Bozeman Fish Cultural Development Center (Dwyer et al. 1981, 1983a, 1983b), trout raised at 7–8°C had only 20% as much growth as trout raised at 13°C after 140 days, but the brown trout tested by Spigarelli et al. grew about as well at fluctuating low temperatures as they did at a constant 13°C. Evidently, diurnally fluctuating temperatures promote more efficient conversion of temperature units to growth than do constant temperatures, presumably by stimulating greater food consumption. Konstantinov and Zdanovich (1986) also found more rapid growth with fluctuating temperatures than with constant temperatures for several species of fish.

Stream Foraging

Trout in streams typically feed more on drifting larvae of aquatic insects than on insects dwelling on substrates. Drift of aquatic insects is influenced by flow, temperature, season, and the species involved, but maximum drift density typically occurs at night with peaks around dusk and dawn (Bishop and Hynes 1969; Elliot 1970; Hynes 1970; Waters 1972). When interspecific and intraspecific competition is intense or benthic food availability is great, salmonids may pick invertebrates off substrates. Unless the prey organism is large, such as some species of stoneflies, however, drift feeding is more energy efficient. The papers just cited record that in small streams (5–10 m wide) with good riparian vegetation, 50% or more of the total diet of trout during the summer months of peak feeding may be invertebrates of terrestrial origin. This often-large terrestrial component of diets makes it difficult to directly relate instream invertebrate production to trout production. Nevertheless, several studies have concluded that trout production is too high to be explained by instream invertebrate production alone. This phenomenon is commonly known as the Allen paradox (Hynes 1970). Some of the discrepancy between trout production and instream invertebrate production probably involves terrestrial input into the trout diet. Many workers believe it is due more to limitations of sampling techniques, which often do not recover invertebrates occurring deep in the substrate (Allan 1983; Winters 1988). However, most fishery biologists have overlooked an invertebrate source of potentially great magnitude. This is the hyporheic fauna,

Allen's paradox
- doesn't seem
to be enough
insects in stream
to support trout
of trout found

44 RELATIONSHIPS, HISTORY, AND BIOLOGY

Hyporheic
zone food.
Trout

the assemblage of aquatic invertebrates that live and forage below ground in the water table of floodplains (~~Stanford and Gauvin 1974; Stanford and Ward 1988~~). This assemblage, which includes caddisflies, mayflies, and stoneflies, can extend more than a kilometer from a river channel (J. Ward, Colorado State University, personal communication). Recruitment from the hyporheic fauna could help explain the Allen paradox.

O 12
~~Stanford~~
~~Gauvin~~

Despite the apparently high consumption of annual invertebrate production by stream salmonids, most studies agree that salmonids do not influence density, biomass, or species composition of aquatic insects; predation takes only surplus production, and the characteristics of stream invertebrate communities show no change when salmonids are removed from a stream section (Allan 1982; Culp 1986). On the other hand, when Wilzbach et al. (1986) modified a small stream in Oregon to enlarge the area used by feeding cutthroat trout, fish growth increased and invertebrate drift decreased, ostensibly because predation depressed invertebrate abundance. The authors concluded that in most natural streams, structural complexity prevents salmonids from feeding efficiently and taking more than surplus production. As discussed earlier in this chapter, surplus invertebrate production often is adequate for the existing fish population; in western streams of high gradient, trout populations are more commonly limited by habitat. Where habitat is limiting, increased fish biomass should be expected from the addition of instream structures that increase the amount and quality of the habitat and make previously inaccessible food available. Conversely, a food-limited population would not be expected to benefit from artificial habitat improvements. For example, the growth and biomass of trout (mainly brown trout) decreased in a zone of the main Au Sable River, Michigan, when pollution abatement markedly reduced the influx of nutrients and, consequently, the production of invertebrate prey. Intensive additions of instream habitat devices failed to reverse the decline of this trout population (Alexander et al. 1979), which appears to be food-limited.

