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**CEDAR RIVER SOCKEYE  
SPAWNING CHANNEL WORKSHOP  
JANUARY 25-26, 1990**

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**SUMMARY OF PRESENTATIONS AND DISCUSSIONS**

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Approved

Submitted

5-23-90

R. P. Fourn.

Director

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# FOREWORD

The following summary of the agenda and resulting discussions from the Cedar River Sockeye Spawning Channel Workshop was originally intended to be assembled as an informal document for distribution solely among the workshop participants; it was not intended to be formally published (i.e., citeable). However, given the interest both in Lake Washington fisheries and in spawning channels, we felt that potentially interested parties might be better served by making this a formal document, which would result in making the information contained herein more accessible to members of the research and management community at large.

We ask the reader to keep in mind that the workshop discussions were recorded in the form of minutes and, thus, are presented as such. We felt there was little to gain from rewriting all the minutes to adhere to grammatical conventions.

The figures and tables are located at the back of this report; they are not numbered because they were not specifically cited in the discussions. Also note that while a number of figures were scanned or re-input for the sake of clean, consistent format, their contents have not been changed.

Robert C. Francis, Director  
Fisheries Research Institute  
and

Marcus Duke, Editor  
School of Fisheries

## PREFACE

On January 25 and 26, 1990, a Cedar River Spawning Channel workshop was held at the University of Washington. As an aid to those who participated in the meeting, we have recorded a brief summary of the discussion. Our Canadian visitors, who provided so much useful information, also consented to let us circulate copies of the transparencies they showed during these presentations.

Enclosed you will find the summary of discussion, copies of the transparencies, a list of the questions circulated prior to the meeting, and a list of participants.

This report is not intended to serve as a source of citation for the material presented by the Canadians. Anyone wishing to cite material presented by the participants should contact the individuals and obtain a direct quotation and journal or technical report reference.

The videotape of the workshop was made by the National Marine Fisheries Service and anyone interested should contact Rollie Schmitten.

My thanks again to everyone who helped in the planning, particularly Jay Rusling and Bill McKay of Puget Sound Anglers, Bob Gerke of Washington Department of Fisheries, and Dave Parkinson of Seattle Water Department. They all suffered through a long series of meetings necessary to make the workshop happen. Special thanks to our "Canadian Guest Experts," Jim Wild, Trevor Evelyn, Ian Williams, Cam West and Kees Groot, as well as Ernie Brannon who came from Idaho for the workshop. Lauren Cole did an excellent job as reporter. Finally, Mr. H. Mason Keeler, through his generous donations to the School of Fisheries, provided the funding for the Canadians' travel and other workshop expenses.

Ray Hilborn  
May 23, 1990

# SUMMARY OF PROCEEDINGS

## DAY 1, THURSDAY, 25 JANUARY

Ray Hilborn welcomed participants, and introduced Joe Blum.

Joe Blum (Director, Washington Department of Fisheries) voiced goal of workshop: working session for a lot of knowledgeable people. Washington Department of Fisheries (WDF) has been interested in a spawning channel for a long time. This session to address questions and pick brains. Thanks to Canadians and UW.

Ray Hilborn described logistics of meeting:

- only those at table may speak
- others may submit written questions
- NOAA is videotaping workshop
- meeting organized by legislative policy committee
- meeting funded by Keeler Professorship

### BACKGROUND OF SPAWNING CHANNEL: ERNIE BRANNON

Sportsmen were the instigators for the idea early on. Objective for a spawning channel: greater success for producing and incubating fry.

Spawning channel controls flow; reduces fine sediments. Brannon reviewed design characteristics for positive and negative effects. Concerns that need to be addressed: behavior of fish; substrate. Early spawning channels had numerous voids in the gravel that compacted eggs at interface of gravel and channel bed, and led to disease and loading problems.

Ray Hilborn introduced the design session and the format of discussion. Only those at the center table may speak. Others may submit written questions.

### DESIGN

- Participants at table for Design session:

Canadians: Trevor Evelyn  
Cam West  
Ian Williams

Kees Groot  
Jim Wilde

Others: Kevin Amos (WDF)  
Ernie Brannon (University of Idaho)  
Tom Flagg (Nat. Mar. Fish. Serv.)  
Dennis Moore (Muckleshoot Indian Tribe)  
Jay Rusling (Puget Sound Anglers)

Ken Bates (WDF)  
Nancy Davidson (SWD)  
Ron Mayo (SWD)  
David Parkinson (Seattle Water Dept.)  
Jim Winton (Fish and Wildlife Service)

### *CANADIAN EXPERIENCE: JIM WILDE*

He sees no problem with Cedar River site. There are about 20 channels in Canada, 9 of which are for sockeye. Climate here is not icy, as in Canada, and that's an advantage. His view of spawning channel: just another piece of river, but with guaranteed flow.

He addressed several of the design questions that were circulated:

(Editorial note: the number before each paragraph refers to the number of the prepared question.)

