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by Hiram Li

Abstract

Chemical treatment to control non-game fish in trout streams is a management concept which must be reevaluated. The reasons for questioning this policy are the following: (1) the evidence used to demonstrate interspecific competition is circumstantial in nature; (2) the major approach which is used to evaluate competitive interactions, comparative dietary analysis, is inadequate; (3) trout territories may be limited in streams, not food resources. Trout are the most aggressive fish in trout streams and unlikely to be displaced; (4) alternative explanations can be used to explain phenomena usually ascribed to competition by non-game fish; (5) predation may be a more important process governing community interactions and fishing is a special form of predation. In conclusion, the concept of managing ecosystems should be promoted to replace single species management policies. A brief discussion of different approaches to analyze interspecific competition is included.

The process of interspecific competition is often invoked to explain shifts in population abundances of game and non-game fish in streams. Chemical treatment of these streams is conducted to reduce populations of non-game fish followed by a restocking program. I believe this is a management concept in need of serious reevaluation, one perhaps, which should be discarded. I believe that interspecific competition has been overestimated among species naturally associated in streams, and there is no scientific evidence which clearly demonstrates interspecific competition in streams is the major factor inhibiting the production of game fish.

What criteria are needed to prove the existence of interspecific competition? The definition I prefer to use is that stated by Weatherly (1966):

". . . competition is the state existing between animals securing supplies of the same resource from one region of the environment resulting in an interaction that produces some actually or incipiently deleterious effects on one or each of the animals."

From this definition we can extract the necessary and sufficient conditions, to use mathematical terminology for proof, these are:

- 1) that more than one species utilizes and is limited by the same resource in the same area,
- 2) the resource in question is in short supply, and
- 3) the removal of any species results in the increased growth

or survival of the remaining species, and conversely, the addition of any species results in the decreased growth or survival of the resident species.

What evidence do we have that interspecific competition exists among members of long established species associations in California's foothill streams, considered problem areas? Most of it is anecdotal impressions or hearsay evidence. Typical of the evidence is passages such as these quoted from a report (Curtis, 1957).

"They (suckers) are natural associates of trout, occurring in many trout streams, and the question can be raised why, under these circumstances, their elimination should benefit the trout. The answer is that the number and weight of these animals, consuming basic food stuffs and occupying living room, is so great that one cannot help believing that their absence would be beneficial."

"It (hardhead) is frequently caught by trout fishermen on trout lures, evidence that it competes with trout for food and living space. . . There can be no question but that the hardhead offers the trout serious competition."

We have relied upon correlative evidence too much; we observe a rise in numbers of one species concomitant with a decrease in another and then conclude the one species had a deleterious effect upon the other. We know however, as scientists, that correlation does not mean causation. Why do we jump so hastily to such conclusions? It is an easy answer and the usual management tool (piscides) is easy to use. For instance, an explosion of cyprinids was observed in Lac Leman in Switzerland following the overharvest of <u>Perca fluviatilis</u> and increased eutrophication. The limnetic habitat for cyprinids changed to favor them because of an increase in aquatic vegetation. Cyprinids then moved into the limnetic zone where they were presumed to compete with the game and commercially important fish for zooplankton (Laurent, 1972). Habitat changes which may stress the game species and physiologically favor cyprinids is an alternate explanation, but was not considered.

A second approach which is relied upon is the measurement of niche overlap, usually dietary overlap. The assumption made is that competitive interactions will result if several species use a resource in common. This is poor criterion, however, as investigators have used overlap as an argument both for and against food competition. It is critical to demonstrate the resource is limited, for only if it is, can competition among species be demonstrated. If the resource is not limiting, then the fish community is conserving energy by utilizing an abundant food resource more fully. Temperate stream fish have evolved into opportunistic feeders in order to cope with the labile and dynamic characteristics of stream systems. As a result, stream fish are more specialized for feeding in a specific portion of the water column or on a specific prey species. Streams are characterized by trophic webs more than by food chains. Food overlap, therefore, should be expected, especially during late spring and early summer when food is abundant (Nilsson, 1967; Gee and Northcote, 1963; Keast, 1966). Another reason why dietary overlap analysis is a poor approach is that severe interspecific competition may result in the

Errata

page 22:

"...the data suggests to us that competition for space may not be an important factor inhibiting the growth of trout towards California roach (Hesperoleucas symmetricus) reinforced habitat segregation in streams."

Competi

should read:

"...the data suggests to us that competition for space may not be an important factor inhibiting the growth of trout populations. Fite (1973) has reported that unidirectional aggression of trout towards California roach (Hesperoleucas symmetricus) reinforced habitat segregation in streams."

complete displacement of one species by another for a food resource and would not be detected.

Better methods are available for studying interspecific competition. I have classified them into three approaches. The best approach is also the most expensive and the slowest to give results: historical and continuous monitoring. This was used by Larkin and his co-workers on one of the few studies which is able to fulfill all the conditions needed to prove that interspecific competition occurred. It was found that the introduction of the redside shiner (Richardsonius balteatus) into a lake reduced the growth and survival of fingerling rainbow trout (Salmo gairdneri) and that the shiner was more efficient in cropping Gammarus than the trout. Gammarus was found to be a minor component of each species' diet during the study. However, an examination of past records revealed this amphipod was more abundant prior to the introduction to the shiner. Records enabled investigators to show that originally Gammarus was a limited resource and a major object of competition between the two species.

The second major approach is composed of two methods: the measurement of feeding and habitat displacement in field studies (interactive-selective seqregation), and (2) measurements of feeding intensity and displacement of feeding electivity in laboratory experiments. The major premise of the displacement method is that no displacement will occur if the resource in question is abundant. Thus the criterion of demonstrating resource limitation can be strongly inferred although not actually satisfied. The implied assumption is that displacement itself may be deleterious to either or all species involved. The basis of the approach is to measure resource utilization of allopatric and sympatric populations either in the field or in the laboratory, noting differences between the populations studied. Interactive segregation is the behavioral displacement whereby differences in feeding and habitat preferences between species are magnified, thus this process reflects the results of interspecific competition. Selective segregation is synonymous with character divergence, i.e., morphological and physiological differences have evolved to reduce interspecific competition. The difficult task is separating confounding effects of both interactive and selective mechanisms. Ivley's (1961) models of feeding intensity and electivity were developed to quantify differences in the amount of food ingested and shifts in food preferences caused by interspecific competition. This is primarily a laboratory approach because it is difficult, perhaps impossible, to determine coefficients needed for his feeding intensity model in the field. Feeding electivity reflects the relative abundance of a prey item in the stomach in relation to its relative abundance in the ecosystem. Shifts away from a preferred food item would indicate that displacement and interspecific competition had occurred. Caution is advised when using Ivlev's models which are descriptively powerful, but are "black box" types, fitted lines rather than "realistic" descriptions of biological processes. Ivlev's description of interspecific effects is also confounded with intraspecific processes.

The third approach has been pioneered by the Oregon State University group and is exemplified by the study of Brocksen, Warren, and Davis (1968). Their bioenergetic analysis in laboratory systems has several advantages: (I) resource limitations can be imposed by the experimenter; (2) metabolic effects of stress can be examined; (3) factorially designed studies can account for confounding factors; and (4) energy is the driving force of all ecosystems. Its major disadvantage is that stream ecosystems in the laboratory are not in order to eliminate artifacts.

There is growing evidence which reinforces my opinion that more work is meeded to determine the intensity and role of interspecific competition in limiting game fish production. Edwin Cooper (1970) concluded that removal of non-game fish resulted in only marginal success in most instances. He cited Chapman's (1966) behavioral work as a possible explanation; trout territories are more limited than the available food supply, thus intraspecific competition for space may be of greater importance than interspecific competition for food. My students and I have found that Shasta strain of rainbow trout (hatchery raised) were more aggressive than suckers or squawfish and clearly dominant in our laboratory streams (Table 1.). Although one must be careful in inter-

TABLE 1

Agonistic Behavior Among Fishes in Laboratory Observation Streams*

| Fish | Interactions/minute |
|---------------------|---------------------|
| trout-trout | 0.750 |
| trout-squawfish | 0.174 |
| trout-sucker. | 0.016 |
| squawfish-squawfish | 0.015 |
| squawfish-trout | 0.008 |
| squawfish-sucker | 0 |
| sucker-sucker | ? |

*Data is derived from 12 laboratory stream channels with 270 to 290 minutes of observation per channel (Li, unpublished).

preting the significance of interspecific aggression, the data suggests to us that competition for space may not be an important factor inhibiting the growth of trout towards California roach (<u>Hesperoleucas symmetricus</u>) reinforced habitat segregation in streams.

Alternative explanations can be used to account for the coincidental increases in non-game fish and decreases in game fish populations. I am going to present three different scenarios, none of which involves interspecific competition as a mechanism.

As Peter Moyle explained, species diversity and habitat diversity increases downstream and with stream size. This occurs through the process of species addition rather than species replacement. Allen (1969) cites the work of Clausen (1936) and suggests that stream fish are aligned on a metabolic gradient. Fish with higher metabolic rates are found in the cooler, swifter water upstream and those with lower metabolic rates, downstream. David Dettman, my graduate student, has found that trout and squawfish are associated in a zone of overlap in the foothill section of Deer Creek, 20 miles north of Chico, California. He found that water velocity and temperature are the two major factors which account for most of the variability in population abundances of the two species. During the late summer months of August and September the diel temperature range was 21° to 24°C. What does this mean physiologically? Let us examine Figure 1. If we assume that metabolic rates





of cyprinids are roughly similar, and granted that carp are extremely hardy fish, one can see that the trout are at the uppermost limit of their metabolic range at those temperatures; whereas the carp have not peaked. Increases in cyprinids and other non-game species at the apparent expense of trout may be attributable to the fact that foothill sections are marginal trout waters. Perhaps trout are being stressed; whereas the conditions may be favorable metabolically for good cyprinid growth. Any human activity can compound the problem. For example, streamside vegetation removal or channelization ay increase water temperatures.

Let me develop another scenario based upon human activity and allow me to develop it from some conclusions made by Jenkins (1969). He believes there are four advantages of territorial behavior for trout: (1) reduces energy lost in scramble competition for food; (2) offers protection from predation because the fish is intimately familiar with the territory it occupies; (3) reduces energy spent in foraging by optimizing its location to current carrying drift without expending excessive amounts of energy in maintaining position; and (4) keeps the most fit individuals in optimal habitats.

The following sequence of events ensue following the impoundment of upstream vater. Stream discharge is lowered and the amount of drift carried downstream is affected. Trout are known to abandon territories at low stream flow and scramble for food. Symons (1974) has found that salmonids which are forced to abandon territories are more subject to predation. Let us couple this to another observation Jenkins made. He saw that tui chubs (Gila bicolor) did not orient with the current, but often foraged broadside to it. This led him to suspect that current interfered with their feeding. Thus, if the current is decreased, less energy is expended in foraging and increases in tui chub biomass result. Similarly, increases in squawfish and hardhead populations in foothill streams may also result from decreased flows.

I have simulated a final scenario using a pair of modified Lotka-Volterra competition equations (Table 2). These equations describe the change in growth rate with respect to time. A recursive part of the simulation model accounted for the population sizes at any point in time. Both populations are limited by the carrying capacity of the stream. The only difference between the two species is that one, trout is harvested. In fact, the model of trout dynamics is a slight modification of Shaefer's model used to estimate maximum sustained yield of an exploited population. The initial conditions were these: (1) intraspecific competition is more intense than interspecific competition; (2) in order to demonstrate that strong interspecific competition need not be important in the scenario, the interspecific coefficient is set to a low value; (3) the carrying capacity for each species is 1,000 fish; (4) a 10% harvest is applied to the trout population. None of the harvested fish are released after capture; and (5) in order to make the demonstration more dramatic, let us assume that a stream has been poisoned and 100 suckers survived and 100 trout were planted.

As can be seen from Table 2, the sucker population grows much faster than the harvested trout population. The difference in the size of the two populations increases through time. The sucker populations stabilized at 996 fish in the 32nd year (1,000 is not reached because fractional integers were chopped off in the computer routine). The trout population reaches an asymtote of 594 fish in the 44th year. The carrying capacity for trout was nearly halved by fishing, which is logical because fishing is a form of predation and predation is one of the factors which determines carrying capacity. If fishing pressure is stopped, the population of trout reaches its saturation level of 997 fish (again, 1,000 fish is not reached because of the chop function) in 21 additional years. We can also set the initial conditions at 1,000

| | and the second sec | |
|------|--|-------------------------|
| YEAR | TROUT | SUCKERS |
| 0 | 100 | 100 |
| 1 | 112 | 122 |
| 2 | 125 | 148 |
| 3 | 139 | 179 |
| 4 | 155 | 215 |
| 5 | 172 | 257 |
| 6 | 190 | 304 |
| 7 | 209 | 356 |
| 8 | 229 | 413 |
| 9 | 250 | 473 |
| 10 | 271 | 535 |
| 11 | 293 | 597 |
| 12 | 315 | 657 |
| 13 | 337 | 713 |
| 14 | 359 | 764 |
| 15 | 380 | 809 |
| 16 | 400 | 847 |
| 17 | 419 | 879 |
| 18 | 437 | 905 |
| 19 | 454 | 926 |
| 20 | 470 | 943 |
| 21 | 485 | 956 |
| 22 | 498 | 966 |
| 23 | 510 | 974 |
| •• | | |
| 45 | 594 st | abilized 996 stabilized |
| | in | year 44 in year 32 |

The simulated effects of constant harvest upon the population dynamics of two species one of which is harvested (trout) and the other of which is not (sucker).

MODELS (modified Lotka-Voletrra Models)

dTrout/dt = [rx Trout] (K - Trout - alpha x Sucker) - [qf x Trout] K

$$dSucker/dt = [rx Sucker] (K - Sucker - beta x Trout)$$

K

Trout (t+1) = Trout (t) +dTrout/dt

 $\operatorname{Sucker}_{(t+1)} = \operatorname{Sucker}_{(t)} + \operatorname{dSucker}/\operatorname{dt}$ RECURSIVE PART OF MODEL

KEY TO SYMBOLS

Trout = numbers of trout, Sucker = number of suckers, r = intrinsic rate of increase, alpha = competitive influence of suckers on trout, beta = influence oftrout on suckers, K = carrying capacity, <math>qf = harvest (catch coefficient x fishing effort)

INITIAL CONDITIONS

Trout = 100Sucker = 100r = 0.25K = 1,000qf = 0.10beta = 0.00015alpha = 0.00015

fish of each species and begin fishing for trout. In 24 years an asymptotic value of 600 fish is reached. We may be wasting time and money by implementing a poisoning program on the evidence of an increased ratio of "rough fish" to trout. This simple mathematical demonstration may suggest a reason for the success of the Hat Creek project: lower trout limits and a catch and release program.

Predation may be more influential in community interactions than interspecific competition. This has been advocated by prominent ecologists, such as Pobert Paine of the University of Washington and Stanley Dodson of the University of Wisconsin. Foerster and Ricker (1941) found that the survival rate of a commercially important species, sockeye salmon, could be greatly increased by gill-netting "pest" species (Table 3). It may shock Californians that fish-

TABLE 3

Effect of the Removal of Trashfish from the Cultus Lake System on The Survival of Sockeye Salmon (after Foerster and Ricker, 1941).

| 944 Anno 1944 - Yong Ballerin Andria State - Andria | | 1974 - Young Constant (1974) | | SURV | IVAL F | ATE |
|--|---------------------------------|------------------------------|------|----------|---------------|-----------|
| | | Natural | from | spawning | Pl | anted fry |
| Before pr After pre | | 1.78 7.81 | | | 4.16 13.05 | |
| Removed: | 10,000 squawfish 2.300 trout | | | | · un | |

eries managers in other regions consider fish we prize as "trash". But it was found that most of the predation on sockeye salmon was attributable to cutthroat trout, coho salmon, and Dolly Varden because their metabolic rates demanded more energy intake than the more abundant squawfish (Table 4) (Hart

TABLE 4

Predator Damage in Squawfish Units (after Foerster and Ricker, 1941)

| FISH | SQUAWFISH UNITS |
|--|---|
| Cutthroat trout Coho salmon Dolly Varden | 5 squawfish 4 squawfish 3 squawfish |

and Burgner, 1972). It has been suggested that sculpins and other "rough fish" are serious predators of trout eggs. Paul Needham, in his classic book, Trout Streams, cites studies which point out the greatest egg predators are trout

themselves. The best testament to this fact is the effectiveness of trout and salmon eggs as trout bait. Needham (1938), and Hart and Burgner (1972), emphasize that most eggs which are consumed by fish are those which drift from the redd and would not have developed anyway. It is another means by which energy in conserved. Campbell (1971) captured suckers foraging over redds during the night. Stomachs were examined immediately; the stomachs contained numerous invertebrates but no eggs were found. Egg predation is not serious because trout usually defend the redd up to three weeks and the eggs are protected by a layer of pea gravel.

Competition between species does occur in some situations. A species may be expanding its range, and thus entering into new interactions. The displacement of a species may occur in the severest instance, or through time competition is reduced through character divergence. Exotic species have always provided the best examples of competitive displacement. Perhaps our impressions of "rough fish" competition stems from the numerous problems caused by the Asian carp, truly a trash fish. Studies of predator-prey and competitive systems have found that stabilization and long-term coexistence is a function of environmental heterogeneity (habitat richness). Simplification of stream systems by channelization and impoundments will intensify competition among fish because the opportunity to express morphological, physiological, and behavioral adaptations will be limited. Drastic environmental perturbations will intensify competitive stress and increase physiological stresses. Reservoirs often have problems because of environmental simplification, introduction of exotic bait fish, and changes in hydrologic conditions. I am not saying the interspecific competition does not exist in natural conditions but until we have better evidence to show that it is intense among members of a natural association, we are guilty of practicing bad science when we apply chemical treatment to streams.

In addition to the biological objections to chemical treatment just discussed, I have two philosophical objections. First, the very fact the terms "rough fish" and "trash fish" are still commonly used by fisheries managers indicates that we are allowing rather narrow social demands to dictate management policies. For example, from the point of view of sockeye salmon managers, species we consider to be valuable game fish are pests because they limit the production of the socially more important (i.e., more valuable) salmon. Similarly many California "rough fish" such as hitch, blackfish, and splittail are prized in oriental communities. In fact "game fish" are only important because of their present social and economic value. We need to broaden our management perspectives and to try to change societal values that have resulted in the narrow policies of the past. Second, we need to recognize there is an increasing need for protein to feed human populations. Carlander (1955) has shown that productivity of a system, as inferred from standing crop estimates, increases with the number of species which inhabit it (Figure 2). It is paradoxical that we cannot make better use of all our fish resources. We are wasting it through chemical poisoning, when perhaps we could be harvesting this protein source.

As these last two objections indicate, most of our fisheries management policies are based upon the management of a single species. Even our mathematical models are mostly devised to estimate the maximum sustained yield of



FIGURE 2. The relationship between production as inferred from standing crops and the number of species in reservoirs (from Carlander, 1955, J. Fish. Res. Bd. Canada).

a single species. Such policies and models are no longer adequate. We now need to view the management of ecosystems as our objective. Hart and Burgner (1972) have illustrated the complexities and problems of managing a species complex using the Cultus Lake and stream system as an example. If one attempts to control predation of sockeye salmon by the predator Dolly Varden, then the stickleback, a sockeye salmon competitor, will increase because it too will suffer less predation pressure. If one controls the stickleback, a buffer species will be removed and sockeye juveniles will be subjected to greater predation pressure. Sculpins prey upon sockeye salmon fry, but the larvae

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and fry of the sculpin are also prey items for sockeye salmon juveniles. We cannot manage intelligently without understanding the mechanics of an entire accesstem.