Substrate diversity influences invertebrate abundance, as pointed out earlier, but an increase in invertebrate production can generally come about only from an increase in primary production, which is governed by light and nutrients. If a small headwater stream is overgrown with vegetation, canopy removal allows more sunlight to reach the water, which increases primary and secondary production (Murphy and Hall 1981; Murphy et al. 1981). Artificial enrichment also may stimulate production, as suggested by the Au Sable example just above. Black Earth Creek, Wisconsin, a stream organically enriched by sewage effluent, had a reported annual trout production of about 400 kg/hectare, which was three to four times greater than unenriched trout streams of the area (Brynildson and Mason 1975; Alexander and Ryckman 1976).

Warren et al. (1964) dripped a sugar solution (sucrose, a normal product of primary production) into test sections of Berry Creek, a very small Oregon stream. The sucrose stimulated massive production of bacteria, which were consumed by aquatic insects. The end result was more than a sevenfold increase in the production of cutthroat trout, although trout food consumption only doubled. The likely explanation of this seeming anomaly is that the trout in tiny Berry Creek had been obtaining barely more than maintenance rations before

the experiment. Suppose a fish required 5 g of food daily just to replace the energy lost to normal metabolism, but it was able to obtain only 6 g, leaving but 1 g for growth. Then a doubling of daily consumption to 12 g would provide 7 g above maintenance requirements for net production. The maintenance energy needs of fish should be kept in mind whenever food enhancement programs are designed and evaluated.

The addition of nitrate and phosphate to nutrient-limited lakes may enhance salmonid production. Fertilization of Great Central Lake, Vancouver Island, with these nutrients during 1970–1973 increased production of phytoplankton and zooplankton severalfold; the survival of juvenile sockeye salmon rose 2.6 times and the number of returning adults rose more than 7 times (Le Brasseur et al. 1978). Fertilization undoubtedly benefited sockeye salmon in Great Central Lake, but the links in the species' food web and the great increase in returning adults are not well understood.

Optimal foraging theory holds that feeding organisms attempt to maximize energy intake while minimizing energy expenditure. According to this theory, trout presented with different-size foods of equal edibility, nutritional value, and ease of capture will select the largest organisms they can handle and swallow easily. Experienced anglers know, however, that feeding trout often ignore larger flies presented to them but strike at rather precise imitations of a tiny insect. Ringler's (1979) laboratory studies suggest an explanation for this contradiction of optimal foraging theory. Ringler conducted feeding trials with prey organisms ranging in size from tiny (brine shrimp) to medium (small crickets and mealworms) to large (large crickets and mealworms). Wild brown trout fed brine shrimp on the first day continued to select, or prefer, brine shrimp on the second day when medium and large food items were introduced. True size selection of prey, as predicted by optimal foraging theory, was not fully manifested until the fourth and fifth days after the medium and large food items were introduced.

In natural streams, one insect species typically predominates in the drift at a time. Trout apparently fix on this species to the near exclusion of all other particles in the drift and on the surface; only after extended exposure to new images of larger organisms is the trout's fixation on the original feeding stimulus weakened. If this explanation is true, then the degree of selective feeding by trout will be inversely related to the diversity in size, shape, and color of organisms in the drift. Individual trout vary considerably in their ability to learn to feed on a new, energetically more favorable food item (Ringler 1985), and trout do select the largest individuals of a species in the drift when preying on a single species (Winters 1988). Thus trout seem to follow the spirit of optimal foraging, if not the letter.

In most streams, the overwhelming majority of aquatic insects—whether expressed in terms of diversity, biomass, or production—are small. When tiny organisms are the only important food supply for trout of all sizes in a stream, the older, larger fish are energetically disadvantaged; a food supply that is adequate for maintenance and growth of a yearling trout of 100 g may not be adequate for an age-3 trout of 300 g. Under such conditions, larger trout cannot meet their maintenance requirements (which are inflated because the fish must

perhaps
scientific basis
to the L> Branch
method of creating
? hatch

green drake

Large Woody Debris and Salmonid Habitat in a Small Coastal British Columbia Stream

Kurt D. Fausch

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and Thomas G. Northcote

Department of Zoology, University of British Columbia, Vancouver, B.C. V6T 2A9, Canada

Fausch, K. D., and T. G. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. Can. J. Fish. Aquat. Sci. 49: 682-693.