1. Good water quality, flow, protection from flooding and settling ponds necessary. Intakes should be put on outside curve of river or if possible in a lake.
2. Impermeable liner: avoid if possible. Good to have upwelling into channel (if have high water table). They use plastic when they use liners. Works if water seeping out, but not if its coming in. Impermeable layers such as clay need to be avoided.
8. Drop structures: they try not to have them because they get in the way of equipment and activity. Cools off water due to large water mass. Inject oxygen instead.
12. For sediment and turbidity control the flow needs to be throttled during floods, especially to keep fines out. If can't get intake from lake, a good settling system is needed. Settling basins shouldn't get flooded.
13. IHN removal may be useless if stock has virus.
6. Landscaping: there may be some advantages to organic input. Conifers drop fewer needles than deciduous trees. Gravel will have to be cleaned no matter what.
9. Artificial cover probably not feasible in channel this size, and probably not that effective.
10. Most important concern for visitors is rest rooms. Make sure there is parking and turn around space for buses. Well defined paths for visitors along the channel makes them happy. Maybe keep displays seasonal--they're expensive.
16. Early channels were staged: it helps the stock build, and helps managers ease into construction and production, though it's a little more expensive. Don't have two outflows. One staged site is more economical than two separate sites.
17. Channel width and flows are determined by amount of water available from source. Most are about 40 ft. wide in Canada.
18. Good idea to build partial channel first. Phase construction in steps interspersed with evaluation.

Other considerations are building costs. A deluxe channel on Vancouver Is. was \$2.9 million in 1979, about \$67/yd<sup>2</sup>. Last one built was \$48/yd<sup>2</sup>, but it was at a remote site with few support facilities. Less infrastructure=lower cost. Channel's cost kept down with in-house design: 2 people for 2 years. Break up job into several stages. Get subcontractors to save money.

3. Barrier racks will be disregarded by nature. Floods bring large debris that cause damage. Don't put in any permanent racks. Wood or aluminum floating fences are needed in low population years, but they won't stop big floods.
4. There are tradeoffs at different locations on the Cedar River. Bottom site may have more advantages: IHN won't affect natural spawners; plenty of broodstock available, outlet enumeration easier, probably more economical.
5. Recommended gravel size is 1/2" to 4". Depth of bed should be 18" to 20". Once fish spawn gravel is compacted 25%.
7. There are some intermediate channel fences in Canada--they don't seem to make much difference. Pivotal panels can be good; on the Cedar it may be good to separate runs with fences.
14. Critical scheduling items: expect a 2 year total design and construction period. Plan to finish 2 weeks before the first spawners to allow for contractor being late. Clear and drain site as soon as possible.

## 15. Experimental oxygen injection possible.

*CANADIAN EXPERIENCE: TREVOR EVELYN, FISH HEALTH*

Biology doesn't have pat answers. Focus on IHN problem, but consider other diseases. Other pre-spawning mortality occurs but is sporadic so not much research has been done on its causes. There's Dermocystidium in the Nimpkish system, Ich in the Nadina system. Columnaris (at Horsefly River) is often associated with low flows and high temperatures.

In contrast to earlier thinking on IHN, researchers now believe spawning fish come back clean and that IHN infections occur on the spawning ground.

Evelyn showed a table of egg-to-fry survival in the Babine system, which has ranged from 16-45% in the last 5 years (see attached). IHN probably was a big factor in the observed survivals. Lab evidence suggests that viral titers of  $10^4$  plaque forming units/g tissue in fry leads to death. Estimated losses due to IHN were about 14%-41% in migrating fry. Weaver Creek has had some of the best studies on IHN. There, egg-to-fry survival from 1965-76 was 76%. From 1977-85 it was 47%, which is still 10x as efficient as in the creek itself. 1987 had a large epizootic: about 10%-20% survival. 49% of the migrating fry were killed by IHN in 1987. Virus always has an impact, but in some years it's worse than in others. Globules of fat on the water surface indicate the presence of dead fry even before you see them.

In Great Central Lake the infection rate is equal in males and females. IHN was not observed in fresh returns; post spawners had a 60%-100% infection rate. Virus was apparently contacted on the spawning grounds. Vertical transmission seems to be the exception, not the rule. IHN is prevalent in ovarian fluid and attaches to sperm, but some evidence from Japan suggests some element in yolk material apparently protects egg from virus.

Other evidence against vertical transmission: in 6 years of study on the Babine system there was no correlation between adult and progeny infection rates, even in embryos.

So where does infection happen? IHN virus is not found in 1 month post-spawning carcasses; it's not detectable in kidney tissues of carcasses of known carriers 72 hr after death. Carcasses probably are not the reservoir of infection.

Virus in ovarian fluid is released on spawning, but where does it go? It's not found in silt, algae, caddis and mayfly larvae, snails, earthworms or sculpins. It is found in leeches (*Nepheosis obscura*) in both Babine and Weaver Creek.

Evelyn summarized his observations:

- IHN probably not carried to sea; acquired on spawning grounds;
- virus amplified on spawning grounds;
- leeches or resident salmonids may be reservoirs of infection; reservoir probably not carcasses of spawned out salmon;
- channels should be designed and located so that impact of reservoirs are minimized—obviously it would help to know what the reservoirs are.

*DISCUSSION: DESIGN SESSION*

Winton: He has found similar results to Evelyn's on the Cedar River. Experience from Alaska sockeye program shows that the tools to control IHN infection (which include surface disinfectants and use of pathogen-free water supplies) are available. A spawning channel in the Cedar River will almost certainly be affected by IHN, but it will be variable unless enough money is applied to achieve total control of the virus. Given enough money, virus-free

sockeye can be reared: a channel could be designed to use virus-free eggs, virus-free water and with plans for removing disease vectors at various intervals to keep IHN losses at a stable, low level. We still have lots to learn about the IHN virus. Given Canadian experiences, we can probably design and operate a channel with relatively low losses from IHN. The priorities in the design and operation of the channel will depend on the overall goal of the project. If maximum fry production, run timing, and genetic concerns are the highest priority, IHN virus control may take a back seat.