Thus, my final recommendation is this. The state of California needs to establish the California Natural History Survey. The needs of the greater public should be served. It is not fair that the sportsmen carry the financial burden of agency conservation work for the entire state any longer. Furthermore, long-term records would enable us to monitor the status of our environment better. The work of Johannes and Larkin (1961) could not have demonstrated competition between redside shiners and rainbow trout without the availability of long-term records. Stephen A. Forbes, the founder of the Illinois Natural History Survey, advised us in his famous monograph, "The Lake as a Microcosm," published near the turn of the century, that one could not understand largemouth bass unless one understood the ecology of the lake in which it dwells. Surely this is the reward of long-term research.

References

Allen, K. R. 1969. Distinctive aspects of the ecology of stream fishes: a review. J. Fish. Res. Bd. Canada 26(6):1429-1438.

- Beamish, F. W. H. 1964. Respiration of fishes with special emphasis on standard oxygen consumption. Can. J. Zool. 42:177-187.
- Brocksen, R. W., G. E. Davis, and C. E. Warren. 1968. Competition, food consumption and production of sculpins and trout in laboratory stream communities. J. Wildl. Mgmt. 32(1):51-75.
- Campbell, P. K. 1971. Influence of light and dark periods on spacial distribution and activity of the white sucker, <u>Catostomus commersoni</u>. Trans. Am. Fish. Soc. 100(2):353-355.
- Carlander, K. D. 1955. The standing crop of fish in lakes. J. Fish. Res. Ed. Canada 12(4):543-569.
- Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. Amer. Nat. 199(913):345-357.
- Clausen, R. G. 1936. Oxygen consumption in freshwater fishes. Ecology <u>17</u>: 216-226.
- Cooper, E. L. 1970. Management of trout streams. pp. 153-162. In: N. G. Benson (ed.) A century of fisheries in North America. Amer. Fish. Soc. special publ. no. 7.
- Curtis, B. 1957. Rough fish control in north fork Feather River under reduced flow. Mimeo Report P.G. & E., 5 pp.

Fite, K. R. 1973. Feeding overlap between roach and juvenile steelhead in the Eel River. Master of Science Thesis, Humboldt State College, 38 pp.

- Foerster, R. E. and W. E. Ricker. 1941. The effect of reduction of precicious fish on survival of young sockeye salmon at Cultus Lake. J. Fish. Res. Ed. Canada 5:315-336.
- Forbes, S. A. 1887. The lake as a microcosm. Ill. Nat. Hist. Surv. Bull. (15):537-550. Reprinted from the Bull. Peoria Sci. Assoc. (1887).
- Cee, J. H. and T. C. Northcote. 1963. Comparative ecology of two sympatrics species of dace (Rhinichthys) in the Fraser River system, British Columbia. J. Fish. Res. Bd. Canada 20(1):105-118.
- Hartman, W. L. and R. L. Burgner. 1972. Limnology and fish ecology of sockeye salmon nursery lakes of the world. J. Fish. Res. Ed. Canada 29(6):699-715.
- Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, 302 pp.
- Jenkins, T. M. 1969. Social structure, position choice and microdistribution of two trout species (Salmo trutta and Salmo gairdneri) resident in mountain streams. Anim. Behav. Monogr. 2(2):57-123.
- Johannes, R. E. and P. A. Larkin. 1961. Competition for food between redside shiners (Richardsonius balteatus) and rainbow trout (Salmo gairdneri) in two British Columbia lakes. J. Fish. Res. Bd. Canada, 18(2): 203-220.
- Keast, A. 1966. Trophic interrelationships in the fish fauna of a small stream. Great Lakes Res. Div., Univ. Mich., Pub. no. 15:51-79.
- Laurent, P. J. 1972. Lac Leman: effects of exploitation, eutrophication, and introductions on the salmonid community. J. Fish. Res. Bd. Canada, 29(6):867-875.
- Needham, P. R. 1938. Trout streams. 2nd ed. Holden-Day Inc., S.F. 241 pp.
- Nilsson, N. A. 1967. Interactive segregation between fish species. Pp. 295-314. In: S.D. Gerking (ed.), The Biological Basis for Freshwater Fish Production. Blackwell Sci. Publ., Oxford, 495 pp.
- Schutz, D. C. and T. G. Northcote. 1972. An experimental study of feeding behavior and interaction of coastal cutthroat trout (Salmo clarki clarki) and Dolly Varden (Salvelinus malma) J. Fish. Res. Bd. Canada, 29:555-565.
- Symons, P. E. K. 1974. Territorial behavior of juvenile Atlantic salmon reduces predation by brook trout. Can. J. Zool. 52(6):677-679.

Weatherly, A. H. 1966. Ecology of fish growth. Nature, 212:1321-1324.

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UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT



ROUTING AND TRANSMITTAL SLIP

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that do a good job of maintaining riparian habitat condition. Data collected thus far on 300 reaches is being used in our Range E.J.S. Only 42.5% of total reaches valed fair on poor, which supprised me. Coive me a call sometime

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WOODY RIPARIAN SURVEY

I. Purpose and Application

This extensive survey was devised in 1976 to fulfill a need for gathering data with which to evaluate the relative impacts of livestock grazing on numerous small headwater streams, and for preparation of an environmental impact statement. No suitable techniques were available which provided meaningful guantitative data with minimal effort. Time limitations and extensive data needs were prime considerations. About 300 stream reaches dispersed over extensive rugged and remote areas had to be analyzed in two field seasons by 1-2 fieldpersons.

The technique is suited to analysis of perennial or ephemeral flow streams which support deciduous woody species on the upper banks. The survey was found to apply to almost all foothills habitats in southwestern Montana. This includes sagebrush steppe, foothills prairie, Douglas-fir forest, and western spruce - fir forest associations identified by Kuchler (1964). Foothill riparian habitats in this area are dominated by willow (Salix spp), with mixtures of aspen (Populus tremuloides), dogwood (Cornus sericea), maple (Acer glabrum), alder (Alnus sinuata), birch (Betula glaudulosa, B. occidentalis), cottonwood (Populus fremontii) and rose (Rosa woodsii). Occasionally conifers, such as Douglas-fir (Pseudotsuga menziesii), spruce (Picea engelmannii), alpine fir (Abies lasiocarpa), Rocky Mountain juniper (Juniperus scopulorum), and common juniper (J. communis) are intermixed. The survey does not apply to closed canopy conifer sites. Likewise, it may be of doubtful value in stands dominated by mature aspen where canopy is sufficiently dense to impair reproduction.

The basic assumption is that condition and vigor of palatable woody species are valid indicators of riparian habitat condition. Values of herbaceous species in riparian ecosystem productivity, bank building processes and sediment entrapment are recognized. However, difficulty is experienced in working with herbaceous species due to their varying availability where livestock are present. A basic disadvantage of the survey is its inapplicability to riparian reaches lacking palatable woody species, though these are rare in southwestern Montana.

The survey is a valuable supplement to stream surveys (BLM 6761), channel stability surveys as described by Pfankuch (1975), and water quality evaluations on streams (BLM 6674). The survey seems appropriate in view of the emphasis placed upon riparian habitat by the Director (WO I.M. 78-410).

II. Methods

A. Pre-survey Analysis

Streams shown on U.S.G.S. quadrangle maps are evaluated on aerial photographs. Color infra-red photography is particularly well

suited to this. All known fences, grazing allotment boundaries, and pastures must be plotted on quadrangle maps or aerial photo overlays. The intent is to identify stream reaches before initiating a survey. A reach is defined as a synonymous woody riparian habitat type within a management area, such as a pasture or grazing allotment. In no case does a survey reach extend beyond a fenced management pasture or allotment. This is necessary, since individual pastures are often managed differently within a system. A reach thus always terminates when a fence is encountered. More than one reach may occur within a pasture, however, if the habitat type changes substantially, or if non-riparian habitat types (dense conifer, etc.) are encountered.

A riparian reach number should be assigned. Series can be used for each planning or administrative unit, such as T-1 for reach number one in the Tendoy Unit. Reach length is measured with a map measuring tool and recorded. This allows selection of a sample step interval which will provide a minimum of 100 sample plants per reach. This satisfies the statistical general rule that $n\mu$ and $n(1-\mu)$ must be equal to or greater than 5, where size and form classes comprise 5% or more of a sample. Judgement on the part of the surveyor may dictate larger sample sizes where unusual variability seems apparent, or woody species diversity is unusually great.

| | Step | Approx. |
|-------------------|----------|-------------|
| Reach length | Interval | Sample Size |
| 0.25 = 0.50 miles | 5 | 94 - 188 |
| 0.50 - 1.00 miles | 10 | 94 - 188 |
| 1.00 - 1.25 miles | 15 | 125 - 156 |
| 1.25 - 1.50 miles | 20 | 117 - 140 |

B. Field Survey

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1. Survey Area

The survey area consists of the upper streambank. This is defined as the area between the normal high waterline and the next break in the topography. Where this cannot be readily identified, the general rule is to hug the high waterline. Woody species providing bank protection are most pertinent to evaluation of grazing impacts. Woody plants well away from the banks are much less significant to the aquatic ecosystem productivity and stability.

On streams large enough to constitute barriers to livestock, record the side surveyed (west/east). Each side constitutes a separate survey reach. On small streams, survey both sides by crossing the stream periodically.

The surveyor walks along the upper bank area, and at the predetermined step interval, selects the <u>highly palatable</u> woody plant nearest to his/her foot. Conscientious effort is required not to overlook small plants.

2. Survey Species

Palatable species in this survey included willows, aspen, dogwood, maple, alder, birches, and cottonwood. Species not surveyed included currant (<u>Ribes spp</u>), rose, sages (<u>Artemisia</u> <u>spp</u>), rabbitbrush (<u>Chrysothamnus nauseosus</u>), cinquefoil (<u>Potentilla fruticosa</u>), and coniferous species. Local variations dictate selection of highly palatable species. The only consideration here is selection of species which are "decreasers" under heavy grazing pressure.

3. Equipment

The survey form (Appendix I), map or aerial photo, plastic flagging, clipboard, SLR camera, hand counter, and measuring stick are the only materials needed. A measuring stick is easily made by marking 1-10 millimeter and 11-15 millimeter intervals on the terminal end of a $1" \times 3/4" \times 24-30"$ fir or pine board. A blunt felt-tip marker and plain paper (or BLM form 4412-16) are useful when taking photographs. A large number (readily visible) may be placed on the clipboard and situated within shrubs or on the ground for reference to photo notes on the survey form.

4. Photographs

When starting and terminating reach surveys, take one photograph upstream and one downstream. Permanent stakes can be utilized, if desired. Additional photos should show typical areas and special problem areas. All photo locations should be shown by number on the map or aerial photo.

5. Shrub Criteria

Once a plant is selected, it is placed in a size class, a form class, and a height class. Dot tallies save space. Defini-tions follow.

a. Size class is determined by measuring the basal diameter at ground level, of the largest <u>live</u> stem on the plant.

b. A plant can be placed in only one form class.

i. Normal plants have fewer than 50% of the second year leaders clipped and are neither decadent nor dead.

ii. Heavily hedged plants have 50% or more of the available second year (not current annual growth) leaders clipped, and are neither decadent nor dead. Normally, bifurcation at the next lowest buds occurs when terminal buds are clipped. This is the best indicator of clipping. Numerous branches should be inspected. <u>Do not</u> consider leaders which are unavailable due to height (above 1.5 meters) or position (overhanging deep water, etc.). If all live leaders are unavailable, the plant cannot be heavily hedged. Hedging can be attributed to stock, big game, beaver, or any combination.

iii. Decadent plants have 30% or more of the crown area dead.

iv. Dead plants have no live tissue.

c. Height classes are established to distinguish between all available and partly available plants for most large ungulates. On most people, 1.5 meters is roughly eye height.

6. Canopy Measurements

Canopy coverage of palatable species, only, is measured at least ten times (every tenth plant). Canopy estimates are made by coverage class as described by Daubenmire (1959). A 4 meter by 8 meter modified Daubenmire quadrate is established by pacing and tying plastic flagging on each corner. The southwest corner is established at the pace point preceding every tenth selected plant. It is critical that bias not be induced by walking to the tenth plant and using it as the quadrate corner. The surveyor can climb to a higher ground level, if desired, to look down upon the quadrate.

7. Bank Erosion

Active bank erosion is estimated each time canopy is measured. Active erosion is defined as unstable bank area. Raw exposed soil areas where cutting is occurring during peak flows are generally obvious. Also included are areas so severely trampled by animals that physical detachment is anticipated in the forthcoming peak flow. Bank sloughing and undercut failures are included.

Dished out areas where severe past erosion has occurred may be characterized by aggregate and rubble compositions and gentle slopes. Such areas generally are not actively <u>eroding</u>, though they are <u>eroded</u>. An ocular estimate is made of the percentage of <u>total bank area</u> seen which is actively eroding, by looking up and down the stream. Constant attention must be given to bank erosion between sample sites, which allow adjustments when estimates are recorded. One bank equals 50% of bank area, thus if 20% of one bank is eroding, and the other bank is entirely stable, a 10% estimate is recorded, subject to adjustment based on observed erosion since the last sample site.

8. Bank Rock Content

Bank rock content is recorded with a dot each time canopy coverage and bank erosion are recorded. These criteria follow those used by Pfankuch (1975) in stream channel analysis. Upon completion of the survey, a large "X" should indicate the bank rock class most characteristic of the entire reach.

9. Potential Canopy

Potential canopy coverage should be estimated upon completion of the survey, in the field. Generally, this requires experience in surveying other similar reaches. Fenceline contrasts are particularly useful. Consider the percentage of hedged plants and the percentage of bank area which would be occupied by suppressed reproduction. Also consider existing canopy. Generally, average canopies greater than 75-80% are rare.

It may be useful to make estimates of the anticipated percentage increase. Judgement tempered by experience and consideration of survey data is required. Even though subjective in nature, it is of value to know if substantial canopy increases may be anticipated.

10. Survey Notes

Record notes on back of survey form. Always document presence or absence of stock, big game, beaver activity, etc. Other important considerations are obvious problems, or observations which may assist in interpreting the data.

11. Droppings

Upon completion of the survey, walk back along the same reach. Tally all livestock and big game droppings on a belt transect 2 meters wide (measured by outstretched arms). Compute droppings per hectare by multiplying 2 meters times reach length in meters, and dividing by 10,000. Record all droppings, irrespective of age.

C. Rating Reaches

The first step in rating reaches is to establish local criteria using streams judged to be in good condition. Exclosures, protected (fenced) streams, and exceptionally well managed areas are invaluable. A 95% confidence interval of mean characteristics for good condition reaches establishes the good category for each rating parameter (Appendix III). Rating parameters include normal plants, hedged plants, dead and decadent plants (combined), canopy coverage, reproduction, and bank erosion. Ratings used in the Dillon Resource Area are shown in Table 1.

Canopy coverage was weighted 3 times greater than other parameters. In this way, a reach with a dense canopy cover rates better than a reach with a sparse canopy, but identical vigor characteristics. Reaches are rated as poor, fair, good, and excellent for inclusion in URA as per BLM 1605.

Once reaches are rated, the land manager can decide if poor or fair ratings are satisfactory or unsatisfactory in terms of meeting various resource goals. In the rating used here, bank erosion of 40% or more and dead-decadent compositions more than 30% resulted in "unsatisfactory" reach ratings. A score is still computed, however.

In a few cases, reaches with high bank erosion rated "unsatisfactory," but "good" in vegetative characteristics. This a good indication of off-site problems, such as upstream watershed condition and peak flow characteristics. Reaches rating "unsatisfactory" due to dead-decadence may have good ratings in form class and reproduction. This is usually an indicator of drastic changes in management, or past artificial treatments (spraying or burning).

III. Results and Discussion

Approximately 300 reaches have been surveyed and rated. Data obtained has been useful as input in proposed AMP's, in evaluations of existing AMP's, and as URA, MFP, and EIS input. Some insight has been gained into an understanding of livestock grazing-riparian relationships. As a general observation, systems which employ "hot season" (7/1 - 9/1)grazing use in more than one year of three appear poorly suited to maintenance of riparian vigor. More detailed analysis of grazing system-riparian condition relationships is planned.

Aging of woody species indicated that the basal stem diameter (B.S.D.) classes are statistically valid indicators of age (Appendix II). Correlation coefficients between age class and diameter for willow, aspen, and birch were .9503, .9576 and .9242, respectively, (valid at 99.9%).

| | | | 1 Contractions |
|--|--|---|------------------------------|
| N O R M. | >78% 64-78% 50-63% <50% | 3 2 1 0 | |
| H E D G E D | <pre><14% 14-28% 29-50% >50%</pre> | 3 2 1 0 | |
| D C C A D A E N T · | <2% 2-16% 17-24% 25-30% >30% | 3 2 1 0 U | - |
| C A N O P Y | > 76% 59-76% 30-58% 20-29% < 20% | 9 6 3 1 0 | |
| R E P R C D. | $ \begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$ | 5MM 15 % ∠ 58 % 58- % 58- % 7- % > | MM % 87% 96% 96% |
| E R O S I O N | <4% 4-15% 16-30% 31-39% 540% | 3 2 1 0 U | |

Instructions:

Rate each parameter as shown and add the cumulative score. In a few cases age classes will fall into different score brackets; score reproduction in the bracket in which two of the three categories fall. Any reach with more than 30% dead and decadent or 40% or more bank erosion routinely rates unsatisfactory (u) irrespective of total score. The total score is a good indicator to determine if the "problem" is on-site or off site in origin.

| Excellent | 19-24 | |
|-----------|---------|--|
| Good | - 10-18 | |
| Fair . | 7- 9 | |
| Poor | <7 | |

| <u>B.S.D.</u> | Salix spp. P. | opulus tremuloides | Betula | occidentalis |
|---------------|---------------------------|--------------------------|--------|-----------------------|
| 1-10 mm | 1 - 4 yrs. 5 - 10 yrs. | 1 - 5 yrs. 6 - 8 yrs. | 1 7 | - 6 yrs. - 11 yrs. |
| >15 mm | + 10 yrs. | +8 yrs. | | +11 yrs |

Insufficient data were collected for <u>Cornus</u> <u>sp.</u> and <u>Alnus</u> <u>sp.</u> for analysis, but the same general relationship appeared to occur.

As an evaluation of the validity of data collected, the correlation between basal stem diameters greater than 15 mm and percentage plants greater than 1.5 meters tall was evaluated for all surveys, totaling 34, in the Ruby Planning Unit. The correlation coefficient was .864 (valid at 99%).

Stem diameter distributions were compared on two streams. Dyce Creek has been managed for approximately 10 years under a livestock grazing system well suited to riparian management. Hot season grazing use (7/1 - 9/1) occurs in only one year of three, and the stocking rate is "moderate." Rape Creek is not included in a management system. It is grazed each year during the hot season. Both streams are typical of mountain foothill riparian types. Sustained flows are 3-4 cubic feet per second, gradients are moderate (2-4%), substrates are mixed coarse gravel-fine gravel-fines, and woody compositions are dominated by willow with minor mixtures of other species.

Stem diameter distributions on Dyce Creek closely approximate a normal, bell-shaped curve (Figure 1). If diameter classes greater than 35 mm were not grouped, this would be more true. Rape Creek diameter classes are distinctively skewed toward larger diameter classes (chi square distribution?). Poor grazing management drastically changes age class composition of palatable woody species.