Sections of a small coastal British Columbia stream that had previously been cleaned of large woody debris (LWD) were compared with sections where most debris was left and with others where debris had been relatively undisturbed for at least 40 yr. Three sections where debris had been removed had simple habitat that was less sinuous, wider, and shallower and had less pool volume and overhead cover than four sections with more complex habitat where debris was retained. Habitat in four relatively undisturbed sections was generally similar to complex sections. Most pools in all sections were scour or plunge pools formed by LWD or large roots oriented perpendicular to the flow or angled downstream. Standing crop (kilograms per hectare) and individual weights of age 1+ and older coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*O. clarkii*) were significantly greater ($P < 0.02$) in complex than in simple sections. Biomass of age 1+ and older salmonids was closely related to section pool volume ($r^2 = 0.92$, $P = 0.0006$). Projections based on this model and average habitat conditions suggest that during 1990 a total of 8.0 kg of salmonid biomass, 5 times the current standing crop, was forgone in the 332-m simple reach due to prior debris removal.

Des segments d'un petit cours d'eau côtier de la Colombie-Britannique dans lesquels on a récemment retiré les gros débris de bois ont été comparés à des segments où la plupart des débris ont été laissés en place, et à d'autres dont les débris n'ont pour ainsi dire pas été touchés depuis au moins 40 ans. Par rapport à quatre segments où les débris n'ont pas été retirés et présentant un habitat complexe, trois segments dont les débris n'ont pas été retirés et présentant un habitat complexe, trois segments dont les débris avaient été retirés présentaient un habitat simple, moins sinueux, plus large, moins profond et ayant un volume de fosses et un couvert végétal plus faible. L'habitat dans quatre segments relativement peu perturbés était généralement semblable à celui des segments à habitat complexe. La plupart des fosses dans tous les segments étaient des fosses creusées par affouillement ou par une chute d'eau attribuables à la présence de gros débris de bois ou de grosses racines perpendiculaires au sens d'écoulement ou formant un angle ouvert vers l'aval. La biomasse totale (kilogrammes par hectare) et les poids individuels des saumons cohos (*Oncorhynchus kisutch*) et des truites fardées côtières (*O. clarkii*) d'âge 1+ et plus dans les segments complexes étaient supérieurs ($P < 0.02$) à ceux mesurés dans les segments à habitat plus simple. La biomasse des salmonidés d'âge 1+ et plus était fortement corrélée au volume total des fosses des segments ($r^2 = 0.92$, $P = 0.0006$). Les prévisions fondées sur ce modèle et sur les conditions moyennes des habitats laissent entendre qu'au cours de 1990, la biomasse de salmonidés dans le segment simple de 332 m a été réduite de 8,0 kg, ce qui représente 5 fois la biomasse totale actuelle, après qu'on y ait retiré des débris.

Received June 11, 1991

Accepted October 28, 1991
(JB077)

Reçu le 11 juin 1991

Accepté le 28 octobre 1991

Large woody debris (LWD) that enters forested streams plays important roles in shaping channel morphology (Keller and Swanson 1979; Bisson et al. 1987; Robison and Beschta 1990a, 1990b). Channels shaped and maintained by LWD in turn form the habitat template (Southwood 1977) to which salmonids and other aquatic biota in Pacific Northwest streams have evolved (Sullivan et al. 1987).

Human activity in the riparian forest frequently reduces the amount of LWD that enters or persists in stream channels. This occurs either indirectly by deforesting the riparian zone that is the source of LWD, or by direct removal of debris from streams. Both are especially detrimental in streams near urban areas where standing dead trees are removed due to the perceived hazard to human life and property, and fallen debris is more or

misguided aesthetic reasons. This cumulative debris removal is expected to greatly alter channel morphology and the biotic processes that depend on it.