Bates: Can IHN be controlled through use of ground or seepage water?

Wilde: Don't use true ground water, it's -too low in oxygen. Seepage water with enough oxygen would probably work.

Evelyn: Seepage water would be virus-free water source, and would help keep impacts down, but we still don't know if virus vectors (leeches?) could work their way upstream if ground water is used. Groundwater won't help the IHN problem if reservoirs are already present on the spawning grounds.

Groot: Initial difficulties with water from alternate supplies: imprint from water supplies are a concern, could affect returns and separate populations.

West: Can't predict what will happen with alternate water sources until you actually do it.

Williams: IHN losses may be part of natural mortality. Bottom line is number of returns, not fry production.

West: Basic, clean fish culture techniques help control IHN. Sometimes highest levels of disease are not correlated with lowest fry-to-smolt survival.

Flagg: IHN in Wenatchee River—there is strong evidence for horizontal transfer in holding pens. Could be a concern in the spawning channel. Is it possible to have a staged operation where adults are transferred after holding? In the Wenatchee system, BKD is transferred vertically. Could that be a problem?

Evelyn: Infection rate of BKD is not severe in pre-spawners, but could be for progeny. Advises not to hold progeny to smolt size. Get rid of progeny as soon as possible.

Rusling: There have been a total of 125 channel years in Canada. Incidence of IHN has only impacted egg-to-fry survival in *one* of those years to the extent that production was worse than that in the natural river.

Evelyn: Even in a bad Weaver Creek year, production from the channel is still better than natural production. The problem is public relations—design a channel to minimize public concerns. It's potentially better to release fry than have been exposed to IHN at low levels in the channel, so "novice" fry aren't released that have not been exposed to natural levels.

Winton: IHN means loss of predictability in production, but it can be avoided if there is also more control. To Evelyn and Williams: what is potential for the increase in fry density in the lake instigating an epizootic in Lake Washington itself?

Williams: IHN is a ubiquitous organism and has been found in all but a few populations. I don't think Cedar River enhancement would affect Lake Washington levels. In order to get epizootic, fish must be stressed, so there's unlikely to be problem.

Evelyn: We've seen die-offs of Kokanee from IHN in lakes, but that wasn't followed by die-offs of any other species. It's highly unlikely that disease levels in the lake could be raised high enough to have a serious impact.

- Amos: (Comment) Cedar River sockeye have had some of the highest levels of IHN, but adults do seem to come in clean. (Question) Have you done anything such as preventative temperature manipulations to protect fish from external parasites?
- Evelyn: It hasn't been done with sockeye. We have simply chosen to take our chances.
- Williams: We've tried to control lice, and used temperature reduction to control sullimaris. In general if you remove stress, you remove the problem.
- Amos: Survival in Weaver Creek has gone down since it started. How can we prevent that in the Cedar?
- Williams: We get lower survivals at higher spawner densities, but don't really know why. We've pushed density higher in recent years.
- Brannon: (Comment) The disadvantage of groundwater is temperature differences that can cause more problems than IHN does. (Question) Some of infected fry that enter the lake won't die. Will they be sources of transmission?
- Evelyn: If a fry survives the infection, evidence suggests that it then gets rid of the virus, and reacquires it on the spawning ground. We need a little more evidence to completely support that.
- West: Fulton Creek has had constant densities, but also decreased survival. Maybe loss of gravel, or addition of silt. There are many reasons for decline of survival.
- Brannon: High densities of eggs are often associated with high levels of infection. Any reduction of stress may help keep virus low.
- Evelyn: If IHN virus is introduced in a high density situation, the virus can spread rapidly. If there is more water flow between eggs, then much of the virus is pushed from the system, thus lessening its spread among fry in the redd.
- Brannon: Tell us more about gravel size.
- Wilde: Probably can use finer gravel, down to 1/8", to keep alevins spread more vertically in gravel. Another comment: keep production goals around 40% rather than 80% to reduce stress. Be conservative in all things.
- Williams: Fred Andrews thinks finer gravel may have contributed to higher survival at Weaver Creek. Due to supplier problems they used 20%-30% of gravel at a lower size than what used to be thought was optimal.
- Brannon: The source of gravel, like the source of water, may effect whether fish will spawn.
- Groot: Each situation is unique.
- Dennis Moore: Is Hydra a possible reservoir of IHN in Weaver Creek?
- Evelyn: It's mentioned in a report and suggested as a possibility, but we don't know. Could be lots of other things. Hydra in Weaver Creek have been tested for IHN virus for two years with negative results.
- Amos: Over long spawning periods, spawning may be continuing while the first eggs are incubating. IHN virus may be shed directly onto yolk fry.
- Moore: Do IHN positive fry die, or shake the virus? For mitigation purposes, how do we count what we're actually producing?
- Evelyn: Bottom line, again, is returns. We count what goes out and what comes back. We estimate IHN deaths in the lake by estimating how many fry carry "lethal titers" on migration to the lake.

Williams: High densities in lake aren't more than 1 fry/m<sup>3</sup>. Anything denser is higher stress.

Mayo: Referred to two sketches: One has diversions off main channel; one has separate intakes from head channel. (Question) Have different channel designs such as these been tested?