When interpreting riparian data, it is important to bear in mind that vegetative condition is only one of the many factors affecting channel stability. As an example, a stream with vigorous woody vegetation may have a high percentage of bank erosion. Upstream watershed condition, peak flow characteristics, channel alterations, and basic channel resistivity (particularly bank rock content), should then be evaluated. If a frail channel occurs, woody riparian species are of even greater value as bank protection. The question must always be asked, how much channel instability would occur if woody species were reduced? Due to the variety of other factors influencing bank stability, it is sometimes not possible to establish close correlations between woody canopy and percentage erosion.

Where channel vulnerability to erosion is documented by a channel inventory, such as that described by Pfankuch (1975), or by bank rock content data, good correlations are shown between bank erosion and riparian vegetative parameters. Cooper (unpublished) observed that





vegetation and bank rock content were the two riparian parameters most significant in terms of bank vulnerability to livestock damage. In this effort, bank rock content and/or Pfankuch stability ratings were obtained only in the Tendoy and Dillon West Planning Units. In these units, a valid (80%) correlation was shown between woody canopy coverage and bank erosion in reaches with less than 20% bank rock content (Appendix IV). A valid (80%) correlation also existed between percent heavily hedged plants and bank erosion. The best correlation (99%) occurred between percent normal plants and bank erosion. In earlier surveys, less exacting criteria were used for identifying hedged plants, thus the difference in validity (80% vs. 99%) may be attributable to slight sampling changes. Both relationships (hedged and normal) probably reflect a combination of trampling damage and indirect bank erosion through vegetative loss.

Several correlations substantiated the validity of the survey as a measure of the impact of grazing animals on riparian vegetation. A valid (99%) relationship between percentage hedging of woody plants and the estimated deficits in woody canopy was documented (Appendix IV). In reaches with 50% or more hedged plants, there was a valid (95%) relationship between percentage hedging and percentage dead-decadent plants. In reaches with 60% or more hedging, a valid (99%) relationship between percentage hedging and valid (99%) relationship between percentage hedging and young woody reproduction (1-10 mm) occurred. Hedging vs. old age class plants (15 mm) correlated closely (80% and 95%) in reaches with 50% and 60% or more hedging.

Significant correlations between riparian rating scores and bank erosion were found (Appendix IV, Figure 2). Riparian scores were altered, for the analysis, only by deleting points attributable to erosion. These relationships add validity to the survey method and further substantiate the relationship between vegetative vigor and stream channel stability. Where channel resistivity, particularly bank rock content, is unknown, the relationship is probably too general with which to predict bank erosion (see Figure 2, all reaches). Where bank rock content is known, bank erosion can probably be predicted with some certainty given a particular riparian condition score (Figure 2).

With bank rock contents of 20-40%, less erosion may be expected with a given riparian condition than on channels with less than 20% rock content. Reaches rating 7 points (low fair) may be expected to have $\pm 32\%$ and $\pm 46\%$ bank erosion where rock content is 20-40%, and less than 20%, respectively. Perhaps the greatest value in the use of the score-erosion correlation is the capability of demonstrating anticipated impacts in the decision making process where riparian habitat occurs. Environmental variability inherent to each riparian habitat must always be considered when predicting impacts of management proposals.

IV. Conclusions

The conclusions are that heavy annual livestock use on woody riparian stands may be expected to: (1) reduce woody reproduction; (2) increase the percentage of dead-decadent plants; (3) substantially change age class structure to the point where old (8-10 yr. plus) plants dominate; (4) eventually reduce total woody canopy as the older plants die and are not replaced; and (5) precipitate increased bank erosion and channel damage.



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Figure 2: Relationship (linear regression) between riparian score and bank erosion.

Degradation of vegetative vigor and channel stability generally increases sedimentation and invariably results in reduced fish habitat quantity and quality. Loss of woody cover increases the vulnerability of streams to livestock trampling damage and organic pollution. Increased summer water temperature and lower winter temperatures may be expected. Small streams may change appreciably from an allochthonous production to an autochthonous one. BLM studies of non-game breeding bird populations have indicated significant reductions in species diversity in poor condition riparian habitats. Poor riparian condition may be an indicator of competition between livestock and moose winter habitat, deer summer habitat, and mountain grouse habitats.

This brief analysis is intended only to document the use and applicability of this extensive survey. Data collected were particularly useful for establishing riparian objectives in grazing management plans. The criteria established for riparian ratings make useful and practical management goals. Once collected, the data are valuable for assessing trend in livestock management areas, big game management areas, and assessments of artificial treatments. A thorough analysis of livestock grazing impacts, considering various management options, is planned with data gathered in this effort.

The author recognizes the potential for use of ecological classifications and successional stages in riparian assessments. Development of such a system would necessitate availability of "near pristine" reaches representative of the various riparian associations. Due to the great attraction of such areas for livestock, unaltered riparian habitats are rare. Establishment of fenced study streams where stock are excluded, have great value for use in establishing management benchmarks and research control areas.

Literature Cited

Cooper, James L.

. .

1977. Unpublished, A Technique for Evaluating and Predicting the relations of Grazing On Stream Channels. 25 pp.

Daubenmire, R.

1959. A Canopy-Coverage Method of Vegetational Analysis. Northwest Science 33(1): 43-64.

Kuchler, A.W.

1964. Potential Natural Vegetation of the Conterminous U.S., Amer. Geographical Soc., Special Publ. No. 36.

Pfankuch, Dale J.

1975. Stream Reach Inventory and Channel Stability Evaluation. U.S.D.A., Forest Service - Northern Region, Missoula, Montana. 26 pp.

| TREAM C | TREAM Cottonwood Cr UNIT Ruby REACH NO. 8 ALLOTMENT #0469 LENGTH 2/ 0.5 | | | | | | | | | | | | | |
|------------------------|---|----------------------|---------------------------------------|-----------|--------------|---------|-------------|--------|------|------------|--------|-----------|---|---------------|
| LOCATION | NE | YNEY | SEC 13 | TO_NE | "SE" | SEC _ | 13 T | 75 | R 61 | W RECORDE | R Me | rritt- | DATE 9 | 13/78 |
| SPECIES | 3/ | SIZE4/ | | | FORM CLA | SSES 5 | | | | |] | PERCENT | HEIGHT | CLASSES |
| | | CLASSES | NORMAL | | HEAVILY | HEDG | ED | | | DECADENT | DEAD | SIZE | <1.5m | >1.5m |
| | | | | S | TOCK | | 1 B.GAME | 1 BEA | VER | | | CLASSES | N N | M N M M |
| . Sali | × | | | E | <u>a :-i</u> | <u></u> | · · | | | | | | U | 区区区 |
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| 65% 1a | irge ang | ular | BANK 140-65.5 m | ROCK CON | TENT9/ | | -40% w/mos | st in | 2 | 0% rock, m | ostly | | | |
| boulder | s 3 dcm | +numerous | \$ 1 ¹ ₂ -3 dcm | cobble | | . 1-1 | l'į dcm siz | e | g | ravel size | S . | | | |

| | DIAMETER | | CORRELAT |
|-----|----------|-------|-----------|
| | MEAN | C.I. | COEFFICIE |
| | (MM) | (95%) | (r) |
| 199 | | | |

BASAL DIAMETER VS. AGE

| AGE | N | DIAMETER MEAN (MM) | C.I. (95%) | CORRELATION COEFFICIENT (r) |
|--|---|--|---|-------------------------------------|
| <u>SALIX</u> <u>SI</u> 2 3 4 5 6 7 8 9 10 11 | PP. 6 17 13 10 8 11 9 11 4 <u>2</u> 91 | 7.83 8.94 8.61 12.6 13.62 13.81 19.00 18.27 17.25 24.00 | $ \begin{array}{r} \pm 1.32 \\ \pm 1.14 \\ \pm 2.02 \\ \pm 2.59 \\ \pm 4.53 \\ \pm 4.97 \\ \pm 8.15 \\ \pm 4.67 \\ \pm 7.41 \\ \pm 4.24 \end{array} $ | AGE = X & DIAMETER = Y r = .9503 |
| POPULUS 5 6 7 8 9 10 11 | TREMULOIDES 8 7 6 5 3 4 2 35 | 9.63 13.28 13.80 20.60 22.00 22.25 24.00 | ±2.60 ±2.87 ±2.85 ±11.08 ±3.00 ±6.40 ±4.25 | r = .9576 |
| BETULA 4 5 6 7 8 9 11 12 19 | 8 5 6 2 3 2 4 3 2 4 3 5 | 9.62 13.40 11.33 16.00 14.00 17.00 19.50 18.66 52.50 | ±3.29 ±3.36 ±2.65 ±2.82 ±6.24 ±7.07 ±8.42 ±4.04 ±34.64 | r = .9242 |

The following reaches were utilized for establishing rating standards for a "good" classification. A 95% confidence interval of mean characteristics established the range used for a "good" rating. 4

- A) Reaches
 - 1) Rochester R-1, 2, 3, 4, 9, 15, 17 2) Ruby R-12

| | Normal | Hedged | Decadent | Dead | 1-10 | 11-15 | >15 | Canopy | Erosio |
|---------|--------|--------|----------|------|------|-------|-------|--------|--------|
| R-1 | 67 | 19 | 7 | 8 | 12 | 15 | 73 | 73 | . 4 |
| P_2 | 68 | 23 | 4 | 4 | 19 | 14 | 68 | 75 | . 12 |
| n 2 | 5.8 | 33 | 4 | 4 | 3 | 9 | 87 | 56 | 12 |
| R-3 | 50 | 16 | 5 | 2 | 14 | 15 | 71 | 70 | 5 |
| R-4 | 77 | 20 | 0 | 0 | 23 | 24 | 54 | 69 | 15 |
| R-9 | 12 | 29 | 7 | 5 | 3 | 11 | 87 | 76 | 4 |
| R-15 | 73 | 16 | | , | | 07 | 50 | 50 | 4 |
| R-17 | 82 | 18 | 1 | 0 | 23 | 27 | 50 | 50 | |
| R-12 | 71 | 10 | .8 | 11 | 2 | 10 | 88 | 70 | 20 |
| | x | x | x | x | x | x | x | x | x |
| | 71 | 20.5 | 4.5 | 4.2 | 12.4 | 15.6 | 72.2 | 67.4 | 9.5 |
| | S | S | S | S | S | S | S | s | S |
| | 7 1 | 7.5 | 2.9 | 3.8 | 8.9 | 6.5 | 14.8 | 9.3 | 6.1 |
| | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% |
| | ±6.9 | ±7.3 | ±2.8 | ±3.7 | ±8.7 | ±6.4 | ±14.5 | ±8.5 | ±5.6 |

APPENDIX IV. CORRELATIONS IN SURVEY PARAMETERS

| Description | r | Validity | n |
|--|---|---|---------------------------|
| Percentage b.s.d. > 15 mm vs. % 1.5 m tall Ruby Unit | 0.864 | 99% | 34 |
| Percentage hedging vs. 1-10 mm b.s.d.(all units)Percentage hedging vs. 1-10 mm b.s.d.Ruby UnitPercentage hedging vs. 1-10 mm b.s.d.Rochester UnitPercentage hedging vs. 1-10 mm b.s.d.Blacktail UnitPercentage hedging vs. 1-10 mm b.s.d.Centennial Unit | 0.022 0.206 0.493 0.210 0.249 | Invalid 80% 95% Invalid Invalid | 86 35 17 26 8 |
| Percentage hedging vs. % Canopy Deficit(all units)Percentage hedging vs. % Canopy DeficitRuby UnitPercentage hedging vs. % Canopy DeficitRochester UnitPercentage hedging vs. % Canopy DeficitBlacktail UnitPercentage hedging vs. % Canopy DificitCentennial Unit | 0.381 0.270 0.683 0.128 0.029 | 99% 80% 99% Invalid Invalid | 86 35 17 26 8 |
| Percentage hedging (550%) vs. 1-10 mm bsd (all units) Percentage hedging (550%) vs. 1-10 mm bsd Ruby Unit Percentage hedging (550%) vs. 1-10 mm bsd Rochester Unit Percentage hedging (550%) vs. 1-10 mm bsd Blacktail Unit Percentage hedging (550%) vs. 1-10 mm bsd Centennial Unit | 0.195 0.593 0.901 0.971 0.020 | Invalid 80% Invalid 80% Invalid | 21 8 3 4 6 |
| Percentage hedging (550%) vs.% dead-decadent (all units) | 0.450 | 95% | 21 |
| Percentage hedging ($\overline{>}$ 60%) vs. 1-10 mm bsd (all units) | 0.793 | 99% | 10 |
| Percentage hedging (Σ 60%) vs. 15 mm bsd (all units) | 0.709 | 95% | 10 |
| Percentage canopy (w <20% rock) vs. bank erosion Percentage normal (w <20% rock) vs. Dillon WTendoy Units | -0.338 | 80% | 16 |
| Percentage hedging (w <20% rock) vs. | -0.000 | 99% | 10 |
| Percentage hedging (w Pfankuch >100) vs. | 0.356 | 80% | 10 |
| bank erosion Dillon wlendoy Units | 0.303 | 00% | 25 |
| Riparian rating score vs. % bank erosion (all reaches) Riparian rating score (20-40% rock) vs % bank erosion Riparian rating score (<20% rock) vs % bank erosion | -0.3701 -0.683 -0.455 | 99% 99.9% 80-90% | 86 28 13 |
| | AND STREET | | |

by

Neal M. Carter

Progress Reports of Pacific Biological Station Nanaimo, B. C., and Pacific Fisheries Experimental Station, Prince Rupert, B. C.

No. 26, p. 19-20, December 1935

Each year several samples of material suspected of being anbergris are received by this Station or the Pacific Biological Station at Nanaino, accompanied by requests for identification. The genuine material is popularly recognized as of considerable value. One lump weighing 44 lb. found on the New England coast in 1922 was worth \$11,000 (\$15.00 per oz.) while 248 h. allogedly found in one lump was valued at \$113,200 or \$15.50 per oz. (year not stated). A single lump weighing 500 lb. has been reported. In recent years, however, the discovery of a partial substitute for ambergris in the perfunery trade has resulted in lesser values than those just quoted.

Since in the past anbergris has been found in small quantities on our shores, fishermen and others living on the coast are naturally on the lookout for such a "find". Unfortunately, the reports on all samples recently submitted for identification here have led to disappointed hopes. Many have proven to be merely discoloured paraffin wax. It is felt, therefore, that a short summary of the properties of ambergris may assist in avoiding such disappointments by enabling the finder of suspected material to apply a few preliminary tests for himself.

Ambergris is a substance originating in the intestinal tract of spern whales and results from an abnormal though not necessarily diseased condition in the whale; hence its comparative rarity. The sperm whale preys on squids, cuttlefish, octopuses and other cephalopods, and some authorities clain that the odour of anbergris originates from such food. It has been stated that when the whale is suffering from a certain intestinal disease, a digestive product known as "anbrein" crystallizes in the intestines and faecal material and accumulates until it is either expelled or results in the whale's death. Other authoritics, basing their statements on the frequent occurrence of fragments of the jaws and internal shell of cephalopods in ambergris, clain that these sometimes lead to indigestion in the whale by their accumulation and that the whale in some cases attempts to assist the passage of such natorial through its intestine by coating the indigestible fragments with a biliary secretion which, mixed with faccal matter, forms ambergris. It is sometimes found in the stomach or intestines during whaling operations, or if already expelled, may be found floating on the sea or washed up on shore.

Anbergris was used by the Chinese for medicinal and ceremonial purposes, but is now almost exclusively used in perfumery. Contrary to popular belief, its value in perfumery lies not so much in the odour of the ambergris itself, but in its peculiar property of "fixing" floral odours when blended, and of giving "body" to the perfume.

When fresh, ambergris is a wax-like substance containing considerable moisture, but when weathered by exposure while floating or lying on the shore, it becomes more compact and begins to lose its property of giving wax-like shavings when scraped by the fingernail. Eventually it becomes brittle and when fairly old and dry can be crumbled between the fingernail and a hard surface. A characteristic, somewhat pleasant odour usually described as "earthy" clings to the substance and is intensified by warming in the hand. Some persons liken the odour to that of damp, decomposing grass or sweet hay. The colour may vary from dull grey through brown to almost black, or it may be mottled or banded throughout with alternate layers of light and dark colour. Commercial classifications of colour in decreasing order of value are "golden grey", "grey" and "black". Recently quoted prices are \$9.30-\$10.00 per oz. for "grey" and \$3.75 for "black" grades.

As already stated ambergris floats, even in fresh water. When slowly heated, it commences to soften at about 140°F, and melts between 145 and 150°F., well below the boiling-point of water, to a dark, oily liquid. A very charactoristic test is to heat the end of a needle or thin piece of wire above a small flame, and then press it gently into the surface of the specimen being tested. Ambergris will melt around the hot metal, forming a dark or almost black liquid which is opaque, unlike the clear liquid obtained when so treating a piece of wax. Moreover, on removing the vire and touching the still hot liquid with the finger tip, ambergris adheres and can be pulled out into pitchlike "strings", while most waxy substances so treated either cleanly coat the fingertip without stringing or merely take its impression. A shall piece of anbergris remains soft and "tacky" nuch longer than wax after being heated. If the needle or wire to which some of the liquid still adheres is re-heated over the flame, ambergris soon emits a white fume having the same characteristic odour as the solid, and then burns with a luminous flame. Waxes do not emit funes until almost ready to ignite, and the fune has a typicol "hot wax" or acrid odour. Suspected substances, which when tested in this way, emit the unpleasant odour of burning hair or horn, are not likely to be ambergris. If fragments of cephalopod jaws or cuttlefish "bone" are found on breaking apart a lump of such material, there is good reason for assuming the presence of anbergris. These jaws resemble the beak of a parrot.

Other methods of identification involving physical and chemical tests are available, and if a specimen still shows indications of being true ambergris after the consideration of the above information this Station will be glad to undertake further examination of a submitted sample, free of charge.

Through the courtesy of a company dealing in ambergris, this Station was supplied with a sample of the genuine "grey" product with which samples submitted for identification can be compared. The Pacific Biological Station at Nanaino also possess reference samples.

environmental biology of fishes

international journal

Prof. E.K. Balon, Dept. of Zoology, University of Guelph, Guelph, Ontario N1G 2W1, Canada Dr W. Junk Publishers, p.o. box 163, 3300 AD Dordrecht, The Netherlands

RECOMMENDATIONS FOR REVISION

Author(s): Lynn M. Decker

Title:

Coexistence of two species of sucker in Sagehen - Date: creek, California, and notes on their status in the western Lahontan Basin

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This paper is of interest because of its documentation of the decline of a native species but the precise reasons for the decline are left open to question. Land use practices and reservoir construction are obvious general influences, but in interaction and competition with Tahoe sucker, what life history stage and what common resource are critical for understanding the replacement of the mountain sucker by the Tahoe sucker? Why is reproduction inhibited in Sagehen Creek?

The decline of the mountain sucker in Sagehen Creek may not be as precisely documented as is implied. During the 1950's, Sagehen Creek was sampled annually for ten years by complete removal of all fishes at ten sampling stations. Complete data were recorded on species numbers and sizes. It would be of considerable interest if these same sampling stations were sampled again in the 1980's and the precise changes noted for mountain sucker, Tahoe sucker and other species (at least all of the stations where the mountain sucker was recorded in the 1950's).

On page 21, line 6, 40 of 280 is given as 18% (should be 14%).

In the discussion concerning hybridization, it is speculated that reproductive isolating mechanisms have broken down between Tahoe and mountain suckers in Sagehen Creek, yet the only evidence for hybridization (Table 4) are collections of 1951 and 1952, all collections after that, including 1982 and 1983, list no hybrids. From Table 4, one might assume just the opposite-that isolating mechanisms were strongly reinforced after 1952.