We studied the role of LWD in forming salmonid habitat in a stream that traverses second-growth forest near the city of Vancouver, British Columbia. Our primary hypothesis was that sections where debris had been removed would have fewer pools and harbor fewer salmonids compared with those left uncleared.

Study Area

The Musqueam-Cutthroat Creek system (Fig. 1), adjacent to the city of Vancouver, British Columbia, drains a 730-ha watershed that is underlain by glacial till and sediments of

This fellow knows his stuff

The Evolution of Salmonid Stream Systems¹

Burchard H. Heede²

Abstract.--Evolution of salmonid stream systems is described in light of terrestrial history. The last ice age was responsible for the macro land forms in high mountain areas, the location of most salmonid streams. Hence, more powerful land-forming agents were at work then than now, and they inherited land forms they had no role in creating. Adjustments were required to carve suitable streambeds and to develop channel characteristics benefitting salmonids. In terms of man, long time spans were required to create a quasi-equilibrium condition within the stream systems as well as with other systems. Interaction with other systems is demonstrated for small salmonid streams running through forests by the incorporation of fallen logs into the channels, providing additional adjustment to overly steep stream gradients. If not disturbed by man, the interaction between the systems is harmonious, and quasi-balance prevails.

Before I discuss stream systems important for salmonids in detail, let us first look at terrestrial developments from a greater distance. This approach may help us to consider these systems in the context of global evolution, and thus enhance our understanding of their integrated existence. Such a view is of increasing importance in a world of rapid technologic development; an era that is not accustomed to accepting long time spans and is therefore not attuned to the mood of our terrestrial history. In this history, speed was not the driving force; time was plentiful for the attainment of systems that, in and among themselves, represented a harmonious entity. That is not to say that weaker systems did not disappear to make room for stronger ones. But evolution, not catastrophe, was the real driving force toward harmony--a harmony which, for example, allowed waterflows to find their bed and fish their home. In other words, this world was created so that each entity, may it be of physical or biological nature, attained its own niche.

As we learn from paleo-magnetism, the Americas separated from the Euro-Asian and African continents 180 million years ago (Alexander 1975), and geophysicists tell us that the continental plate on which you and I are sitting or standing at this moment, is still moving a few centimeters per year (Carr and Coleman 1974, Irving 1977), an imperceptible distance during our symposium. How

very much in agreement is this rate with overall global evolution, and how merciful it is with us human beings.

Evolutionary developments also took place at times we are inclined to judge as catastrophic. I think here of the Ice Ages. There were many ice ages on this globe, but average temperatures dropped by only a few degrees. Ice ages thus developed slowly, and disappeared slowly. This allowed vegetation and animals, and later man, to evade the glaciers and hostile environments. Many plants and animals migrated east and west around the Alps to warmer areas in Europe, and more directly to southern regions in the Americas. Between these ice ages, warming occurred to even tropical conditions to give relief from the impact of hostile environments.

The last ice age ended only 8,000 to 10,000 years ago. It lasted for some 1.5 to 2 million years, and like the former ones, was interrupted by warming periods. In high mountains, glaciers carved wide, U-shaped valleys. On the lowlands, continental ice masses plowed the earth surface, and in areas surrounding the frozen land, increased waterflows put their imprint on the land. Thus, in spite of many millions of years of land-forming processes, it was this last ice age that molded the shape of much of our land. The Pleistocene age, as we call the last ice age, is responsible for the present macro landforms in many regions.

This last statement has implications for salmonid stream systems, since the majority of them are located in mountainous land. If we compare our present mountain streams with the immense landforming agents of the ice age, for

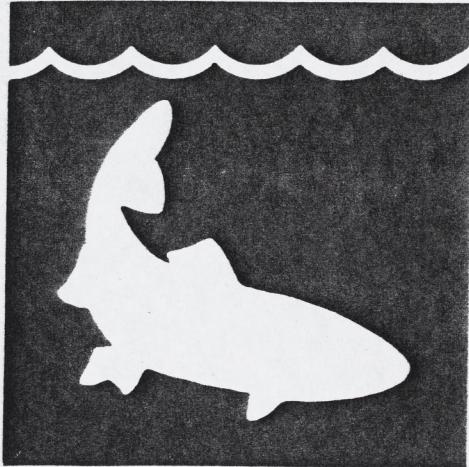
¹ Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24-25, 1984.