Wilde: It might be good to have separate loops because spawners spawn over a long period of time.

Mayo: Have you tried different water flows to different loops?

Wilde: Fish will spawn whether you think they will or not.

Groot: The possibility of multiple channels allows for experimentation, but is difficult. May be able to design parallel systems from the start.

West: There's so much variability in channels that lots of background information on a channel, and many replicates. To have many parallel situations careful preparation is needed.

Mayo: (Comment) Groundwater may be water much like regular river water, but with less silt. (Question) Have there been tests on the effect on adult attraction if a water supply is disinfected, i.e. with ozone?

Groot: Difficult to answer. Coho have been shown to prefer river water over groundwater, and their sense of smell is strong. In any case, keep designs simple. Also, groundwater has higher temperature.

Mayo: What about residences? (Question 11)

Wilde: To save money, don't have much infrastructure. But there will need to be some accommodation. Groundwater comment: still need channel water available.

Mayo: Can spawners be removed after spawning?

Evelyn: Removing carcasses could potentially remove a source of IHN, but virus doesn't seem to last long in tissues. Removal of carcasses probably should be low on the list of economic considerations.

Mayo: How formal is integration of disease work into actual design of facilities?

Evelyn: Still don't have much biological info for actual incorporation.

Wilde: We talk every now and then.

Hilborn closed the design portion of the meeting.

## OPERATIONS

Participants at table:

Canadians: Evelyn  
West  
Williams

Groot  
Wilde

Others: Jim Ames (WDF)  
Tim Bodurtha (FWS)  
Ernie Brannon (UI)  
Nancy Davidson (SWD)  
Conrad Mahnken (NMFS)  
Jim Russell

Ron Mayo (SWD)  
Dennis Moore (MSI)  
David Parkinson (SWD)  
Larry Peck (WDF)  
Jay Rusling (PSA)

Ray Hilborn introduced the session speakers. Ron Ginetz couldn't make it; Cam West will speak for him.

*CANADIAN EXPERIENCE (FRASER RIVER)—IAN WILLIAMS*

A spawning channel is a piece of enhanced habitat. Channel designs on the Fraser River are at the low end of slope and velocity habitats found for sockeye spawners. A channel was built at Weaver Creek because of clearcutting for a ski hill. Flooding after clearcuts led to almost no egg-to-fry survival before the channel was built. Williams showed a graph of egg-to-fry survival versus female spawner density in the Fraser River. The slope was much steeper in the channel population than in the natural population. So, don't load channels too densely. Per Kees Groot's data, if there are waves of spawners, channels can hold up to 2 females/m<sup>2</sup>. There is also evidence that sockeye spawners congregate at mid channel, though distribution in some channels is at the top first. Each case is different.

There seem to be pockets of unsuitable habitat within a channel. Williams displayed data from Weaver Creek that shows dissolved oxygen decreasing towards downstream. He also showed that intragravel dissolved oxygen changes between seasons in Weaver Creek, possibly leading to fish stress. Pockets of unsuitable habitat lead to a larger IHN problem that may spread. Stick to 1- $\frac{1}{2}$  yd<sup>2</sup>/female.

Williams showed that in 1982 high escapement from Weaver Creek led to lower escapement from Cultus Lake. If there's a surplus, the fish are hard to get rid of.

Problems seen in channels: algae build-up, accumulation of muck, frazzle ice caught on drop structures, flooding from debris torrent from ski hill at Weaver Creek, plugging of intake screens, channel utilization by chum (they're now diverted back to creek), diversion of fish into channels (used electric fencing that Williams didn't like, but that didn't seem harmful). Also carcass removal—they buried them, but now dump them into a nearby oligotrophic lake. Williams repeated Fred Andrews advice to include some pea gravel in the channel substrate.

Williams think channels work, although there are disease—particularly IHN—problems, which can be reduced through low densities. He reiterated Kees Groot's observation, that it's best to build a few parallel channels so some manipulation and experimentation can be incorporated. He thinks three 25,000 adult channels would be good. Channels work to the fry stage, but problems with outmigration and adult mortalities in dams on returning still need to be addressed.

*CANADIAN EXPERIENCE—CAM WEST (FOR RON GINETZ)*

West addressed the Operations questions that were distributed.

1. In the Babine system the channels is completely dried, which doesn't seem to affect productivity. But these have riprap sides, which can be habitat rearing area that is lost.
4. Don't know what diversion problems will occur until a facility is built. It shouldn't be any problem to divert fish away from a channel. If a channel has a specific attractant, fish will delay spawning and go into the channel in waves, kicking previous spawners off the redds.
5. Redistribution is different in different channels. A fence in mid-channel will help keep distribution even. Or, don't load the last several thousand fish until after others are finished (in a small channel).
6. Take peak part of run to load channel.
7. Water quality impacts of operation vary with the channel. High public visibility in the Cedar River bears weight in channel operations. To clean: push around gravel with a bulldozer,

rake (for fine material). They're now experimenting with a catch basin to settle out fines. Something important to consider.