Actually, to my knowledge, hybridization between Tahoe and mountain suckers in Sagehen Creek was never documented by critical examination of specimens. Hybridization was yudged qualitatively by assessing the degree of "notch" development at the junction of upper and lower lips of specimens in the field. Thus, depending on who was making the hybrid judgement during the annual sampling, the percentage of hybrid specimens recorded from Sagehen Creek would vary from year to year, and there is no sound basis to discuss trends of hybridization and breakdown of isolating mechanisms.

On page 20, it is stated that the mountain sucker never occurs in lakes. The book: Wyoming Fishes, Baxter and Simon 1970 (Wyoming Game and Fish Dept., Cheyenne), gives several references to <u>C</u>. <u>platyrhynchus</u> living in lakes in Wyoming. * Introgressive Hybridization

Anderson, E. & L. Hubricht. 1938. Hybridization in Tradescantia III. The evidence for introgressive hybridization. Amer. Jour. Bot. 25: 396-402.

Anderson, E. Introgressive Hybridization. 1949. John Miley & Sons, M.Y.

Heiser, C. B. 1949. Natural Hybridization with particular reference to Introgression. Bot. Rev. 15: 645-687.

Heiser, C. B. Introgression Re-examined. 1973. Bot. Rev. 39: 347-366.

* Leptokurtic Gene Dispersal and Restriction of Gene Flow

Levin, D. & H. Kerster. 1974. Gene Flow in Seed Plants. In Dobzhansky, Hecht & Steere [eds.] Evolutionary Biology 7: 139-220.

Grant, V. 1980. Gene Flow and homogeneity of species populations. Biologische Zentrallblatt 99: 157-169.

* Specific Examples of Introgressive Hybridization and Alternate Hypotheses

Juniperus

Hall, M. 1952. Annals Mo. Bot. Gard. 39:1-64. [pro-introgression]

Hall, M. 1955. Annals Mo. Bot. Garden 42: 171-194.

- von Rudloff, E., R. Irving & B. L. Turner 1968. Amer. Jour. Bot. 5:660 (Abstract) [refutation of introoression]
- Turner, B. L. 1970. In J.B. Harborne [ed.] <u>Phytochemical Phylogeny</u> 1970. pp. 187-205. Academic Press [refutation]

Flake, R., E. von Rudloff & B. Turner. 1973. In Runeckles & Mabry [eds.] 1973. Terpenoids: Structure, Biogenesis and Distribution. pp. 215-228. Academic Press. [refutation]

Helianthus

Heiser, C. B. 1949. Univ. Calif. Publ. Bot. 23:157-196. [pro-introgression] Heiser, C. B. 1973. Bot. Rev. 39: 347-366. [doubtful or alternate hypothesis] Heiser, C., D. Smith, S. Clevenger & W. Martin. Memoirs Torrey Bot. Club 22: 1-218. [alternate hypothesis] Olivieri, A. & S. Jain. 1977. Madrono 24:177-189. [alternate hypothesis]

Asclepias

Noodson, R. 1947. Annals Mo. Bot. Garden 34:353-423. [pro-introgression] Wyatt, R. & J. Antonovics. 1981. Evolution 35: 529-542. [alternate hypothesis]

* Primary Intergradation as an Alternate Hypothesis to Secondary Intergradation

Barber, H. & W. Jackson. 1957. Natural selection in action in <u>Eucalyptus</u>. Nature 179: 1267-1269.

Endler, J. 1977. <u>Geographic variation, speciation and clines</u>. Princeton Univ. Press, Princeton.
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AND Record

THE APPLICATION OF IMMUNODIFFUSION TECHNIQUES AND IMMUNOGENETICS TO PROBLEMS OF SALMONID SYSTEMATICS

by

Richard A. De Long

During 1968 studies will be conducted to appraise the efficacy of immunodiffusion techniques for solving salmonid systematic problems. Much speculation has centered on the origins and relationships of various salmonid genera. It is hoped that information derived from biochemical tests, cytogenetics and classical taxonomic data may help to clarify salmonid systematics.

Early in the 1900's Nuttall demonstrated that proteins obtained from different animals were species-specific. He was able to demonstrate with precipitin ring tests that the intensity of the antigen-antibody precipitates indicated the relative degree of relationship between the species compared. While these studies provided a powerful tool for studies in comparative zoology, no information was obtained with respect to the nature of the protein antigens and their modes of inheritance.

Since World War II the development and perfection of sophisticated techniques have allowed analyses and syntheses of bio-organic molecules rivaling even Nature herself. Serum proteins from different species were found to be functionally analogous but immunologically different. Evolutionary chemical modifications among the proteins were detectable as alterations in immunologic specificity. The species-specific nature of proteins has been elaborated in greater detail in both plant and animals. The choice of serum proteins for this study is based upon the following observations. Relatively stable systems represented by cytochrome c hemoproteins and eye lens proteins are useful in demonstrating phylogenetic relationships at the higher levels of family, order, class and phylum. At the species level high molecular weight, eye lens proteins show wide cross-reactions between species; i.e., they share many components and thus exhibit slow rates of evolutionary change. In this respect they must have retained antigens derived from more primitive ancestors. Serum proteins are more limited in their cross-reactions, indicating faster rates of evolution. In addition, serum proteins are synthesized by a variety of cells that have different rates of evolution. Unlike eye lens proteins, serum proteins show immunochemical similarities within a taxonomic range mainly restricted to the same class, i.e., Osteichthys in this study.

In recent years electrophoretic studies of proteins from different vertebrate species have demonstrated the species-specific nature of each species electrophoretic pattern. Further studies demonstrated that, in addition to the species-specificity, many serum protein components are polymorphic; i.e., two or more forms of the fraction persist in the same population with the rarest form in a frequency too high to be accounted for by recurrent mutation alone.

For fish serum transferrins (iron-binding B globulins), polymorphisms have been demonstrated for <u>Cyprinus carpio</u> by Creyssel, Richard, and Silberzahn, (1964), <u>Salvelinus alpinus</u> by Nyman (1965), <u>Ictiobus</u> <u>cyprinellus</u> by Koehn and Johnson (1967), and for species of <u>Tilapia</u> by Malecha (1968). In oceanic species transferrin polymorphisms have reported for <u>Anguilla anguilla</u> by Fine, et. al. (1965), <u>Gadus morhua</u> and other gadoid fishes by Moeller and Naevdal (1966), and for scombroid fishes by Barrett and Tsuyuki (1967). According to Fine, Drilhon, Boffa, and Amouch (1964) the polymorphic transferrins seem to be inherited in a simple allelic fashion, i.e., perhaps with three co-dominant alleles expressing six possible phenotypes.

During the last decade there has been increasing use of immunodiffusion techniques. Immunodiffusion tests involve the diffusion of antigens and antibodies in agar gel media and their precipitin reactions at the zone of interaction. Agar gel electrophoresis allows separation from protein mixtures the fractions having different electrophoretic mobilities. A combination of immunodiffusion and electrophoresis, immunoelectrophoresis, allows not only the separation of electrophoretically different antigens, but also the formation of an independent precipitin arc as each antigen reacts with its specific antibody. The value of immunoelectrophoresis is further enhanced by its ability to resolve from an apparent single fraction several components having identical electrophoretic mobilities but different diffusion rates.

The earliest use of immunoelectrophoresis in solving taxonomic problems of fish was by Bargetzi (1958) who demonstrated serum protein differences between two forms of <u>Coregonus</u> occurring in Lake Neuchatel, Switzerland. Krauel and Ridgway (1963) demonstrated by immunoelectrophoresis that serum protein polymorphisms exist in <u>Oncorhynchus nerka</u> for all components except albumin. In their study they identified all serum components on the basis of their electrophoretic mobilities. While they demonstrated the existence of a specific lipoprotein in sera from spawning females, the other precipitin arcs were not identified by specific staining or labeling techniques.

Williams (1964) indicated that serum albumin is one of the more "conservative" antigens and may be expected to demonstrate family, genus, and even species differences. Using immunogenetic techniques, Hafleigh and Williams (1966) compared the relative cross reactivities of 22 primate serum albumins with human serum albumin. They classified the albumins into distinct taxonomic categories that were consistent with the phylogenetic relationships of these primate species to man. The results were evidence that protein structure had undergone progressive and divergent evolutionary modifications. It was clear that immunochemical correspondence diminished with remoteness.

Basic to salmonid systematics is the placement of the genera <u>Salmo, Salvelinus</u> and <u>Oncorhynchus</u> in their correct positions in the salmonid phylogenetic tree. An attempt will be made to estimate the relative amount of similarity or taxonomic distance between the three genera. By means of preparative electrophoresis I plan to separate albumin components from serum of representative species belonging to the three forementioned genera. Since <u>Salvelinus</u> perhaps represents the earliest divergence occurring in the subfamily Salmoninae, antiserum to <u>Salvelinus fontinalis</u> albumin will be used to perform immunodiffusion tests with albumin antigens from <u>Salmo salar</u>, <u>Salmo</u> trutta, <u>Salmo clarki clarki</u>, and <u>Oncorhynchus nerka</u>. I hope to establish by reactions of identity, non-identity and partial identity (Figures 1, 1-1, and 1-2) the relative amount of similarity that has been maintained in serum albumins of present genera since the time of their ancestral divergence from each other. In the case of close but not identical relationship the length of the spur denotes the relative degree of relationship. In figure 2 the shorter spur formed between turkey ovalbumin and antiserum to chicken ovalbumin suggest that the chicken and turkey are more closely related than are the chicken and the duck.

At the interspecific level I plan to use immunoelectrophoresis as a tool to investigate the relationships of the cutthroat and rainbow groups. Cytogenetic and taxonomic data suggest that the interior cutthroats, <u>Salmo clarki sp</u>. (2N=64) and the rainbow, <u>Salmo gairdneri</u> (2N=60) probably stem from a common ancestor, perhaps today most closely represented by the modern Coastal cutthroat, <u>S. clarki clarki</u> (2N=70). By using <u>S. clarki clarki</u> antiserum, I plan to check the overall immunoelectrophoretic patterns of interior cutthroats, <u>S. clarki</u> sp., rainbows, <u>S. gairdner</u>i and Kokanee salmon, <u>Oncorhynchus nerka</u>. Hopefully, this information may help to solve the question of whether <u>S. gairdneri</u> branched off from an early <u>S. clarki clarki</u> like ancestor or evolved more recently from an interior cutthroat ancestor. The question of <u>Oncorhynchus nerka's</u> ancestry may also be clarified.

An additional interspecific problem concerns the origin of <u>Salmo</u> <u>aguabonita</u>, the Golden trout, and its relationships with <u>Salmo clarki sp</u>., the interior cutthroats and <u>Salmo gairdneri</u>. Behnke (unpublished) believes that <u>S</u>. <u>aguabonita's</u> chromosome number (2N=58) and low vertebra number suggest that <u>S</u>. <u>aguabonita</u> may have been more easily derived from an interior cutthroat type (2N=64) than from the other presumed ancestor, <u>S. gairdneri</u> (2N=60). Serum samples from several <u>S. aguabonita</u> populations from Sequoia-Kings Canyon National Park will be analyzed by immunoelectrophoresis and compared with patterns of <u>S. clarki sp</u>. and <u>S. gairdneri</u>. Patterns from known and suspected golden-rainbow and golden-cutthroat hybrids will also be studied.

Studies on intraspecific variability will focus upon the interior cutthroat series. Behnke and Needham (unpublished) recognized three basic types of interior cutthroats: <u>S. clarki henshawi, Lahontan</u> cutthroat, <u>S. clarki stomias</u>, Greenback cutthroat, and <u>S. clarki lewisi</u>, Yellowstone cutthroat. Other types recognized as subspecies fit best in the Yellowstone cutthroat group. It has been often stated that subspecific distinctions between various populations of <u>S. clarki</u> have been altered or destroyed through introductions of Yellowstone cutthroats, <u>S. clarki lewisi</u> and Rainbow trout, <u>S. gairdneri</u>. In order to identify, preserve, and manage relict populations, it would be helpful to know something about their genetic variability as well as the genetic background of known and suspected hybrids.

Cope (1957), in a study based upon morphological characteristics, suggested that races of cutthroat trout inhabit Yellowstone Lake and each home to a particular stream during the spawning season. A serological study by Liebelt (1968) suggested that serum antigenic differences may indicate five separate subpopulations using different spawning streams of Yellowstone Lake. This study, however, failed to indicate whether these differences were due to polymorphisms or to sexual dimorphism as observed by Krauel and Ridgway (op. cit) in <u>Oncorhynchus</u> nerka and in Atlantic salmon, Salmo salar, by Drilhon and Fine (1963).

During June, 1968, I plan to obtain serum samples of <u>S</u>. <u>clarki</u> <u>lewisi</u> from spawning streams of Yellowstone Lake. These samples will be subdivided, and separated according to individuals and by sex. In order to produce an antiserum of greatest possible variability and specificity, sera from all fish of each sex will be pooled as the antigen to be used for immunization. Because of possible variations in a rabbit's immunological response, several rabbits will be immunized with each pooled antigen.

Also during June, serum samples from a fine-spotted form of <u>S</u>. <u>clarki</u> <u>lewisi</u>, the Snake River cutthroat, will be obtained from the Jackson, Wyoming Federal Hatchery. The adaptive significance of the fine spots is not known although similar situations occur in the Rio Grande cutthroat, <u>S</u>. <u>clarki virginalis</u>, synonomous with <u>S</u>. <u>clarki lewisi</u>, and in the Gila trout, <u>Salmo gila</u>.

In July and August, 1968, I plan to secure serum samples from a suspected relict population of Greenback cutthroat, <u>Salmo clarki stomias</u>, located in the Thompson River, Forest Canyon, Rocky Mountain National Park. Serum samples will also be secured from possible <u>S</u>. <u>clarki lewisi</u> populations of tributary bench streams above Forest Canyon to the south.

Serum antigens from all individual fish of the types mentioned will be analyzed by immunoelectrophoresis using complete antisera. Fractions exhibiting polymorphisms will be selectively stained, and their phenotypic frequencies calculated. Genotypic frequencies will be calculated and differences within and between subpopulations will be statistically analyzed for significance. Differences due to sex will also be noted.

Data derived from immunogenetic analyses together with meristic counts may help to establish the distinctiveness of various salmonid species and subspecies populations. Subspecies have the possibility of participating in the gene pool of the entire species, although they are sufficiently separated to exhibit individually unique gene frequencies. The distinction between subspecies is, therefore, not absolute; subspecies may differ in the relative frequency of a particular gene but these differences do not prohibit gene exchange.

Just as genetic differences at particular loci, are not sufficient to indicate subspecific differences, similarities for particular gene frequencies between two populations does not necessarily indicate subspecific differences. Likewise similarities for particular gene frequencies between two populations does not necessarily indicate subspecific identity.

The criterion for evaluating the differences between populations of a single species is based essentially upon gene-frequency differences. When these differences are numerous, it is advantageous to consider populations as separate entities, categorized broadly as subspecies or races. The forces producing racial differences are primarily adaptive; i. e., gene-frequency changes are usually the response of a population to the selective forces operating within a particular environment. At times these subspecific or racial differences are accompanied by observable morphological differences, but at other times observed subspecific or racial differences extend only to gene or chromosomal differences.

Literature Cited

- Bargetzi, J. G. 1958. Application de methodes d'analyse biochimique a une etude taxonomique: les coregones du lac de Neuchatel. I methodes immunologiques. Experientia 14:187-188.
- Barrett, I and H. Tsuyuki. 1967. Serum transferrin polymorphism in some scombroid fishes. Copeia (3):551-556.
- Cope, O. B. 1957. Races of cutthroat trout in Yellowstone Lake. U. S. Fish Wildlife Service, Spec. Sci. Rept., 208:74-84.
- Creyssel, R., G. Richard, and P. Silberzahn. 1966. Transferrin variants in carp serum. Nature 212:1362.
- Drilhon, A. and J. M. Fine. 1963. Dimorphisme sexual dans les types proteins sériques de Salmo salar: Etude electrophorétique. C. R. Soc. Biol. 157(11):1897-2000.
- Fine, J. M., A. Drilhon, G. A. Boffa, and P. Amouch. 1964. Les types de transferrines chez certains poissons migrateurs. p. 165-168. <u>In:</u> H. Peeters, ed., Protides of the biological fluids. Elsevier Publ. Co., Amsterdam.
- Hafleigh, A. A. and C. A. Williams, Jr. 1966. Antigenic correspondence of serum albumins among primates. Science 151:1530.
- Koehn, R. K. and D. W. Johnson. 1967. Serum esterase polymorphism in an introduced population of the bigmouth buffalo fish, Ictiobus cyprinellus. Copeia (4):805-808.
- Krauel, K. K. and G. J. Ridgway. 1963. Immunoelectrophoretic studies of red salmon (<u>Oncochynchus nerka</u>)serum. Int. Arch. Alergy 23: 246-253.
- Liebelt, J. E. 1968. A serological study of cutthroat trout (Salmo clarki) from tributaries and the outlet of Yellowstone Lake. M.S. Thesis. Mont.St. Univ. 15 pp.
- Malecha, S. R. 1968. Studies on the serum protein polymorphisms in some populations of introduced fresh water fishes. M.S. Thesis. Univ. Of Hawaii 122 pp.
- Moeller, D. and G. Naevdal. 1966. Serum transferrins of some gadiod fishes. Nature 210:317-318.
- Nyman, L. 1965. Species specific proteins in freshwater fishes and their suitability for a protein taxonomy. Hereditas 53(10):117-126.
- Williams, C. A., Jr. 1964. Immunochemical analysis of serum proteins of the primates: A study in molecular evolution. pp 25-71 <u>In</u>: g. Buettner-Janusch, ed., Evolutionary and genetic biology of primate. Volume 2, Academic press, New York.



Fig. 1. The three general types of serological relationship of antigens. Antigens in wells 1 and 2, antibodies in well 3. A: Reaction of serological identity. The precipitale coalesce, which indicates that the antigens in 1 and 2 are serologically identical. B: Reaction of serological non-identity. The precipitates cross one another, which indicates that the antigens in 1 and 2 are serologically unrelated. C: Reaction of partial serological identity. The precipitates are partly confluent, indicating that the antigens have at least one antigenic determinant in common.





Figure 2. Serological relationships of chicken, turkey, and duck ovalbumins.

Ken waenes

Trout Pollution?

by

P. L. Cadwallader¹ and R. D. J. Tilzey²

¹Fisheries and Wildlife Division, Ministry for Conservation, Snobs Creek Freshwater Fisheries Research Station and Hatchery, Private Bag 20, Alexandra, Vic. 3714.

²New South Wales State Fisheries,

P.O. Box N211, Grosvenor Street, Sydney, N.S.W. 2000.

Introduction

Fishing is undoubtedly a major outdoor recreational activity in Australia. A survey commissioned by N.S.W. State Fisheries and conducted by McNair Anderson Associates in May 1977 found that 30% of New South Wales residents aged 13 and over go fishing at least once a year (J. G. Pepperell, personal communication). The continuing creation of inland impoundments has resulted in lentic freshwater fisheries playing an increasingly important recreational role. For example, a creel survey of Lake Eucumbene, N.S.W., found that 579 000 man hours were spent fishing during the 1970-71 season (Tilzey, unpublished data). An inland angling survey by Collins (1976) revealed that 66% of freshwater fishing effort in N.S.W. was directed towards introduced trout species, 7% towards Australian bass Macquaria novemaculeata, and 27% towards warmwater species such as Murray cod Maccullochella peeli, golden perch Macquaria ambigua and catfish Tandanus tandanus. No comparable data are available for freshwater angling in Victoria, but considering the much more limited availability of warmwater habitats, it would appear almost certain that a greater proportion of Victorian freshwater angling effort is directed at trout. It is thus hardly surprising that south-eastern Australian fish propagation and stocking practices have, until recently, centred solely upon trout. Each year brown trout Salmo trutta, rainbow trout Salmo gairdneri and brook trout Salvelinus fontinalis are stocked in the waters of mainland S.E. Australia by the state fisheries agencies of N.S.W. and . Victoria (brook trout stocked by N.S.W. State Fisheries only). The waters stocked include rivers and streams, natural lakes and man-made lakes. In this paper we examine the role of trout in man-made lakes in Victoria and N.S.W., with particular reference to their use, desirability and effectiveness as angling species.