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re. Stream Continuum Theory: groupings by function (types feeding)

Table 15. — A general classification system for aquatic insect trophic categories (after Cummins 1973)

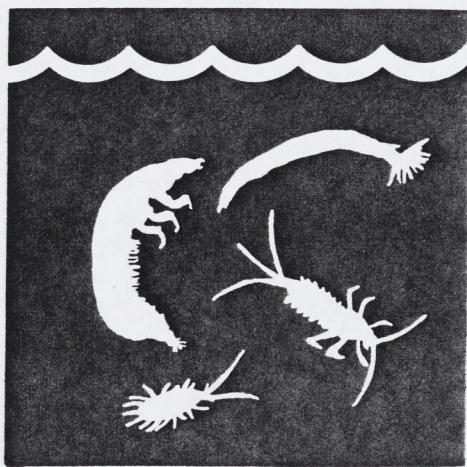
General category based on feeding mechanism	General particle size range of food	Subdivision based on feeding mechanisms	Subdivision based on dominant food	North American aquatic insect taxa containing predominant examples
SHREDDERS	Microns < 10 ³	Chewers and miners	Herbivores, living vascular plant tissue	Trichoptera (Phryganeidae, Leptoceridae) Lepidoptera Coleoptera (Chrysomelidae) Diptera (Chironomidae, Ephydriidae)
		Chewers and miners	Detritivores (large particle detritivores): decomposing vascular plant tissue	Plecoptera (Filipalpia) Trichoptera (Limnephilidae, Lepidostomatidae) Diptera (Tipulidae, Chironomidae)
COLLECTORS	< 10 ³	Filter or suspension feeders	Herbivore-detritivores: living algal cells, decomposing organic matter	Ephemeroptera (Siphlonuridae) Trichoptera (Philopotamidae, Psychomyiidae, Hydropsychidae, Brachycentridae) Lepidoptera Diptera (Simuliidae, Chironomidae, Culicidae)
		Sediment or deposit (surface) feeders	Detritivores (fine particle detritivores): decomposing organic matter	Ephemeroptera (Caenidae, Ephemeridae, Leptophlebiidae) Trichoptera (Glossosomatidae, Helicopsychidae, Molannidae, Odontoceridae, Goerinae) Lepidoptera Coleoptera (Elmidae, Psephenidae) Diptera (Chironomidae, Tabanidae)
SCRAPERS	< 10 ³	Mineral scrapers	Herbivores: algae and associated material (periphyton)	Ephemeroptera (Heptageniidae, Baetidae, Ephemerellidae) Trichoptera (Glossosomatidae, Helicopsychidae, Molannidae, Odontoceridae, Goerinae) Lepidoptera Coleoptera (Elmidae, Psephenidae) Diptera (Chironomidae, Tabanidae)
		Organic scrapers	Herbivores: algae and associated material (periphyton)	Ephemeroptera (Caenidae, Leptophlebiidae, Heptageniidae, Baetidae) Hemiptera (Corixidae) Trichoptera (Leptoceridae) Diptera (Chironomidae)
PREDATORS	> 10 ³	Engulfers	Carnivores: whole animals (or parts)	Odonata Plecoptera (Setipalpia) Megaloptera Trichoptera (Rhyacophilidae, Polycentropidae, Hydropsychidae) Coleoptera (Dytiscidae, Gyrinidae) Diptera (Chironomidae)
		Piercers	Carnivores: cell and tissue fluids	Hemiptera (Belostomatidae, Nepidae, Notonectidae, Naucoridae) Diptera (Rhagionidae)



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BIOLOGICAL REPORT 88(13)
JUNE 1988



Cooperating Agencies:

Fish and Wildlife Service
Environmental Protection Agency

Types of habitat assoc. w/
dif. invert.,