9. They haven't had a problem with getting fry to leave. Water velocity required is typically 1-2 ft./sec. Channel flows are raised at dusk after most of the fry have migrated to flush it.
11.  $1\frac{1}{2}$  yd<sup>2</sup>/female spawning density seems to work, without loss of fry production. Again, channels are different.
13. Need to measure flow and temperature. Not much is known about silt loading, but that should be measured—it may be possible to monitor with a porosity meter.
14. Spawning density affects egg-to-fry survival. Also algae growth (a diatom bloomed in one channel, causing mortality).
15. Personnel requirements depend on goals. Two people for fry enumeration; add personnel for monitoring and experimentation.
17. It's probably not possible to separate discrete stocks. Best thing to do is load channel in waves, but there may be some redd superimposition. Wave loading over a couple months is OK. Divider structures aren't cheap. Other possibilities are floating fences and other density control devices.

West reiterated the wisdom of creating a sectioned channel. There's a lot we don't know, and have to go on guesswork, so need to optimize channel for getting more information.

#### *DISCUSSION: OPERATIONS*

Ian Williams: (Comment) For measuring physical parameters, water supply gauges need to be top quality to prevent mistakes. May also want to monitor D.O. Need 20 years in a standard channel to get good data, so if a channel is set up as a production facility as well as experimental it's possible to get feedback faster.

Cam West: (Comment) Don't pitch carcasses unless you want to enumerate them.

Ron Mayo: How are egg-to-fry numbers evaluated?

Williams: Get a fecundity estimate per size and an estimate of % spawned.

Mayo: Used blackboard to illustrate question. Did Williams use a curve from egg-to-fry survival to calculate density?

Williams: Yes, but use a conservative estimate, because never know when disease might hit. Choose low on the curve.

Mayo: Does it make sense to manipulate loading to reduce a disease problem?

Williams: If eggs haven't hatched, it shouldn't matter.

Evelyn: Wave spawning may expose susceptible fry to virus when spawning fish are releasing virus upstream of them, but that probably can be avoided by proper channel design.

Mayo: Can you have a series of bypasses to put later fish at the top of a channel?

Groot: I think its better to load from the top. Experiments showed egg retention increased when spawning density got higher than  $1\frac{1}{2}$  yd<sup>2</sup>/female. In confined conditions, male/male aggression creates problems, so load 60 females:40 males, and that ratio could probably go lower.

Mayo: To all 5 Canadians: what density is best?

Groot: Make sure you watch behavior. Recommends 1 female/2 m<sup>2</sup>.

- Williams: I'd have 2 channels, and start with 1 female/2 m<sup>2</sup>, then adjust that as needed in the second channel.
- West: 1 female/1.5 yd<sup>2</sup> based on Babine experience curve of fry production.
- Williams: Spawning density in the Adams River is something of an anomaly. Calculated 3 different ways, optimal density is 2 females/m<sup>2</sup>. The slope is greater, and there is good flushing.
- Groot: In the Adams River, there are places for fish to go. So behaviorally, it's best to have pools within a channel to reduce territoriality. But pools are harder to clean. There are definite preferences in different parts of the channel, all determined by the way water flows over the substrate.
- Wilde: They put pools in all channels now.
- Mayo: Are pools part of the calculated area?
- Wilde: Pools are not counted as spawning area for loading densities. You may get higher survivals with greater slope, and you should have pools. There are bigger fish in the Adams River than in the Cedar River. Size your channel on biggest run years, as controlled by the lake. He suggests 1.6-1.7 m<sup>2</sup> for the smaller Cedar fish.
- Mayo: What portion of channel is pools?
- Wilde: There should be one pool for every leg of channel. Pool should be off to one side so a back eddy 6'-8' deep is created.
- Mayo: What size pool?
- Wilde: Big enough to get a back eddy; 6'-8' deep.
- Mahnken: What causes fish to hold up in pools? If it's the shading caused by deeper water, can a cover be provided?
- Groot: They're looking for escape from aggression in low velocity water.
- Nancy Davidson: What's the best way to clean channels?
- West: Air and water cleaner works well, flushes silt out. Flush silt back out to river, or excavate and de-silt elsewhere. In development are gravel cleaners that pick up gravel, sort and clean it as they go downstream.
- Davidson: Is in-channel cleaning successful?
- Williams: The key is whether sediment dumping is allowed in the river.
- West: In-channel cleaning may not be as effective, but it's cheaper and adequate.
- Williams: Channel could be designed to accommodate machines.
- West: Showed overhead illustrating survival with and without cleaning. If no cleaning, survival decreases sharply over time. Since cleaning, survival still decreasing but not as steeply. Yes, channel cleaning is effective, dependent on method and effort.
- Davidson: Have you tried disinfecting a channel?
- West: No, but they've thought about it.
- Wilde: Don't use less than 1/2 meter of gravel. Cost of removing, cleaning and replacing gravel is about \$100,000.
- Davidson: Are there disadvantages to cleaning other than cost?

Groot: A normal river has variable, shifting flows, that clean it naturally, and a spawning channel doesn't have that, so it must be cleaned.

David Parkinson: How often do you clean?

West: Depends on the situation. Every year is probably optimal.

Dennis Moore: Does cleaning affect IHN reservoirs, or organic food for alevins?

Evelyn: We don't know about effect on reservoirs because we are uncertain about the identities of the reservoirs.

Williams: Channels we dried didn't get thoroughly dry, so maybe that wouldn't affect reservoirs.

Evelyn: Can use black plastic over moist channel to raise the temperature and "steam clean" bed: this gets rid of BKD bug and likely also the IHN virus.

West: If you have a dirty channel and its dried, that leads to compaction and need for excavation.

Moore: Could channels with upwelling be inadvertently selecting for substocks?

Williams: Intriguing question but we have no idea.

Moore: Should fry be flushed out of the channel, or allowed to migrate?