Reservoir Classification

When discussing trout in man-made lakes it is convenient to separate such waters into three arbitrary groupings:

2. Marginal trout fisheries. Waters in which surface temperatures exceed 22°C and hypolimnetic D.O. levels below 4 mg/l restrict trout distribution for part of the year.

3. Non-trout fisheries. Waters in which seasonal water temperatures exceeding 25-26°C and/or D.O. levels below 3 mg/l preclude trout survival in any part of the water column.

Group 1 waters comprise lakes occurring along the eastern ranges, usually above 900 m altitude. Their comparatively narrow seasonal physicochemical regimes are often similar to those of ancestral (i.e. European and North American) lentic trout habitats and trout are often the only recreational species found therein. Group 2 waters comprise tableland lakes at 400-900 m altitude, although some occur at lower altitudes. Such lakes encompass a wide seasonal range of physicochemical regimes some of which often differ markedly from the optima for trout survival (Weatherley & Lake 1967, Tilzey in press a) and result in periodic trout kills. Recreational species other than trout are often present. Group 3 waters comprise low-altitude lakes of the eastern seaboard, the western plains of N.S.W and the Mallee region of Victoria. Such lakes are unsuited to trout survival and are not discussed further in this paper.

Table 1.

Numbers of brown and rainbow trout liberated in various types of water in Victoria during the period 1972-78, with the proportion (%) of fish liberated in each type of water in parentheses. Compiled from Fisheries and Wildlife Division records.

| | | Rivers and streams | Natural lakes | Man-made lakes |
|----|---------------|--------------------|-----------------|--------------------|
| Α. | Brown trout | | | |
| | 1972 | 324 330 (30.78) | 83 250 (7.90 |) 645 961a (61.31) |
| | 1973 | 277 082 (42.88) | 70 500 (10.91 |) 298 578 (46.21) |
| | 1974 | 448 178 (67.79) | 58 427 (8.84 |) 154 547 (23.36) |
| | 1975 | 145 400 (35.61) | 25 200 (6.17 |) 237 724 (58.22) |
| | 1976 | 161 306 (37.39) | 39 777 (9.22 |) 230 337 (53.39) |
| | 1977 | 143 232 (44.65) | 47 524 (14.82 |) 130 004 (40,53) |
| | 1978 | 240 014 (52.28) | 51 000 (11.11 |) 168 070 (36.61) |
| Β. | Rainbow trout | | | |
| - | 1972 | 21 400 (2.96) | 425 017 (58.74 |) 277 197ь (38.29) |
| | 1973 | 17 400 (2.76) | 342 652 (54.47 |) 269 035 (42.77)_ |
| | 1974 | 36 213 (6.37) | 253 435 (44.55 |) 279 197 (49.08) |
| | 1975 | 48 010 (9.65) | 231 609 (46.54) |) 218 012 (43.81) |
| | 1976 | 8 500 (1.55) | 335 177 (61.15) |) 204 442 (37.30) |
| | 1977 | 7 344 (1.45) | 179 235 (35.50) |) 318 350c (63.05) |
| | 1978 | 30 834 (9.21) | 96 933 (28.96) | 206 940 (61.83) |
| | | | | |

a, includes 170 381 fry; b, includes 47 717 fry; c, includes 74 675 fry.

Table 2. Numbers of rivers and streams (RS), natural lakes (NL) and man-made lakes (MM) in Victoria stocked with brown and rainbow trout during the period 1972-78. Compiled from Fisheries and

Wildlife Division records.

| | Brown trout | | ź | Rainbow trout | | | |
|-------|-------------|-----|-----|---------------|------|------|-----------------------|
| | RS | NL | MM | RS | NL | MM | |
| 1972 | 48 | 10 | 29 | - 4 | 13 | 29 | • |
| 1973 | 44 | 10 | 29 | 3 | . 10 | 35 | • . |
| 1974 | 42 | 7 | 24 | 4 | 9 | 37 | |
| 1975 | . 32 | 6 | 36 | 4 | 9 | . 36 | - |
| 1976` | 33 | . 7 | 35 | -3 | . 9 | 38 | * |
| 1977 | 39 | 9 | .37 | 3 | 7 | 38 | |
| 1978 | 54 | 9 | 33 | 13 | 9 | 31 | چەنىپە مەنبۇر م |

Trout Stocking

The healthy condition of most established Australian trout fisheries has produced its own dogmas. Stocking is what started it all and stocking is the procedure revered by most trout fishermen. In our democracy what the majority of anglers wants, it usually gets. Stocking is therefore still the backbone of Australian trout management policy. The numbers and proportions of overall production of brown and rainbow trout stocked in rivers and streams, natural lakes and man-made lakes in Victoria between 1972 and 1978 are presented in Table 1. In 1978 almost 62% of rainbow trout and almost 37% of brown trout produced at the State fish hatchery were stocked in man-made lakes. The trend in trout management in recent years.has been towards the production of fewer and larger fish, and in Victoria the majority of liberations in 1978 were made with fish 150 mm in length or longer. The actual numbers of each type of water stocked in Victoria between 1972 and 1978 are given in Table 2 where it can be seen that in recent years brown and rainbow trout have each been stocked consistently in more than 30 man-made lakes per year. Most of these man-made lakes are dammed waters but there a few, such as the Bambra Coal Mine Lake (Winchelsea), which have been formed by the flooding of old mine workings.

Of the 26 major S.R.W.S.C. reservoirs in Victoria most have been stocked with trout during the last 20 years (Table 3). Lake Eildon has received the most fish, with over 1 330 000 rainbow trout and about 300 000 brown trout released since 1958. However, these figures include about 82 000 rainbow trout fry and about 230 000 brown trout fry whose survival must have been negligible (see below). During the same period, Lake Eppalock received just over 400 000 brown trout, including about 100 000 fry, and over 420 000 rainbow trout, and Rocklands Reservoir received just under 200 000 brown trout and just over 690 000 rainbow trout. These figures are for fish stocked directly into the reservoirs and do not include fish stocked into rivers and streams flowing into the reservoirs. The trout fisheries in these reservoirs followed the normal pattern of high growth and catch rates in the early years of impoundment with a subsequent decline to a more or less stable situation in which fishing is relatively poor (Butcher 1967).

In N.S.W. during the period 1971-77 2 725 000 rainbow trout and 3 323 000 brook trout, together with 99 500 Atlantic salmon <u>Salmo salar</u>, were released from the two N.S.W. State Fisheries trout hatcheries. From 1965 onwards, brown trout were not produced at either hatchery since most permanent N.S.W. trout waters contain self-reproducing brown trout populations and some waters, such as Lake Eucumbene (Tilzey 1972), are over-populated with this species. However, continued pressure from angling groups has recently resulted in limited numbers again being released "on an experimental basis". Recently (1978) there has been a shift in emphasis from rearing brook trout, which have had limited success in most established trout habitats, to producing greater numbers of rainbow trout and Atlantic salmon. Although concise figures for the various types of release localities are unavailable for N.S.W., most of the trout and all of the salmon were liberated into man-made lakes and/or their catchments.__ Nearly all trout were released as fingerlings.

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The 19th century attitude of liberating trout almost everywhere and anywhere they may survive has not changed significantly in recent years. The fact that the state fisheries agencies of New South Wales and Victoria now have a policy of only stocking trout into waters in which they have previously been liberated means little when it is realised that most suitable waters have had trout liberated into them at some time in the past. In South Australia, the Department of Fisheries is not involved in trout liberations which are, instead, hendled by the South Australian Fly Fishers' Association. Although private dams are stocked with trout, government reservoirs are not stocked because present policy does not allow access for fishing, but many streams receive trout liberations on the basis that "if a section of water will hold trout for 4 out of 5 years we consider it worth stocking"!

Justification for trout releases is based on "giving the angler what he wants" and, indeed, this attitude appears to be justified by the amount of pressure for trout releases exerted by certain angling bodies. However, as pointed out by Lake (1978) many native species provide just as good sport as trout on light gear and are far superior in edible qualities. He goes on to say that the overrated qualities of trout "go back to the time when trout fishing was mainly confined to the rich, and some sort of anob appeal still lingers. Ignorance of the native fishes was, and still is to some extent, enother reason for the attitude towards trout".

Stocking Efficiency

The 1977 price of trout produced at commercial fish farms in Victoria varied from 9 to 11 cents each for fry, 13 to 17 cents each for fingerlings, 19 to 35 cents each for yearlings and 42 to 75 cents each for two-year-old fish (Anon 1977). At the Victorian State fish hatchery at Snobs Creek the "average cost" of an individual trout by the time it is eventually liberated is about 33 cents (this figure is based on running costs of the hatchery, staff salaries, maintenance of trout-liberation trucks, etc.), so it can be seen from the numbers of fish liberated annually (Table 1) that a great deal of money is involved in the stocking of man-made lakes and other waters in order to maintain Victorian trout fisheries.

Whereas there is no doubt at all that stocking is essential to the continuation of trout fisheries in which the fish for one reason or another cannot breed, there is also little doubt that most stocking effort is wasted through placing fish in established trout waters. Nicholls (1958) studied the effectiveness of stocking in a Tasmanian stream and concluded that less than 2% of hatchery-reared fish reached the angler. Lake (1957) arrived at essentially the same conclusion for New South Wales trout waters. More recent quantitative studies are lacking, but there is no reason to suppose that today's stockings of lotic trout waters are any more successful. The situation in Australian lentic waters is even less clear since no quantitative studies, aimed at determining the proportion of released fish reaching the angler, have been conducted in such habitats.

Tilzey (in press b) found that in Lako Eucumbene the annual angling harvest for "wild" trout up to three years of age was 11.1-12.3% for browns and exceeded 22.0% for rainbows. He also (unpublished data) found that total mortality in the first year of life exceeded 98% for both species. The proportion of any releases of under-yearling trout reaching the angler in Lake Eucumbene or in similar habitats would thus almost certainly be of an extremely low order. However, intensive stockings of brook trout and Atlantic salmon (aged from 0+ to 3+) in nearby Lake Jindabyne, a water also containing wild populations of brown and rainbow trout, have resulted in the former two species comprising a significant proportion of the angling catch. Release/percentage-recapture studies are clearly needed to determine stocking success in such lentic waters.

American studies such as that of Rawstrom (1973) have shown that even when trout are planted at a legally-takeable size and the harvest in most cases exceeded 40%, the cost of each fish caught was about U.S.\$1.00. The cost of each hatchery-reared trout which reaches the Australian angler is certainly much higher when considering the extremely low harvest rates. An economic appraisal of Australian trout stocking practices is definitely needed to establish the efficiency and effectiveness of such policies.

The above comments relate to group 1 waters only, i.e. those in which physicochemical conditions favour trout survival. It is likely that an even smaller proportion of released trout would reach anglers fishing in group 2 waters since the physicochemical stresses of high surface water temperatures and low D.O. levels typically occurring in summer months would (a) result in high trout mortalities and (b) confine trout to the metalimnetic zone where they are much less accessible to anglers.

Biological factors also markedly influence stocking success. In group 1 waters the trout themselves are a major factor with high population densities typically resulting in poor growth and survival.

Numerous researchers, e.g. Neave (1953) and Fraser (1969), have shown that the survival of salmonid juveniles decreases markedly with increasing population density. Similarly, the comparative failure of the recently introduced brook trout to establish self-reproducing populations in N.S.W., despite the large numbers released, is probably attributable to competition _ from the well established brown and rainbow trout. Factors other than trout also influence trout survival, particularly in group 2 waters. For example, the survival of trout stocked in some Victorian reservoirs, e.g. Tullaroop Reservoir (Hume 1979), appears to be minimal, and it may be significant that of the 26 major S.R.W.S.C. reservoirs in Victoria, at least 20 contain European perch, Perca fluviatilis (Table 3). Moy (1974) reported an interesting experiment that was performed to check the hypothesis that predation by European perch on newly released trout accounts for the poor trout fishing in some reservoirs. The study was carried out in Barkers Creek Reservoir, a deep water with a surface area of 58 ha. It contains a large population of European perch and was stocked regularly with Trout. In the experiment, two areas of the reservoir were selected as release sites and both these areas and the remainder of the reservoir were gill-netted to determine the density and distribution of European perch. About 3000 * brown trout averaging 75 mm in length were then released at the two sites. A further 300 trout were held in cages (to protect them from predation) in the reservoir for five days. The reservoir was gill-netted for several days after release of the trout. The newly hatched fish were not taken by the nets, but European perch were taken and their stomach contents There was no significant mortality among the 300 trout held in examined. the cages, indicating that physicochemical conditions at the time were suitable for trout survival. However, there was a marked increase in the density of European perch in each release area after the trout were liberated and 90% of the perch taken in these areas, with food in their stomachs, had been feeding on newly released trout! The experiment was

repeated three months later using several thousand trout averaging 200 mm in length, but no trout were found in the stomaches of the perch netted after this second liberation. The results of these experiments indicate the futility of liberating small trout into reservoirs containing European perch. Small trout, particularly fry, merely provide an expensive source of food for another introduced predatory fish.

European perch also pose problems in several N.S.W. impoundments, notably Blowering and Talbingo Reservoirs on the Tumut River and Lake Hume on the Murray River. All are large impoundments and are prohibitively expensive to stock with yearling trout (i.e. > 200 mm long). Consequently, little stocking of these waters has been carried out and all are relatively poor fisheries containing few fish of catchable size. (European perch inevitably overpopulate, resulting in greatly reduced growth rates and small mean fish size.) There certainly appears to be a need to consider the merits of recreational species other than trout when formulating-

Native Fish Stocking

Until recently there have been no concerted efforts to breed and raise native fishes of recreational importance with a view to producing sufficient numbers for stocking. Butcher (1967) indicated that only residual populations of native fish are to be found in the impounded waters of S.E. Australia, but whereas trout have been released regularly in many of these waters there have never been, until very recently, corresponding releases of native-fish. Golden perch, silver perch <u>Bidyanus</u>, catfish and, to a lesser extent, Murray cod are now being bred at the N.S.W. State Fisheries Inland Research Station at Narrandera, and at the Victorian Fisheries and Wildlife Division's Murray cod pilot project at Lake Charlegrark (about 90 km west of Horsham) techniques are also being developed for the breeding and raising of Murray cod. During the period

1977-79 large releases of golden perch and silver perch were made in certain N.S.W. impoundments (Table 4), some of which, such as Burrendong, Burrinjuck and Wyangala, also contain trout. Techniques aimed at producing stockable numbers of Australian bass are also being developed by N.S.W. State Fisheries. This popular sporting fish is catadromous and has been particularly adversely affected by the building of dams on coastal rivers (Bishop & Bell 1978).

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Table 4. Impoundments in New South Wales stocked with native fish during the period January 1977-March 1979.

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|--|---|---|---------------------------|
| Impoundment | Locality (see Fig. 1) | Species stocked | Number of fish stocked |
| Burrendong Dam | 38 | GP | 180 000 |
| | | SP | 54 700 |
| Burrinjuck Dam | 33 | GP | 35 000 |
| Copeton Dam | 41 | GP | 200 000 |
| Gillenbah Lagoon * (Narrandera) | | GP | 147 500 |
| Glenbawn Dam | 39 | GP | 127 000 |
| | | SP | 68 000 |
| Lake Albert * | 32 | GP | 25 000 |
| Lake Wyangan * (Griffith) | - | GP | 12 500 |
| 1100 | | SP | 12 500 |
| Wyangala Dem | 35 | GP | 106 000 |

* Natural lakes raised for irrigation purposes; GP, golden perch; SP, silver perch. However, the above native species are not coldwater fish and although some, such as silver perch and Murray cod, can withstand periods of very low temperature, growth rates in coldwater habitats are usually slow. Virtually nothing is known about the survival rates of native fishes in any warmwater or coldwater impoundment. Stocking of such species would be inappropriate in group 1 waters and may be of limited value in the coldest waters of group 2. However, the warmer waters of group 2 can derive considerable benefit from these species. A good example of a thriving mixed-species fishery in a group 2 water is that in Burrinjuck Dam, N.S.W., where self-maintaining populations of Murray cod, silver perch, brown trout and rainbow trout provide much sport. Stockings of golden perch in this water have also proved successful.

A further two native species have particular potential for stocking the cold waters of group 2, viz. Macquarie perch Macquaria australasica and trout cod Maccullochella macquariensis. Ironically, both of these species are now considered to be threatened with extinction (Lake 1978). Both Macquarie perch and trout cod have been known to thrive in man-made lakes. For example, after Lake Eildon was formed in 1927 the Macquarie perch fishery was apparently quite prolific and existed alongside a flourishing trout fishery. This condition persisted until after construction of the second, larger wall in 1951, but since the late 1960's Macquarie perch have virtually disappeared from the lake (Cadwallader & Rogan 1977). In about 1929 trout cod from the Ovens River were introduced into Lake Sembell (Beechworth, Victoria), a small (6 ha surface area) lake formed by the flooding of old mine workings, and maintained themselves in the lake until an unexplained fish kill in 1970. To date, the knowledge or, indeed, the incentive required to breed and raise large numbers of Macquarie perch and trout cod has not been available, but the Victorian Fisheries and Wildlife Division now has projects underway to develop breeding and rearing techniques for both species with the view of ultimately restocking them in suitable waters within their former range. The development of reservoir fisheries for these species, either by the establishment of spawning populations or on the basis of a put-and-take operation, can now be considered as a future viable alternative to trout fisheries in group 2 waters. If only part of the finance, time and effort that has been channelled into trout production in the past had been channelled into the study and production of native fishes then perhaps species such as Macquarie perch and trout cod would not now be considered endangered.

It can be seen that trout have dominated impoundment stocking policies in the past. Although increased efforts are now being directed towards native fish production, trout still dominate. It is worth mentioning here too that although the construction of inland impoundments has in many cases expanded suitable trout habitat with a corresponding increase in trout populations, it has also caused a marked depletion of native fish stocks by altering the flow and thermal regimes of many rivers (Cadwallader 1978).

Angling satisfaction is composed of a myriad facets. The river blackfish <u>Gadopsis marmoratus</u>, another of the few native coldwater angling species, is not renowned for its fighting qualities, but nevertheless it could constitute a popular impoundment fish. The following verse by C. J. Dennis concerning freshly caught blackfish must surely reflect the sentiments of many anglers:

> "True no great gamefish matching and yet a goodly string A meal well worth the catching, a breakfast for a king! By sea or stream no fish is sought sweeter than blackfish freshly caught I plead for native fishes whose stocks are running out For sweet and toothsome dishes I loathe the taste of trout."

References

Anon. (1977). Fish in farm dams. <u>Victoria, Fish. Wild. Div., Inf</u>. Publ. 5, 9 pp.

Australian Water Resources Council (1976). "Review of Australia's Water Resources 1975". Dept. Nat. Res., Canberra, 170 pp.

Bishop, K. A. & Bell, J. D. (1978). Observations on the fish fauna below -Tallowa Dam (Shoalhaven River, N.S.W.) during river flow stoppages.

Aust. J. Mar. Freshwater Res. 29, 543-9.