Williams: In the Babine system, we flush only the last 2%.

Brannon: Had comments on several areas of discussion.

- Low D.O. levels shown by Williams in interstitial spaces are an important point, possibly causing mortality. Those were criteria used to determine optimum loading densities. Weaver Creek fry are 2x the size of Cedar River fry, but Weaver Creek also has the smallest gravel.
- Interface between gravel and bed isn't cleaned in in-channel cleaning methods, and that's the most important place to clean, so in-channel is only partial cleaning. Survival will go down.
- Sockeye fry are rheotactic on velocity, and most channel flows are sufficient to induce fry to leave.
- Loading density: the issue is one of fish health versus maximum production; higher densities may lead to lower survival percentage but increased production.
- All Canadian channels have relatively short peak spawning periods, but in the Cedar River spawning takes place over several months, from August to January. More than one channel may be needed to compensate for these subpopulations. Will have to decide which population section to optimize in a channel.

Break

Ames: The intent of a Cedar River channel is for mitigation. Natural run size is several thousand spawners. If a channel is successful, half the fish will be from the channel.

Groot: Experience has shown that population shifts to channel domination. It has to be watched, because you may just be shifting from natural to artificial production.

West: Actually a complex situation. In the Babine system, natural stocks weren't rebuilding even before the channels. We must be aware of overharvesting natural stocks, but channels are sometimes scapegoats for natural fluctuation.

Ames: All our fish are coming back to the same river.

Groot: There is some disagreement on the effect by the Canadians.

West: We don't have a very good method for discriminating between stocks.

Larry Peck: This is an upper vs. lower site question for the Cedar River. Are there correlations of channels which had native sockeye stocks with the ones that have IHN?

West: We can't exclude stocks well enough to determine that.

Rusling: You may be sacrificing substocks with channels in the Babine system, but you still are increasing the total amount of fish. From the sportsmens' perspective, there should be a maximum sustained production and maximum sustained harvest. In order to get those, would you try to load over a 2-3 month period, or load at the peak period?

West: Load channel sequentially, but in sections which could be loaded over short periods of time.

Brannon: You must identify first whether there are subpopulations. Then you can choose the segment of the population to enhance. Manipulation of temperature may not choose subpopulations without costs. It's a management question in Lake Washington, rather than a question of sustaining genetic populations.

West: Are there compensating mechanisms in the spawning?

Ames: They come down to the lake from June to December.

West: Sounds like there would be protracted fry migration.

Brannon: Lake Washington is nutritive and productive now, but what about in 20 years? Will the age structure also be the same?

Bedurtha: Are major amounts of a maintenance budget taken up with cleaning? What are the best sources of gravel?

West: Gravel cleaning costs are a major part of a maintenance budget: about \$20,000/yr with an air-and-water cleaner; about \$100,000 to remove gravel for cleaning.

Wilde: Take gravel from natural bars in the river. Don't get waste concrete or something similar.

Mahnken: There's been a need expressed by the Canadians to have experimental design incorporated with production. Should this be three parallel channels for adaptive management purposes, or several channels for true replicated experiment situations?

Groot: Best would be to look at the whole thing as a research project. You can learn from our mistakes, and start out from the beginning by building ways to monitor and experiment. Make sure a good researcher has a voice in design.

(Audience): Are any physical/chemical measurements taken during cleaning? Has runoff been analyzed for IHN?

Wilde: Yes.

(Audience): In double spawning waves, does hatching of the first wave stimulate early spawning of the second wave?

All: No.

Mayo: We need information from Jim Wilde for design.

Wilde: Channel cleaners produce lots of dirty water, and that hasn't been addressed.

Mayo: We need more on spawning density. Is 1.4 m<sup>2</sup>/female for 5 lb fish appropriate?

Groot: From behavior experiments on the spawning bed, we know that sockeye establish territory in the morning. In the afternoon females start to redd, but spawning doesn't begin till after dark. They might spawn for 4-5 nights in a row, and then females live 4-5 days after that. But it's not known if smaller fish would actually occupy smaller spawning territories.

Mayo: But what are your intuitions?

Groot: I think bigger fish would occupy bigger areas.

Mayo: How long can eyed eggs go without a water flow if the flow gets shut off for some reason?

Groot: I'll send a written reply from Nanaimo.

West: General guideline is about 10 min.

Mayo: Anyone have experience with water shut-offs?

West: No real experience with that.

Wilde: If your water goes off, its a major problem. Design so that can't happen.

Mayo: Our situation requires we at least think about shut-offs.

Wilde: You should have some kind of full backup, especially for electrical failures.

Parkinson: Are you actually recommending we build at 3 different sites—do you think we should have 3 separate areas?

Groot: We think you should have 3 parallel systems, with separate inflows.

Parkinson: That would take 95% of the river flow.

Groot: That's your problem.

Wilde: Develop your design based on amount of water you can divert.

Groot: It's possible to have 3 upper levels that come together as one.

Parkinson: The Washington Department of Wildlife wants to put steelhead above the channel.  
Will that cause an IHN problem?

Evelyn: That depends on timing—whether there are susceptible fry at the time steelhead are around. If the virus levels shed by the steelhead are not high, they may not affect the fish downstream.

Mayo: You've suggested 2 cfs/channel width. How long of a channel does that mean?

Wilde: Doesn't matter if you re-aerate with drops.

Moore: What's needed for adult handling? Is there stress involved?