- Butcher, A. D. (1967). A changing aquatic fauna in a changing environment. I.U.C.N. Publs., New Series, 9, 197-218.
- Cadwallader, P. L. (1978). Some causes of the decline in range and abundance of native fish in the Murray-Darling River System. Proc. R. Soc. Vic. 90, 211-24.

Cadwallader, P. L., & Rogan, P. L. (1977). The Macquarie perch, <u>Macquaria</u> <u>australasica</u> (Pisces:Percichthyidae), of Lake Eildon, Victoria.

Aust. J. Ecol. 2, 409-18.

- Collins, A. J. (1976). Inland angling in New South Wales. <u>N.S.W. State</u> <u>Fish., Res. Bull.</u> 14, 11 pp.
- Fraser, F. J. (1969). Population density effects on survival and growth of juvenile coho salmon and steelhead trout in experimental stream channels. Pp. 253-66 in T. G. Northcote (Ed.) "Salmon and Trout in Streams". Univ. British Columbia.

Hume, D. J. (1979). Census of fish in the Tullaroop Creek System, Victoria. <u>Victoria, Fish. Wildl. Pap</u>. 19, 12 pp.

Lake, J. S. (1957). Trout populations and habitats in New South Wales. Aust. J. Mar. Freshwater Res. 8, 414-50.

- Lake, J. S. (1978). "Australian Freshwater Fishes An Illustrated Field Guide". Nelson, Melbourne, 160 pp.
 - Moy, D. R. (1974). Survival of trout liberated into Barkers Creek Reservoir, Harcourt. <u>Victoria, Fish. Wildl. Div., Freshwat. Fish.</u> <u>Newsl.</u> 6, 19-20.

Neave, F. (1953). Principles affecting the size of pink and chum salmon

populations in British Columbia. J. Fish. Res. Bd. Can. 9, 450-91.

Nicholls, A. G. (1958). The population of a trout stream and the

survival of released fish. <u>Aust. J. Mar. Freshwater Res.</u> 9, 319-50. Rawstrom, R. R. (1973). Harvest, mortality and cost of three domestic

strains of tagged rainbow trout stocked in large California impoundments. Calif. Fish Game 59, 245-65.

Tanner, R. W. (1977). The management of water storages. Pp. D1-D9 in "Freshwater '77", a symposium organised by the Victorian Piscatorial Council and the Fisheries and Wildlife Division, Victoria.

Tilzey, R. D. J. (1972). The Lake Eucumbene trout fishery. <u>Fisherman</u> (N.S.W.) 4, 1-9.

Tilzey, R. D. J. (in press a). The key factors in the establishment and success of trout in Australia. <u>Proc. Ecol. Soc. Aust.</u>

Tilzey, R. D. J. (in press b). Tag loss by brown trout <u>Salmo</u> trutta L. with particular reference to double tagging experiments and the influence of fish size. <u>J. Fish. Res. Ed. Can</u>.

Tunbridge, B. R., & Rogan, P. L. (1976). "A Guide to the Inland Angling Waters of Victoria". Govt. Printer, Melbourne, 149 pp.
Weatherley, A. H., & Iake, J. S. (1967). Introduced fish species in Australian inland waters. Pp. 217-39 in A. H. Weatherley (Ed.)
"Australian Inland Waters and their Fauna". A.N.U. Press, Canberra.

CONSIDERATIONS FOR QUANTIFYING ENVIRONMENTAL PARAMETERS FOR TROUT IN THE RED RIVER

STAStream Flow]

Assuming that Molycorp people will make a determined effort to attack minimum flow recommendations designed for maintaining trout abundance at optimum levels, it will be necessary to obtain a sound basis of evidence for flow recommendations that is least vulnerable to criticism.

Our evidence should be able to correlate environmental parameters with trout biomass and to predict how a change in flow regime will affect these parameters, and, in turn, the trout population. To accomplish this objective, I believe we will need data on other parameters that are affected by flow besides depth and velocity measurements, and we should establish new depth and velocity preference curves specifically on brown and rainbow (wild, not hatchery) trout in the Red River.

If I put myself in the position of Pennak and tried to attack the validity of any recommendations based on present data, my questioning would be along the following lines. In current ecological theory, the concepts of niche and habitat are considered separately. Niche is defined as the role of a species in its community -- its interactions with biotic and abiotic elements of its environment. Habitat is defined as the physical, abiotic components of the environment. The distributional response of a species to its habitat can be measured and quantified. Thus, Instream Flow methods can quantify habitat, but does not consider niche. Habitat is only part of the niche and quantification of only habitat of rainbow trout and of brown trout does not give the whole picture of rainbow trout and brown trout niches. This omission can explain why the Instream Flow curves of weighted useable area predicts that rainbow trout should be dominant over brown trout in the Red River, when, in reality, the brown trout is probably the dominant species (Pennak could probably get quite eloquent -- or at least verbose -- argueing on this point).

In looking for flaws in Instream Flow preference curves, I examined some of the published reports on which they are based. My conclusions are that the upper and lower limit end points are essentially correct, but the shape of the curves are open to question -- they have much non-genetic (not species specific) noise. In most situations, the fish under study, could not express true preference because their options were limited -they had to make do with what was available. Also, preferences are dependent on the size of the fish. A rainbow trout of 32 inches prefers deeper water with higher velocity and much larger substrate for spawning than does a 7 inch rainbow trout (the giant Kamloops rainbow of Kootenay Lake is a source of data for developing Instream Flow preference curves). Taking velocity and depth measurements on the same fish spawning at the same site in high flow and low flow years would yield different sets of data.

If spawning preference curves for depth, velocity, and substrate (and all other habitat characteristics) were plotted for data on Gila trout and Apache trout (from publications of Ken Harper and John Rinne), curves quite distinct from the Instream Flow rainbow trout curves would be apparent. However, such curves are not species specific preferences of Gila and Apache trout. They are only a reflection on the very limited habitat available in the tiny streams where the data were collected. That is, there would not be a species specific basis for Gila and Apache trout curves.

If the Gila and Apache trout were removed from the tiny streams where they were studied and rainbow trout stocked, I am confident that the rainbow trout would duplicate the "preferences" of the Gila and Apache trout.

A small difference in the shape of the preference curves between species generates larger differences in the computer model. Thus, the "shakiness" of the curves causes predictive errors. Barry Nehring found the Instream Flow model to have very low success in predicting what trout species would be dominant in any particular habitat in several Colorado streams. I also note that the spawning and incubation curves (probability of use criteria for Salmonidae) do not coincide. If, in nature, they did not coincide, then a basic tenet of natural selection would be violated. Because natural selection favors those individuals who produce the most offspring, deposition of eggs in sites most favorable to hatching would be strongly selected for and there could be no difference between optimum spawning sites and optimum incubation sites -- two different preference curves are a contradiction of evolution.

The obvious accusation that could be made is that if the species specific habitat preference curves cannot accurately predict the species success then the data on which they are based contains errors -- how then can erroneous information be validly used as a basis for flow recommendations? We might get around this problem by making generalized "trout" preference curves. However, I believe to obtain defensible evidence for recommendations for Red River flows, habitat preference curves should be developed on brown and wild rainbow trout in the Red River. Also we should borrow from Allen Binns' Wyoming model for predicting trout biomass from environmental parameters to more fully quantify rainbow trout and brown trout niches.

Other significant facets of the environment that are amenable to quantification may become apparent after field studies are underway. For example, two pools equal in depth and volume, but differing in structure would be expected to have different densities of trout due to different amounts of "microhabitats" present.

I would also expect that when adequate data have been gathered on the Red River trout and their environment it will become apparent that all habitat criteria are not equal as determinants of trout biomass, and any model developed should take this into account and not give equal weight to all criteria (unless all are affected identically by flow).

PREFACE

[ca19905]

The motivation for this work began on a trout fishing expedition to the Wyoming Range located in western Wyoming where the headwaters of Columbia River, Colorado River, and Bonneville drainage basins meet. It was a fine, sunny day late in the summer of 1990. My uncle, an avid fly fisherman, and his wife had traveled all the way from Maine, so I thought it would be fun to attempt a trout fishing 'Grand Slam' and introduce my aunt and uncle to the spectacular salmonid biodiversity near my hometown of Pinedale, Wyoming--namely, four different subspecies of cutthroat trout: (1) a variety of the Colorado River cutthroat trout (Oncorhynchus clarki pleuriticus) native to the upper Green River, distinguished from other *pleuriticus* on the basis of its relatively smaller spotting pattern and higher scale counts, (2) the fine-spotted cutthroat trout, an unnamed subspecies native to the Snake River drainage that appears to be adapted to specializing in main-stem fluvial habitats, (3) the Yellowstone cutthroat trout (0. c. bouvieri), a large spotted subspecies also native to the sympatric Snake River and apparently living in syntopic reproductive isolation from the closely related fine-spotted cutthroat trout, and (4) the Bear River cutthroat trout, a variety of the Bonneville cutthroat trout subspecies (0. c. utah) which is actually probably more closely related to Yellowstone cutthroat trout than to the cutthroat trout of the southern Bonneville Basin in southern Utah and eastern Nevada.

I also wanted to take the fishing trip in order to see first-hand the habitat of the trout that I wanted to study in a project leading to an M.S. degree in fishery biology. For the area was valuable in a scientific sense, as well as in a recreational and educational sense, in that the area was an ideal natural laboratory for studying inter-basin dispersal in freshwater fishes. Of

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all fish species native to the western United States, the cutthroat trout is the most highly adapted to taking advantage of rare headwater stream captures in order to achieve dispersal (Smith 1978, Behnke 1988, 1992, Behnke and Platts 1990). Furthermore, the headwater tributary of the Gray's River (which flows forks. into the Snake River) is barbed where it nearly meets the headwaters of Labarge Creek (which flows into the Green River) at a low, gentle pass. Such geomorphological situations are taken by geologists to be prima facie evidence that the two headwater streams were once connected, rather like the current situation at Two Ocean Pass in Yellowstone Park. In addition, the major groupings of cutthroat trout populations composing the Colorado River subspecies (0. c. pleuriticus) are isolated from one another except during brief periods that occur about every 100,000 years, when the waters of the main-stem Colorado and Green Rivers are cool enough to allow trout dispersal. Finally, the relatively finer spotting pattern of the upper Green River cutthroat trouts seemed to me somewhat reminiscent of fine-spotted cutthroat trout of the Snake 2110/01-River. LOT

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Thus the circumstantial evidence suggested (to me, at least) that secondary gene flow had occurred between the trouts of the Snake and upper Green Rivers. This hypothesis could be easily tested by genetically examining the upper Green River cutthroat trouts and comparing these samples with those taken from the Snake River and more distant samples of Colorado River cutthroat trout--assuming, of course, that the problems of shared primitive traits and so on could be worked out.

At any rate, as we approached Nylander Creek--a tributary of the Green River and home to one of the last few surviving populations of upper Green River cutthroat trout--I could see that the area was also valuable in an economic

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sense. Numerous cattle were grazing in the riparian zone, and the willows and stream banks showed it. Moreover, the site sits atop a gigantic bubble of natural gas--the famed Overthrust Belt of western Wyoming. Nonetheless, I must confess my surprise upon seeing that the U.S. Forest Service would allow a gas well to be drilled 100 feet upslope from a tiny stream containing a Category 2 fish species. $-\frac{less}{d > m > ge}$ Then liverTeck.

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Feeling dubious, we proceeded to the stream and commenced to fish. Nylander Creek, itself, was scarcely larger than a typical Wyoming irrigation ditch, i.e. with a width of about two feet and a discharge rate of less one cubic foot per second. The map showed a first-order stream of about two miles in length. An elaborate gabion fish barrier had been installed near the mouth of the stream where in flowed into Cottonwood Creek in order to prevent the invasion of exotic rainbow trout (*Oncorhynchus mykiss*) that lived there. The willows lining the stream had been heavily browsed, but were still in fairly good shape. There were few undercut banks, however, and silt lined the stream bottom. Nevertheless, numerous cutthroat trout fingerlings could be observed despite the seemingly inhospitable conditions.

A small amount of angling effort soon produced an adult specimen of perhaps seven inches in length. Immediately apparent to my recently trained eye was the more profuse spotting pattern on the Nylander Creek specimen that I held in my hand in comparison with Upper Green River cutthroat trout from Rock Creek. I was witnessing the process of evolution first-hand! I also marveled that *any* trout population could persist in such seemingly harsh and tenuous living conditions. I yelled excitedly to my uncle, who had the only camera. He was too far away to hear me, however, so I released the trout unharmed back into Nylander Creek, the only token of its existence being the visual image forever burned into my brain

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of a beautiful, silvery animal covered with profuse fine spots glinting in the late summer sunlight. It was not long before I learned that I had just held one of the last vital avatars of a terminally ill local population.

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One of the virtues of freshwater fish biology is that it is sometimes possible to visualize an entire Mendelian population or species, if composed of a single population. (Phil Pister once described stumbling through the dark one night with an entire species of fish contained within two buckets!) As I walked up the slope to where the car was parked near the gas-well drilling pad, I was almost able to view the entire extent of Nylander Creek and its unique cutthroat trout linked together by the bonds of gene flow and dynamic ecological coactions into a single Mendelian population evolving to the best of its ability local life history traits suited to coping with its local environment. I felt that it was good (and lucky) that it continued to survive.

Just then a hard working but well intentioned biologist employed by the Wyoming Game and Fish Department happened to drive up and asked if we could see all the fish that the department had recently stocked. He explained that recent electrofishing surveys had revealed a drastic population decline. Therefore, a massive infusion of hatchery Colorado River cuthroat trout descended mostly from the Rock Creek population had been required in order save the Nylander Creek population from extinction. By doing so, however, the genetic uniqueness of the original population was swamped, thus destroying its usefulness for helping restoration efforts elsewhere. Cuthroat trout may still swim in Nylander Creek, but the Nylander Creek cuthroat trout population exists in name only.

I formally protested to the Wyoming Game and Fish Department and urged that the remaining adult cutthroat trout be removed from Nylander Creek while they could still be sorted on the basis of size in order to found a new brood stock

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in order to preserve the genetic uniqueness of the original Nylander Creek population. The department responded that it had neither the resources nor the inclination to save a "variety of a variety of a subspecies." Indeed, it later turned out that the tactic of supplemental stocking had also been applied to other pristine populations. As a side effect, the number of independent samples for my little proposed project was reduced from perhaps six to two. Thus very early in my career, for better or worse, I was confronted by the dilemma that most ecologists and evolutionary biologists inevitably face: if we want any biodiversity left to biologize about, then we had better take time out from our science and become an active force for the preservation of biodiversity, even at

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the level of the "variety of a variety of a subspecies." (e.g. Behnke 1992) The following essays argue for a non-anthropocentric environmental ethic regarding endangered biodiversity. The fundamental premise I first heard as the only undergraduate in a graduate seminar at the University of Chicago. Leigh Van Valen tossed out a bone of contention as food for thought the following proposition: organisms do not benefit from reproducing. Of course, the class pretty much pooh-poohed the idea at the time. Thus I mostly forgot about it until I later encountered the same idea in the writings of Holmes Rolston, III: "In this sense a female grizzly does not bear cubs to be healthy herself, any more than a woman needs children to be healthy." (Rolston 1988) Interestingly, the proposition that organisms do not benefit from their own reproduction is also used by Richard Dawkins (1978) to argue for his selfish gene theory.

In the essays that follow, I side with Rolston over Dawkins. The upshot of my arguments are that populations and species are best conceptualized not as "like clouds in the sky" as Dawkins (1982) would have it, but as "particular, self-regulated, dynamic and potentially eternal living systems capable of
adaptations determined by the genotypes of individuals," as the Russian evolutionary biologist Shaposhnikov (1984) aptly phrases it. Then we can begin to understand the basis of our intuition that unjustifiable anthropogenic extinction is a moral wrong.

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REFERENCES

Behnke, R. J. 1988. Phylogeny and classification of cutthroat trout, R. E. Gresswell, ed., Status and management of Interior Stocks of Cutthroat Trout: American Fisheries Society Symposium 4:1-7.

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- Behnke, R. J. 1992. *Native Trout of Western North America*. American Fisheries Society, Bethesda.
- Behnke, R. J., and W. J. Platts. 1990. The occurrence and paleolimnologic significance of cutthroat trout (*Oncorhynchus clarki*) in pluvial lakes of the Estancia Valley, central New Mexico. *Geological Society of America Bulletin* 102: 1731.
- Dawkins, R. 1978. Replicator selection and the extended phenotype. Zeitschrift fur Tierpsychol. 47: 61-76. Reprinted in E. Sober ed., Conceptual Issues in Evolutionary Biology. MIT Press, Cambridge.

Dawkins, R. 1982. The Extended Phenotype. Oxford University Press, Oxford. Rolston, H., III. 1988. Environmental Ethics: Duties to and Values in the

Natural World. Temple University Press, Philadelphia.

- Shaposhnikov, G. Ch. 1984. Aphids and a step toward the universal species concept. *Evolutionary Theory* 7: 1-39.
- Smith, G. R. 1978. Biogeography of intermountain fishes. in K. T. Harper, and J. L Reveal, eds., Intermountain Biogeography--A Symposium: Great Basin Naturalist Memoirs 2: 17-42.

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MAF Fisheries Research

Ministry of Agriculture and Fisheries Fisheries Research Division P.O. Box 8324 Riccarton Christchurch, N.Z.

Location: Kyle Street Riccarton Christchurch Telephone (03)488-902

23 July 1985

Dr R J Behnke Colorado Co-operative Fisheries Unit Colorado State University Fort Collins Colorado USA

Dear Bob

I am preparing a broad review of the occurrence of diadromy in fishes primarily for a conference in Boston next March (organised by AFS). However it has all grown far beyond that into a very interesting project. Obviously <u>salmonids</u> are one of the groups. I enclose my review of anadromy in the family and would much appreciate your comments, corrections, additions, etc.

I also enclose a listing of the species that I regard as diadromous (their latitudinal ranges are included for mapping purposes). Any comments you might have on the list would also be very useful.

Good wishes

(R M McDowall)

Dr. R. M. Mc Dowall Armai Ministry AN M.A.7. Fisheries Research P.O. Box 8324, Riccarton Christchurch, New Zealand Near Bob: I can only suggest a few minor bits of information to "fine-teene" your diadromous fish paper. Evidently there is a typo in regards to the "4000 km" migration of Si salar (bottom p. 45) -- probably should be 1000 km As you des mention, intraspecific vouation in anadromous life histories can be greater than interspecific. Chenoole selmon of Chinook salmon enter rivers on sparoning runs and act also spawn in every months of the year, somewhere throughout their range. Some noces of sockeye solvion go to sea (some only 25 mm) (Bugser, V. 7. 1984. Method for identification of sockeye salmon, Ouconhynchus nerks, of different spawning populations in the Komehotka River bosin, Jour. Ichthyd. 24(2): 47-53; English Translation of Voprosy IkhTidogii). I recognize 14 subspecies of cutthroat hout, S. clarkie Only one subsp. (S. clarki (lorki) is anadromous -- actually estuarine, they are not known to enter open ocean. In this respect, you might consider three "gradations" of anadromy -- slight (restricted To bays, estuaries, shallow coastal regions, such as coastal authroat trout and eastern brook trout); moderate (more extended movement and/or time at sea such as other Salvelenus and

brown trout); and extreme " (long periods of long distance movement in open ocean, such as Onconfigurelus, A and steelhead trout). Of course, gradations implies a lack of clear-cut boundaries. For example, marking experiments show different races of Chinook salmon chave quete different ocean migrateon patterns. I the suspect that the New Zealand anadromous Chinooks were derived from a race that did not roan the North Pacific (similar to Baltic (s. solar) (perhaps restricted to Puget Sound and that is why they became established in New Zealand (they may not move far offshore) Note, although the California golden trout more closely matches authaout trout in coloration and merustic characters, I've had to change my opinions on its relationships. Chromosomal and electrophonetic data clearly place it with the rainbou trout line of evolution. I might add we will soon be calling rainbour trout Parasalmo mykiss. In a 1968 publication I pointed out that rainbow and cutheout Trouts (Parasalmo) and Oncorhynchus are more closely related to each other than Parasalmo is to Salmo. In The 1984 book, "Ontogeny and systematics of fishes", Kendall and Behnke that paper on the with phylogenetic deagram of Salmonidae. We prave Paresalmo as a genus without comment.

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I how very few cases there are of an anadromous salmoned, becoming established when transplanted away from its mative shores.

T. Okazaki: 1984. Genetic dwergence and its Zoogeographical implications in closely related species Salma gavidneri and Salmo mykies. Jap. Dour. Ichthydl, 31(3): 277-308, recommends Synorymiging gairdner under mykiss. For more than 20 years I've had no doubt that they are some species, but its taken 50 years for non ichthyologist to use S. gairdneri instead of S. indeus a S. shasta for their experimental subjects -- I didn't want to assume blame for nome change, I recently discussed matter with R.R. Milley and he will take the bull by the horns and use Parasalmo mykess for nambou Trout in his next paper, I still waver on recognition of Japanese . shodorus as species or only subspecies of O. mason. Obviously they are closely related. In 1982, a Japanese book was published on O' maser and O' shoderes Unfortunately, everything except scientific Mames are in Japanese. But from what I've been able to interpret, both salmon occur in some streams, but rarely in same habitat. That is, they may be sympatric but rarely syntopic, and hybrids between the two are found. It's a borderline case for species recognition. There is another species of Salvelinus That is anadromous in For East (Kamchatta),

9 a peculiar charry has been known as the stone chan' (Rassien, kamen golets). In 1977 it was named Salvelinus albus, based on silvery anadromous specimen from Kamchatka R, In 1978, it was named again, S. kronocus, from lake population. My 1980 opinion that the stone chav and bull trout are sister species has been supported by karyotypes (very similar or identical). The latest opinions on char were recently published by Univ. Manitoba Press," Biology of the arctic chave: proceedings of the international signposium on arctic charr. " I've modified some of my views of 1950 publication. I noted in California Deadeny's ichthyology newsletter that you are compiling info on morphological and electrophoretic defferences between N. Zealand salmoneds and source populations, I assume all New Zealand nambou thout are derived from Sonoma Creek, California strelhead (& Parasalino mykiss indeus, The coastal rainbou trout in my latest classification). I recall Stokell's old work comparing N. Z. rainbows from several lakes and trying to match characters with Jordan and Evermann's key, He ded find defferences between lakes (but in a similar paper he also demonstrated the validity of So sebago and origin of N.Z. landlocked salmon). One you ou so pursuing this matter in greater depths?

For reveral years I have comp made comparisons between known parental sources and their derived populations, often in very different environments. In general, pylonic calca numbers are most stable and scale counts most subject to change, There is a problem, of course, in sorting out the genetic vs. direct environmental influences. I have found gillraker number to change - 122 in parent stock of a cutchroat trout to 21 and 20 in two introduced populations and from 23,7 in original Pyramid Lake culthroat trout to 26.1 m introduced population of in a tiny stream. I attribute this to the Founder Principle effect. Univ, Calif., Davis people did much electrophoretic work with California golden Trout. as I recall from one of this unpublished reports, an allele that occurred in Mulky Creek golden trout (parent stock) in fairly high frequency (co. 40%), was absent in Cottonwood hake golden trout (introduced from mulky creek in 1876). Again, I would consider this as example of Founder Principle. Sincerely,

- Parasalmo myleiss - 1 condell-B. S. mylens - Okozewa cutto only cosetal and - steelhead anti- chrinople anticonfluentus = 31bus both and. nestan restaux - whitefriker siber Museline nesident. Vagustent - zvertin J. clark - suturnalis lausterras sordialle nasus, Muksun, - no - (redbard) Pyramid L. Scole conto least goldentrat. Newclitter Syst. Ichthyol. looking for enorg-bological & electrophoreter dif. between N. Zeel. salmonids. source pop. -- yellowstar L. - MT- 2 5 T- 20 2 2-21-20 cutt hreat 14 subsp on 4 1 - "estuarine" Q. nerks Komehalike R. words open sos nother subi. - Auctic ch. no access to sea Y. U.Y. 7 Ses V.I. - S.I. 2-3 months at res back and . Sr salar "op to 4000 km" generality a 211 sp. - mading > north decessor & finite and bude excopt A: peringi Chimple arou great intraspection bridgelik te Ew - montre stre - occur was und time of non time spanning

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He considered that populations further south were more completely anadromous, and suggested that this is related to the very cold water temperatures in the winter, at the northern limits of this species' rance. McCleave et al . (1977)considered A. <u>brevirostrum</u> to be primarily estuarine and brackish in the waters of Maine.

Other North American sturgeons resemble the above in their history patterns, some like the western green sturgeon life A. (wdely in the North Pacific is Schenial and western North America) being regarded as fully anadromous, others like the medirostris white sturgeon, transmontanus are thought to move A. little beyond estuaries (Miller, 1972, Kohlhorst, 1976). The Arctic Lena sturgeon, A. <u>baeri</u>, in Siberian Russia resembles the Atlantic sturgeon, being fully anadromous, although Sokolov and

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Malyutin (1977) thought that the adults continued to feed during Nikolsky (1961) recorded it myratup 1300 km up the Yenisee Rever the spawning migration. The European species, A. sturio may I saw that spendeduct return to the see, while the juvender may spend how or deryeass in remain in fresh waters for up to three years before going to sea (prunning in the Carpean and i one moving to do. (Wheeler, 1969). TWO <u>Huso</u> /are also Russian species of life history anadromous, with æ comparable to that of the

Atlantic sturgeon (Berg, 1962). <u>H. huso</u> is reported to reach an

enorm#ous size, figures up to 1500 km being published (Frank, Nikalohy (1961) described both autum and spring run rows of H. huso and said that 4 969). Little is known of the other anadromous sturgeons, the 1969). Little is known of the other affer hatching, the young and sa turn run for go funther up man than spring run stocks. After hatching, the young and sa 1969). go straght to see, not largenerg in the rivers (Nikotsky 1961). The related H dawnows have generated so much culinary interest. enderthy dog not move for to de endently does not move for to de Deviation in sturgeons from the anadromous life cycle discussed above occurs in various ways. Some genera are wholly (Scaphirhynchus); fresh water some species of otherwise

anadromous genera are wholly freshwater in habit (A. ruthensis in

Asia and A. fulvescens in North America). Berg (1962) reported that the anadromous A. <u>Sturio</u> in Russia has landlocked Nikolsky (1961) reported thing A bareni in Scherce, and Asturno in werden Curopo populations, and Haynes et al. (1978) said the same for the American A. transmontanus, which has become landlocked in hydrolakes in the Columbia River.

Trouts and salmons - family Salmonidae 3.

The trouts and salmons are probably the archetypical anadromous fishes and are amongst the most studied of fishes owing to their great importance for angling and as food. They are medium-sized to large fishes (reaching more then 1.5 metres in length). They are cylindrical to compressed fishes of highly streamlined form. Perhaps the most characteristic feature of these fish is the presence of a rayless adipose dorsal fin behind the normal rayed dorsal fin. Commonly the mouth has large, recurved teeth, and there are small scales, although not on the head.

Salmonids are characteristic of cool and cold waters of all northern continents, occurring from the Arctic south as far as the Mediterranean and northern Africa. The family contains about 68 species in nine genera. All of these spawn in fresh water (Nelson, 1976) but anadromy is strongly and widely represented.

Anadromy in salmonids may be typified by the Atlantic salmon, <u>Salmo</u> <u>salar</u>. This fish spawns during winter, in gravelly nests in swiftly flowing streams (as in almost all salmonids), and it may take place a long distance upstream (up to where However, it is not always a long way from the sea. 4000 km). Some weeks after hatching in the gravels, the young alevins

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emerge into the streams where they feed and grow. Freshwater life in juvenile Atlantic salmon may last only about a year, but is often longer, up to eight years in extreme cases (Power, 1969). Migration to sea follows a well-defined physiological change known as smoltification, at which time the fish become able to osmoregulate in sea water, and at which time their colouration changes. Not all the young actually go to sea, some maturing as "precocious males" in fresh water, at an age of only a year. Atlantic salmon range very widely at sea, stocks from the east coast of North America, Britain, and Scandinavia all reaching Greenland, many hundreds of kilometres away. The return migration of mature adults to fresh water and the migration upstream to spawn may take place after only a year at sea (early maturing males known as 'grilse'), or may occur after ? to ? years at sea. During the upstream spawning migration the adult fish do not feed. After spawning many adults die but some, mostly females, return to the sea to feed, and recover condition again, before spawning a second time. A very few females may spawn a third time.

The brown trout, <u>Salmo</u> <u>trutta</u>, (widely distributed in for the White Act and Act Area for the former (Masua) Africe round and Turkey Europe) is closely related to the Atlantic salmon. It has a much more variable life cycle but shares many of the features of that of the Atlantic salmon. The essential difference is that the migratory cycle is much more facultative, and it appears that not only do some fish in a population go to sea and others not, but also that some fish may go to sea in one year, return, and not go to sea the next. The cycle is so facultative and

Howen, sea-migration (anadromy) on & i mudic, present in Northeon regions and any anadromous. Post-spawning survival in brown trout is much south as the Bay of Biscay. Further south, population one confined to fur (Treneva, 195,3) higher than in the Atlantic salmon, and it may spawn repeatedly over five to ten or more years. Movement at sea, however, appears to be much more restricted and less clearly defined. In the sea, brown trout probably remain largely close inshore, although they sometimes wander (rather than 'migrate'?) longer distances. Wheeler (1969) suggested distances of up to about 300 km as 'not uncommon' and distances of more than 600 km being on record. Jonsson (1985) described a population in a Norwegian lake in which there were sympatric anadromous and resident stocks, the anadromous fish smolting and leaving for the sea during the spring, the return migration of spawning adults occurring in autumn; resident and migrant fish were observed to spawn together.

variable that it might be argued that the brown trout is scarcely

Two eastern North America trouts, the rainbow trout, <u>Salmo</u> <u>gairdnerii</u>, and the cutthroat, <u>S. clarki</u>, are also anadromous, the rainbow being known for having lower post-spawning survival than <u>some</u> other <u>Salmo</u>. Movement to sea of the rainbow trout occurs after smolting, Conte and Wagner (1965) showing that it smolting is related to size (about 150 mm) rather than to age. Behnke (1968) described the life history of the Kamchatka trout, <u>S. mykiss</u>, as being comparable with that of the rainbow trout (there appears to be some doubt about whether the two species are actually distinct, a question that seems to have been avoided by salmonid ichthyologists).

Some of the species of char, (genus <u>Salvelinus</u>) are also anadromous, as in the alpine char, <u>S. alpinus</u>, which is virtually

circum-Arctic, the brook char, <u>S. fontinalis</u>, in eastern North America, the dolly varden, <u>S. malma</u>, in western North America and eastern Asia, and two rather more localised species – <u>S.</u> <u>leucomaenis</u> in northeastern Asia and possibly <u>S. confluentis</u> in Fuget Sound, in western North America (Behnke, 1980).

The Arctic char is, with little doubt, the most widespread northerly distributed species of freshwater/anadromous fishes; it occurs widely (as widely as there is land within the Arctic circle, reaching about 82.5°N - Johnson, 1980). It spreads south into northern New England in the eastern United States. Anadromy is well-developed. Arctic char are slow growing, and do not reach maturity until a considerable age (4-8 years, sometimes up to 10). They live at sea during the brief far northern summer, and the entire population leaves the sea in late summer-autumn, returning to fresh water. Not all the return migrants spawn - the immature fish leave the sea with, or a little later than the spawners and accompany them onto the spawning grounds. They home accurately onto their natal streams, Glova and McCart (1974) suggesting that they actually return to the same spawning ground throughout their lives. Spawning takes place in river rapids or around lake shores, on the latter (according to Johnson, 1980) because the rivers may totally freeze during the winter. Both post-spawning adults and non-spawners overwinter in fresh water, being largely inactive where unfrozen water remains. They return to the sea to feed in the spring, when the ice melts. However, some fish may remain in fresh water for several years without returning to the sea.

Johnson (1980) observed that the spawning population may comprise some new sea-migrants, some fish that had left the sea a year or two previously, and some that had never been to sea; all three types 'appear to intermingle on the spawning grounds and to spawn at about the same time'. The fish survive spawning, spawn several, perhaps many times, and reach a great age - Johnson wrote of reports of Arctic char up to 33 years old and six or seven spawnings with gaps of three or four years; However, annual spawning is known (Nordeng, 1961).

The eggs develop during the winter, often under ice, and hatch in the spring, up to three months after spawning. The young feed for a considerable time in fresh water - probably several years (four to five commonly but up to nine) before going to sea, with a much less marked smoltification than is known for species of <u>Oncorhynchus</u>. Arctic char smolts then make annual migrations to (during spring) and from (autumn) the sea prior to their first spawning. At sea, they are generally found along the coasts and in bays, in shallow water, and perhaps do not move far from their source river.

Nordeng (1963) identified three sympatric stocks of Arctic char in Norwegian rivers and lakes - 'anadromous, small and large freshwater residents'. He found that the progeny of each type segregated to produce some of each sort, regardless of the parentage, and that individual char may pass through more than one of the above types of stock during its life. In the south (south of about 65°N), he found that anadromy failed to occur, but when southern, non-anadromous fish were transplanted north to where there were anadromous stocks, the transplanted fish became

anadromous.

Other species of <u>Salvelinus</u> resemble <u>S. alpinus</u> in details of the life history. Dolly varden, <u>S. malma</u>, have a sub-Arctic and Arctic distribution in eastern North America and western Siberia, and have a life history similar to Arctic char - autumn spawning, spring hatching, life in freshwater for several years before a sea migration by smolts at about three years of age. The whole population leaves the sea to overwinter in fresh water, some spawning annually, others every two years. Some males remain in fresh water as 'residuals', mature early at a small size and participate in spawning amongst the larger adults. The dolly varden is said to spend only a month or two feeding in the Spawning survival is said to be sea (Mathisen et al., 19??). lower in the dolly varden than in the Arctic char, few surviving

more than two spawnings (Armstrong and Moore, 1980). Brook char (Sfould measure Canado han the sak-Arote and south in to the eastern Understehe. They Lalso have a comparable life history strategy in the more northern

parts of their range, but further south they mature earlier and wilder (1952) Studied o population (brook char in which fusher growing, layer induced may spawn annually. Whereas in the north it is suggested that meno another main showe growing malls ones, were without lakely to be an protothis species, and other chars, leave the sea and move into fresh water to escape the very cold temperatures of the Arctic winter, others (Mullan, 1958) suggest that further south, brook char leave the sea in the spring and move to fresh water to escape the warmer sea temperatures of the summer. Brook char probably do not range very widely when at sea.

> In the Asian genus <u>Hucho</u> one species, <u>H. perryi</u> is anadromous. Okada (1960) reported that it occurs along coasts and in bays, and that it returns to the sea after spawning. Bup (1962) sand that does not never for upstream.

Anadromy is widely present (though not well desribed) in the whitefishes and ciscoes (genus <u>Coregonus</u>). The extent of their anadromy seems to vary widely. Some, like the Arctic cisco, C. shough Be autumnalis, are described as fully anadromous in Arctic Canada nod & down Asia and Europe, running into fresh water in early spring in 21 may more long derhance (allean 1500km) up neut (Nikor Roshetn (Wynne-Edwards, 1952). [In this species a distinct, Canada of there is no feeding during this migration downstream, post-spawning migration is reported in late autumn-Then a commonent spawn & summar, and the may spaw two . These funes Spanny , winter. The Bering cisco, <u>C. laurettae</u>, possibly has a similar & ans life history strategy in the Bering Sea drainages of Alaska (McFhail and Lindsey, 1970), and possibly also of Siberia, but its upstream migration is thought to be in autumn. The broad whitefish, C. nasus (in nearly all Arctic drainages of North America, Asia and Europe), has been described as 'evidently

anadromous' (McFhail and Lindsey, 1970), moving downstream "at

least into brackish water' and having a summer return migration. Spawning migrants are said to cease feeding during migration, but have found no information on the downstream movement of the young of this, or other species of Coregonus, or the age at which they enter the sea. Svardson (1979) recognised two anadromous species of <u>Coregonus</u> in Scandinavia/Baltic Sea drainages - <u>C.</u> lavaretus and C. wildgreni, which seem to have similar (and I which is northern concemption in the Arche C. lavaretus/was described equally poorly understood) habits. . milly Bry (1962) a my aute by Svardson as spawning every two years, during the spring/ and yours

To over gravelly rapids, the post-spawners returning to the Baltic the Ruman Subernam Arctic M learneth see for the ruman the Cato mumar, hoth mature & unador before the winter. The English houting, <u>C. Oxyrinchus</u> is making a the see num cerep; they do not more for ups Tream. Then an appointly two search described by Wheeler (1969) as being typically estuarine, only mpate for rarely moving far to sea. The same appears to be true of the 18

Canadian whitefish, C. canadensis (Scott and Crossman, 1973). Egn then seen to ! spring rauter supe

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Another actus spen Comerkun was reparded as anodronnone by R The sprost megal for wrother, by cours with ott of lear the section the autern to st

The inconnu, Stenodus leucichthys is a further coregonine that is also anadromous. It occurs widely in species. 800 (1962 northwestern North America and in the Arctic drainages of Siberia Horan south into the Benny See (Kor Bay) rander for all for (1970) described it as probably not straying far from river a part of the lefe a rew, and poully medicines, had pot Grossenster, metion incoded a new mouths. It evidently has an upstream migration lastics and Russia. as far east as the White Sea. / McPhail and Lindsey followy i a meet 0 2 months over the summer period, with no highly concentrated, or rease during impation. spanning is in autium (Oetske - Buy (962) well-defined movement. / However, McPhail and Lindsey refer to a 'tremendous rush' of spawned-out adults, moving downstream during The young an decauted as taky second year to more decontrace to t the autumn, after the late summer-autumn spawning, (see also Thus there is hept spawner Behnke, 1972, and Alt, 1969*******). surene Insthe related gives, <u>Prosoprum</u>, is essentially prestwater though (Vorder (1970) and Walter (Facific salmons (genus <u>Oncorhynchus</u>) comprise six species. The essential structure of their life cycle resembles that of the Atlantic salmon - spawning in fresh water in gravelly streams, a movement to sea of the juveniles, growth to maturity in the sea, and a return migration to the stream of birth. Returning adults cease feeding on or before entry to fresh water. Pacific salmons are characterised by virtually complete post-spawning mortality, through Robertson (1957) showed that a very few precocious males of the chinook salmon (O. tshawytscha) may survive spawning. However, although the basic cycle is the same. details varv.