Williams: For separating species, a manual gate sends chum back into Weaver Creek. It's simple to calculate oxygen consumption needs from pilot studies.

Brannon: Spawners/unit area is valid, but you also need to look at the fecundity of the population. And don't forget fish health.

Wilde: Best not to push densities.

Brannon: How can you incorporate experimental design with production goals?

Groot: The only way we know what's going on is to monitor. We found out in the Babine system that in even years returning pinks eat outgoing fry. If you do a spawning channel and are successful, everyone will be happy. If you do it but aren't successful, you will know nothing.

Moore: From an operational standpoint, will a channel work in the Cedar River?

Groot: Probably, but we'll talk more tomorrow on evaluation. (Question) It's been shown that jacks increase when populations are interfered with. They create havoc on the spawning bed. Do you expect a jack problem here?

Ames: The proportion of the population returning as jacks in the natural population has decreased to 2%-3%.

Groot: Will there be management problems if the jack population doubles?

Ames: We'll need to have a harvest advantage for jacks.

Groot: You need to pay attention to the person running the operation, because you need someone who's aware of fish behavior. The best system will fail if you don't have the right person to run it. Are there strange changes in other systems, depending on the managers?

West: There's so much variation, we can't statistically say if the human factor has much difference. But we see many situations where optimal management of a channel varies with the person doing the operating.

Moore: What are some operational costs?

West: There's some economy of scale. About \$100,000 + salaries to run a mid-sized channel, depending on the type of cleaning. It's very site specific.

Larry Peck: This will be a tourist attraction. Is this a concern?

Wilde: Keep paths away from banks; fish will shy.

Groot: We put up barriers; keep 80% closed to public and just have a small area for observation. Fish will spook and be stressed if people are too close.

Peck: Have you had to do anything extraordinary to control predators?

West: No.

Wilde: There will be more fry in Lake Washington, which may have little effect other than to produce more squawfish.

Moore: Do you have underground viewing areas?

Wilde: Yes, though you need ramps. People like it a lot.

Rusling: Regarding building in some research, could experiments be run in sequence rather than parallel, and save on water?

Hilborn: In conjunction with that question, which of three factors (loading density, IHN treatment, gravel size) would be a problem in series experiments?

Groot: A series experiment doesn't really produce satisfactory results.

Hilborn: Is 10% of channel area good for experimental purposes?

Groot: Yes.

Bedurtha: There could be a conflict with fences on the Cedar River with other recreational users such as boaters. Do you have any experience with this situation?

Wilde: Yes, it's a problem. Floating fences can help; boaters can get over them.

Mayo: Are there annual reports on operating costs?

West: Yes, I'll send you information.

Mayo, Groot, Wilde: The manager should be incorporated into the design team.

Hilborn closed the Operations session.

## DAY 2, FRIDAY, JANUARY 26, 1990

Ray Hilborn introduced the session.

### EVALUATION

- Participants at table for Evaluation session:

<u>Canadians:</u>	Evelyn West Williams	Groot Wilde
<u>Others:</u>	Ernie Brannon Jay Rusling Nancy Davidson Steve Schroeder, WDF Bob Gerke, WDF	Ron Mayo David Parkinson Dennis Moore Conrad Mahnken

### *CANADIAN EXPERIENCE: KEES GROOT*

He'll deal primarily with the ideas behind evaluation; Cam West will deal with numbers. He showed a slide of the Babine system in N. British Columbia. Three spawning channels were built in the system: Fulton 1 & 2 and Pinkut. He described the three channels, and pointed out some of the problems they had. One evaluation system has a platform that can be lowered into the channel, where samples can be taken, then raised back up to a permanent platform. There is laboratory space for analyzing samples and counting of fry and eggs. There is winter sampling to check on condition of eggs and fry.

Groot showed an overhead giving specifics of the history of the Babine Lake system. It was inferred that about 20% of spawners were spawning in the lake. The lake capacity seemed sufficient for holding many more fish, and the three channels were built in the late 1960s. The aim was to have 78,000 females in the system at 1.5 m<sup>2</sup>/female for an additional 125 million fish in the lake.

Several assumptions were made that they wanted to test in the system, including the assumptions that the spawning channel would produce extra fry that would be as viable as those from natural spawning.

Groot then went into more detail on the monitoring program, and showed a list of information that they collected from the channels in the system (attached). He suggested there would be changes in the age structure of the population when a channel was built, including increases in jacks, and that should be monitored. In some years, egg retention is high, and that also needed to be watched. Embryo-alevin development was difficult to determine, but techniques have been published, as have Groot's results on monitoring timing of fry out of the channel and river. Techniques for marking channel and river fish will be discussed later, but Groot's project just clipped fins.

They had a boat specially built to monitor juvenile distribution in the lake, and they found surprising results. The fry had substantial migrations in the lake after they moved into it, first moving south 50-70 miles and then north again. Sockeye seem to move all the time. Vertical migrations were monitored through the ice, and they tried to determine cues that were influencing sockeye migrations. Finally, adult returns were monitored.

In summary, a monitoring program needs to find out the numbers of eggs, fry, smolts and adults in the channel and in the river. On his overhead, Groot marked the highest priority evaluations for any system, given economic limitations.

Groot then summarized his experimental findings. Survival varied by  $\pm 40\%$  as expected. Expected differences in fry distribution, growth and lake survival weren't found. There were smolt increases, and survival and growth of fish in the lake didn't change, suggesting that the lake capacity wasn't overtaxed. Adult returns showed every-other year variation, and didn't meet expectations.