At one extreme. in the pink salmon, <u>O. gorbuscha</u>, and the chum salmon. <u>O. keta</u> (both present in western North America and in north-eastern Asia from northern Japan, northwards) spawning may take place close to the sea (it may in be in tidal waters in the pink salmon - Hanavan and Skud, 1954), but it may be well

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- up to at least 200king (Samo, 19) and rearly 500 king Canado upstream in the chum. Chum are known to leave the sea on their unhoth pink 1 Chum spawning migration in both spring and autumn, and a similar dual migration is known in some other Onyorhynchus, e.g. the chinook, O. tshawytscha. On hatching and emerging from the gravels, the young may go almost immediately to sea, without feeding beforehand, though in the chum feeding in fresh water can be quite extensive prior to the migration to sea. These species spend two (pink) or more years in the sea, before returning to spawn. The coho salmon, O. kisutch, is very widely distributed in lands bordering the northern Pacific, occurring from the northern islands of Japan (Hokkaido) northwards along the Siberian coastline, east to Alaska and south along the coastline of North America to central California. Coho leave the sea in autumn, moving upstream to spawn, and usually spawn only moderate distances up from the sea. The young, when they emerge from the spawning gravels during the spring, may either go very rapidly to sea (Foerster, 1955), or more usually, may remain in fresh water streams, normally for a year, sometimes two, rarely three years (Miller and Brannon, 1982). The chinook has a similar distribution to that of the coho, and spawns very widely from streams not far upstream from the sea, to others vast distances into the inland, perhaps 2000 km upstream in extreme examples. The life cycle of the chinook is also similar to that of the coho, though, as noted above, well-defined spring and autumn spawning runs can be identified. Most of the young chinooks move out to sea during the first year of life, some after only a few weeks feeding in fresh water, many after about three months, some staying for up to a year, and a few for two years in streams

of the far north. Some of the outmigrants may dwell in brackish estuaries for a period before moving on out to sea. Chinooks spend several years at sea, and may return at anything from two to nine years of age, most usually three to five years. In the sockeye salmon. O. nerka (again widely distributed on both sides of the northern Pacific), the young migrate from the spawning streams to a lake, where feeding and early growth takes place for one to two, occasionally three or four years, before migrating to sea. Sockeye migrate to sea at a larger size than other species of Oncorhynchus. Thus in the pink and chum salmon, the movement takes place without feeding and soon after emergence, in the coho and chinook there is a freshwater life, with feeding and growth lasting several months as the fish move downstream, while in the sockeye there is a definite feeding migration of the young followed by another distinct migration to sea.

The masou, or cherry salmon, <u>O. masou</u> is found in eastern Asia, from Japan, Korea, and Siberia. Although it is essentially migratory like other species of <u>Oncorhynchus</u>, Miller and Brannon (1982) indicated that in riverine populations there may be a 'significant number of fish that never leaves fresh water rivers'. The non-migrant, river-resident part of the populations are largely, though evidently not exclusively male (Berg, 1948). Berg found that only males mature in fresh water in the north but that the south both males and females are involved. The spawning run of the masou salmon beings early (February), continuing through the spring and summer. Okada

(1960) suggested that masou continue to feed and mature during their freshwater spawning migration (unlike all other species of Oncorhynchus), and this was supported by Miller and Brannon (1982). Spawning takes place during late summer through autumn (July to October), and as with other Oncorhynchus, all the spawners die. The emerging young may spend a year, sometimes two years in fresh water, and they return as spawning adults only a year or so later. Homing is highly characteristic of the Salmonidae having been reported in many different species.

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Deviations from these basic life cycle patterns are several and varied. In fact Miller and Brannon (1982) suggest that ad differences between stocks of a given species nearly match in A magnitude those among species. The occurrence of estuarine spawning in the pink salmon (Hanavan and Skud, 1954) means that at that point, this species becomes only marginally anadromous. However, such spawning seems to be exceptional. It is 18% d interesting that this has occurred in a species in which 05 migration to sea occurs almost immediately following emergence of the young from the gravels, i.e. the young are able to cope with f the fresh water/sea water transition very early in life, in contrast with some other species of <u>Oncorhynchus</u>. No salmonid g has become totally marine. In various measures and in differing 6 (442) ways, however, species have modified their basic life history A strategies. Some species have established lacustrine \star populations, either enforced by the impoundment of lake outlets ♥ (natural, or man-made), or without such compulsion. This is true of sockeye salmon, masou salmon, Atlantic salmon, cutthroat, rainbow trout, and other trouts, several chars, various ciscoes and whitefishes, and others. Pink, coho and chinook salmon, have all successfully established lake stocks in the Great Lakes of North America, although they have failed to do this within their natural ranges in western North America. Chinooks have also done this in New Zealand, voluntarily, after anadromous stocks of this species were introduced and became established in the early 1900s (McDowall, 1978a).

While establishment of lacustrine stocks of salmonids is not rare, rather fewer species are facultative as regards loss of anadromy within river systems. Most successful in this regard is the brown trout, which seems to be highly flexible in the life cycle adopted. Jonsson (1982, 1985) identified different stocks of brown trout in Norway. In an evidently anadromous population, one part of the stock was found to smoltify and migrate to sea while another part remained in the streams to mature at stunted size. The non-migrants could be either all males, or include both sexes. Northcote (1969) demonstrated a similar tendency in Marinbow trout - a population above an impassable fall was interpreted as surviving because of a genetic

tendency for some fish in the stock to not migrate to sea. had earlier the months the months provided of the same phenomenon in Arctic char, us involved on Nordeng (1963) recognised the same phenomenon in Arctic char, us involved on while rainbow trout and brook char also successfully establish the in connu in same to have sympathic revenue and non-diadromous fluviatile stocks. an education shocks for the same files and the same for the s

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There is not only local variation in the occurrence of anadromy in northern populations, but also, towards the south of species' ranges, anadromy tends to disappear altogether. The brook char, like the brown trout, is anadromous at the northern

extreme of its range, but is less so further south, and anadromy disappears altogether towards the southern limits of its occurrence (Kendall, 1935). Arctic char were shown to become non-anadromous at a latitude of about 65°N in Norway, by Nordeng (1961) and are not anadromous in Baltic Sea drainages; nor are they anadromous south of about 490N in Newfoundland, in eastern Canada (Bigelow, 1963). In many instances the non-anadromous stocks are riverine (not lacustrine), so that in regard to several salmonids, Baker (1978) is incorrect in claiming that when there is loss of diadromy in fishes, a downstream migration always ends in a lake - although this seems to be true of <u>Oncorhynchus</u> - all non-anadromous <u>Oncorhynchus</u> seem to be lacustrine.

Interspecific variation within the various salmonid genera follows the same general pattern, there being distinct species in nearly all areas and in nearly all generic groups that have excluded the marine migratory phase from the life cycle, derivative species either becoming lacustrine and migrating into tributaries to spawn, or becoming wholly fluviatile. This is true of <u>Salmo</u>, <u>Salvelinus</u>, <u>Hucho</u>, and <u>Coregonus</u> but not Oncorhynchus, unless the Japanese species O. rhodurus is accepted as being as distinct from <u>O. masou</u> - it isn't by most authorities (e.g. Behnke et al., 1962). It could easily be assumed that the standard pattern of evolution of non-anadromous salmonid species, in genera such as <u>Salmo</u>, <u>Salvelinus</u>, <u>Coregonus</u>, etc., is by the establishment and isolation of landlocked populations. An example of a landlocked anadromous derivative species is <u>Salmo</u> aquabonita, said by salmonid ichthyologists to be allied to and

derived from the anadromous <u>S. clarki</u> (Schreck and Behnke, 1971, Legendre et al., 1972). Although this has undoubtedly occurred in various salmonid lineages, accounts of the relationships of some of the inland species of <u>Salmo</u> in western North America by Miller (1972), Behnke (1966, 1972), and others, indicate a significant amount of speciation amongst already non-anadromous species, Miller (1972) pointing to <u>S. chrysogaster</u> as having primitive origins with other species being derived from it. whether such species as <u>S. chrysogaster</u> have anadromous origins cannot now be determined.

4. Smelts - family Osmeridae

The smelts are smallish (to about 300 mm), silvery, shoaling fishes, usually of compressed and slender form. Like salmonids they have an adipose dorsal fin. They have large, stronglytoothed mouths and are well-covered with thin scales. The family is widely distributed in the cold to cool northern hemisphere, on all continents and in all oceans. The family contains about 12 species in six genera, and is variously anadromous, freshwater or marine; anadromy is a well-recognised phenomenon in the family.

The rainbow smelt, <u>Omerus mordax</u> is representative of anadromy in this family (McKenzie, 1964). It occurs in eastern North America from the Labrador coast of Canada, south to Delaware Bay in the United States, and also in some Arctic drainages of northern Canada and sub Arctic drainages of the northern Facific of the United States. In New Brunswick (Canada) adult rainbow smelt move inshore during the autumn, but

LISTING OF DIADROMOUS FISH SPECIES ACCORDING TO TYPE OF DIADROMY WITH LATITUDINAL RANGE

1. ANADROMOUS FISHES

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FAMILY PETROMYZONIDAE

<u>Petromvzon marinus</u> Lampetra iaponica Lampetra evrsii Lampetra fluviatilis Caspiomyzon wagneri

FAMILY GEOTRIIDAE Geotria australis FAMILY MORDACIIDAE Mordacia mordax Mordacia lacipida - 28°N - 55°N 34°N - 71°N 38°N - 58°N 42°N - 59°N 48°N - 54°N

35°S - 44°S

FAMILY ACIPENSERIDAE Acipenser oxyrhynxhus 28°N -54PN 34°N -Acipenser brevirostrum 45°N 30°N Acipenser medirostris 590N 36°N -Acipenser transmontanus 60°N - 70PN 68°N Acipenser baieri 43PN Acipenser sturio 710N - 56°N 46°N Huso huso 52°N 52°N Huso dauricus

FAMILY SALMONIDAE Salmo salar

41°N - 68°N

| Salmo trutta | 43 360N | | 68 - N |
|--------------------------|---------------|---|-----------------|
| Salmo clarkii | 40=N | _ | 61°N |
| <u>Salmo gairdnerii</u> | 329N | - | 61°N |
| Salmo mykiss | 50 - N | _ | 60 ° N |
| Salvelinus alpinus | 45°N | | 82°N |
| Salvelninus fontinalis | 41°N | _ | 60 0 N |
| <u>Salvelinus malma</u> | 48°N | _ | 71 ° N |
| Salvelinus leucomanis | 42°N | | 60 - N |
| Salvelinus confluentis | | | |
| Hucho perryi | 42°N | - | 55°N |
| Stenodus leucichthys | 60°N | - | 73 - N |
| Oncorhynchus masoud | 58 - N | | 73°N |
| Oncorhynchus nerka | 38 - N | - | 69 - N |
| Oncorhynchus kisutch | 37°N | - | 68 - N |
| Oncorhynchus tshawytscha | 37 - N | - | 68°N |
| Oncorhynchus keta | 33-N | | 71°N |
| Oncorhynchus gorbuscha | 35°N | | 71°N |
| Coregonus autumnalis | 65°N | _ | 739N |
| Coregonus laurettae | 58°N | - | 69°N |
| Coregonus nasus | 609N | | 73 ° N - |
| Coregonus lavaretus | 65°N | | 73 ° N |
| Coreaonus wildareni | | | |
| Coregonus oxyrinchus | 51°N | | 57 - N |
| Coregonus muskun | 69°N | | 73°N |
| Coregonus canadensis | 43°N | - | 44°N |
| Coregonus sardinella | 58 ° N | - | 739N |

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FAMILY OSMERIDAE

| Osmerus mordax | 41°N | | 73 - N |
|-------------------------------|---------------|---|---------------|
| Osmerus eperlanus | 38 0 N | - | 68°N |
| <u>Spirinchus lanceolatus</u> | 42°N | | 45°N |
| Spirinchus thaleichthys | 38 0 M | | 61°N |
| Thaleichthys pacificus | JAPN | | 60 0 M |
| Hypomesus transpacificus | 38 - M | | 73 ° N |
| FAMILY SALANGIDAE | | | |
| Salangichthys microdon | 32°N | | 52°N |
| Salanx ariakensis | 31°N | - | 33 0 N |
| Salanx ishikawae | 33°N | - | 39 9 N |
| Salanx cuvieri | 38 0 M | - | 39 0 N |
| <u>Salanx acuticeps</u> | 23°N | | 20 0 M |
| Protosalanx hvalocranium | 31°N | | 35°N |
| Necsalanx <u>iordani</u> | 35°N | | 40 ° N |
| Hemisalanx prognathus | 31°N | - | 40 ° N |
| FAMILY AFLOCHITONIDAE | | | |
| Lovettia sealii | 4105 | - | 44 0 5 |
| FAMILY RETROPINNIDAE | | | |
| <u>Retropinna retropinna</u> | 34°8 | | 47 0 3 |
| <u>Retropinna tasmanica</u> | 4105 | - | 44 - 5 |
| <u>Stokellia anisodon</u> | 43°S | | 47 ° S |
| FAMILY CLUPEIDAE | | | |
| Alosa pseudoharenous | 34°N | | 52 - N |
| Alosa sapidissima | 28°N | - | 51 ° N |
| Alosa mediocris | 28°N | - | 45 ° N |

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| Alosa chrysochloris | 28°N | - | 309N |
|-------------------------------|---------------|-----|---------------|
| Alosa aestivalis | 28°N | | 47°N |
| Alosa alabamae | 29°N | | 30 - N |
| Alosa alosa | 43°N | - | 60 - N |
| Alosa fallax | 43°N | - | 65 ° N |
| Nematalosa vlaminghi | | | |
| Dorosoma cepedianum | 21°N | - | 499N |
| Dorosoma petenense | 22 - N | — | 399N |
| <u>Hilsa ilisha</u> | 230 N | - | 50N |
| Hilsa macrura | 1100 | - | 805 |
| Hilsa toli | 2201 | J - | - 10°5 |
| Hilsa pr∉stipasteroides | 5°N | | -1005 |
| | | | |
| GASTERUSTEIDAE | | | |
| <u>Gasterosteus aculeatus</u> | 29 ° N | | 719N |
| PERCICHTHYIDAE | | | |
| Morone saxatilis | 34°N | _ | 46°N |
| 2. CATADROMOUS FISHES | | | |
| FAMILY ANGUILLIDAE | | | |
| Anguilla anguilla | 28 °N | | 65°N |
| Anguilla rostrata | Ģ ≏ N | - | 609N |
| Anguilla japonica | 22°N | - | 429N |
| Anguilla mossambica | 3508 | - | 25°N |
| Anguilla celebensis | 24 - N | - | 1105 |
| Anguilla marmoratus | 24 0 N | - | 3308 |
| Anguilla nebulosa | 23°N | - | 30 ° S |
| Anguilla bicolor | 22°N | | 27 - 5 |
| | 0 | | |

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| | Anguilla obscura | 20N | | 27-5 |
|---|---------------------------------------|--------------|------|---------------|
| | Anguilla borneensis | 2°N | | 2°S |
| | Anguilla megastoma | 195 | | 25 - 5 |
| | Anguilla interioris | 395 | - | 905 |
| | Anguilla reinhardtii | 1095 | - | 38 - S |
| | Anguilla australis | 18•S | | 4705 |
| | Anguilla dieffenbachii | 34-5 | | 47 - S |
| | FAMILY GALAXIIDAE | | | |
| | <u>Galaxias maculatus</u> | 33-5 | | 55-5 |
| | FAMILY CLUPEIDAE | | Fine | |
| | Potamalosa richmondia | 290 | s — | 8405 |
| | FAMILY PERCICHTHYIDAE | | | |
| X | Macquaria novemadlyeata | 26°5 | - | 3908 |
| | FAMILY CENTROPOMIDAE | | | |
| | Lates calcarifer | 2005 | | 2301 |
| | FAMILY MUGILIDAE | | | |
| | Mugil cephalus | 42°S | - | 42°N |
| | Agonostomus monticola Myxus petodi | 28°N 26°S | - | 349N |
| | FAMILY FLEURONECTIDAE | | | |
| | <u>Rhombosolea retiaria</u> | 3405 | _ | 47 - S |
| | 3. AMPHIDROMOUS FISHES | | | |
| | FAMILY PLECOGLOSSIDAE | | | |
| | <u>Plecoglossus altivelis</u> | 23 PN | | 44°N |
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FAMILY GALAXIIDAE

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| <u>Galaxias truttaceus</u> | 3795 | - | 4405 |
|---|--|---|--|
| <u>Galaxias brevipinnis</u> | 3405 | - | 53°S |
| <u>Galaxias fasciatus</u> | 34 ° 5 | | 47 0 5 |
| Galaxias argenteus | 34 ° S | - | 47 ° S |
| Galaxias postvectis | 34 - 8 | - | 4705 |
| <u>Galaxias platei</u> | 40 ° S | - | 5405 |
| FAMILY APLOCHITONIDAE | | | |
| Aplochiton taeniatus . | 40°5 | | 5505 |
| Aplochiton zebra | 40 ° S | - | 5405 |
| FAMILY PROTOTROCTIDAE | | | |
| Frototroctes maraena | 3405 | - | 44 0 5 |
| Frototroxtes oxyrhynchus | 34 ° S | ÷ | 47 ° S |
| | | | |
| FAMILY MUGILDIDIDAE | | | |
| FAMILY MUGILDIDIDAE Cheimarrichthys fosteri | 3405 | | 47 - 5 |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEOTRIDAE | 3405 | | 47 - S |
| FAMILY MUGILOIDIDAE <u>Cheimarrichthys fosteri</u> FAMILY ELEOTRIDAE <u>Gobiomorphus huttoni</u> | 34°S | | 47 ⊳ S 47 ⊳ S |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEOTRIDAE Gobiomorphus huttoni Gobiomorphus hubbsu | 34•9 34•9 34•9 | | 47°5 47°5 47°5 |
| FAMILY MUGILOIDIDAE <u>Cheimarrichthys fosteri</u> FAMILY ELEOTRIDAE <u>Gobiomorphus huttoni</u> <u>Gobiomorphus hubbsu</u> <u>Gobiormorphus gobioides</u> | 34•9 34•9 34•9 34•9 | | 47°5 47°5 47°5 47°5 |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEOTRIDAE Gobiomorphus huttoni Gobiomorphus hubbsu Gobiormorphus gobioides Gobiomorphus cotidianus | 34•9 34•9 34•9 34•9 34•9 | - | 47•S 47•S 47•S 47•S 47•S |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEOTRIDAE Gobiomorphus huttoni Gobiomorphus hubbsu Gobiormorphus gobioides Gobiomorphus cotidianus Gobiomorphus coxii | 34•S 34•S 34•S 34•S 34•S 34•S | | 47°S 47°S 47°S 47°S 47°S 43°S |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEDTRIDAE Gobiomorphus huttoni Gobiomorphus hubbsu Gobiormorphus gobioides Gobiomorphus cotidianus Gobiomorphus coxii Gobiomorphus australis | 34•S 34•S 34•S 34•S 34•S 26•S 30•S | | 47°S 47°S 47°S 47°S 47°S 43°S 37°S |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEOTRIDAE Gobiomorphus huttoni Gobiomorphus hubbsu Gobiormorphus gobioides Gobiomorphus cotidianus Gobiomorphus coxii Gobiomorphus australis FAMILY GOBIIDAE | 34•9 34•9 34•9 34•9 34•9 24•9 30•9 | | 47°S 47°S 47°S 47°S 47°S 43°S 37°S |
| FAMILY MUGILOIDIDAE Cheimarrichthys fosteri FAMILY ELEOTRIDAE Gobiomorphus huttoni Gobiomorphus hubbsu Gobiomorphus gobioides Gobiomorphus cotidianus Gobiomorphus coxii Gobiomorphus australis FAMILY GOBIIDAE Sicyopterus extrapeus | 34•9 34•9 34•9 34•9 34•9 34•9 34•9 | | 47°S 47°S 47°S 47°S 47°S 43°S 37°S |

Lentipes concolor

Sicvidium ????Japan

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19°N - 22°N