Groot advised that a channel be built primarily as a research project. Other considerations for channel design and evaluation were discussed. Groot showed marine survival patterns for several different sockeye stocks, which showed effects of ocean conditions. Survival was correlated with salinity at the point of marine entry and increased with increased salinity, which is an indication of upwelling. Temperature changes and salinity changes probably don't have direct effects, but research is continuing on causes. Ocean predators also have an effect on the marine sockeye population, including many hake along the west coast. A match-mismatch hypothesis is being watched in relation to hake predation.

Groot also showed return patterns around Vancouver Is. that changed dramatically around 1977. Something seems to have happened in the North Pacific around that time, but the cause isn't yet known. The number of fish returning from the north seems to be correlated with coastal temperatures. The bottom line is that something is happening in the ocean environment that effects fish behavior. He also showed catch data that showed shifts in fishing success in different areas.

Groot expects bigger changes in the ocean environment due to global warming. He suggested that Lake Washington, being on the southern limit of sockeye distribution, needs to be watched in terms of global warming and its possible effects on the populations here. He discussed changes in sea surface temperatures, sea level, precipitation and ocean currents. Despite many uncertainties, he takes projected changes very seriously, and showed a table of potential differences in salmonid development times that may project alterations of timing and salmonid ecology. Groot thinks sockeye production will be shifted north, with southern populations eventually dying off. Pathogens may also shift north.

In conclusion: treat the Cedar River project as a research situation, where assumptions can be tested. Scientists should be part of a design team. Get the best manager you can find. Understand ocean survival better, and take global climatic changes seriously.

#### *CANADIAN EXPERIENCE: CAM WEST*

West reiterated the importance of global trends, and gave examples of decreased precipitation at Weaver Creek.

The Babine Lake system produces 90% of the sockeye in the Skeena River system. Its a well-monitored system. He thinks adult returns are the ultimate indicator of success in a channel. Data from the Skeena showed that there's been about a 1 million net increase of adult returns. West modelled the complex system of several substocks using well known timing curves. The model separates out the channel returns from the rest of the Skeena system, and shows very significant increases due to the spawning channel projects.

The real question isn't whether channel projects have worked, but whether they can work. The Nadina system has a very small post-channel increase in production that isn't yet well understood. Predation, pollution or parasites in the lake could be holding back production. There may also be faulty adult stock assessment or significant amounts of poaching. Although the sampling and

enumeration at Babine are intense, sampling at Nadina is only fry enumeration. It's possible that the spawning channel is the only thing keeping the stock from extinction. Weaver Creek doesn't have an intense monitoring system, but it's successful, so no one cares. If a project isn't an immediate success, then there is no way to know why if monitoring is not taking place. West gave an example of big differences in egg-to-fry survival at the two Fulton Creek channels, and suggested that that system shows why replicate systems are important for monitoring.

The time frame for evaluation is important—it can't be done in just a few years.

At the end of West's talk, Hilborn pointed out that "success" of a channel depends on the group doing the evaluating, and on political agendas.

#### *DISCUSSION: EVALUATION SESSION*

Steve Schroeder: Summarized the technical committee's evaluation planning on the spawning channel. The Landsburg Dam was built on the Cedar River in 1911, and the objective for a spawning channel is to mitigate for lost spawning habitat due to dam construction. The technical committee needs plans to make sure that the city reaches its mitigation goals. A bill was passed in the legislature that required the city to produce enough fry to mimic lost habitat, and to make sure those fry were of comparable quality to the natural stock. The first goal of the plan is assessment of fry production, and the second goal of the evaluation plan is assessment of the physical parameters of the channel. His main question: How are behavioral, morphological, and physiological comparisons made between channel and natural fry?

Groot: For differences in morphological characteristics, not much difference between channel and river fry has been found. Behavior differences weren't reflected in lake behavior.

West: Migration of channel and river fry are within several days of each other, but channel fry are not quite as far along in development.

Brannon: Measurements in the Cedar River have found no morphological differences, but many things can change due to the incubation environment. An oxygen deficit can cause early emergence, and yolk sac fry may not compete with later fry. Behaviorally, he expects less delay of emergence from an oxygen deficit in well-irrigated channel fry, compared to the river environment which usually isn't near saturation.

Schroeder: Findings suggest morphometric changes in fry dependent on time of emergence may compact emergence time. Are there different temporal frames for sampling?

West: There is a difference in channel and river fry in maturation time, but a standard sampling regime seems to be adequate.

Schroeder: How should we mark emergent fry during the 24-hr window when they come out?

Groot: Strontium and rare earth marks have been tried with varying success. One method that shows promise is using the parasite fauna as a marker. Temperature shock and elemental introductions need to be looked at more carefully because clipping fins isn't desirable. Need something with less handling.

Schroeder: If the channel is above Landsburg Dam, channel fry will be moving down the river with river fry. How do we collect wild fish out of this mix?

Williams: We tried getting an estimate on those coming out of the channel, and subtracted those from numbers we get farther down the river for an estimate of wild fry production.

Mahnken: How were out migrants sampled as they left Babine? Were there problems with the fin clip?

West: About 2% of fry are caught, enumerated and stapled with a colored tag. It was a multiple mark-recapture program.

Groot: There is back-calculation of fin-clipped fish compared to others to get estimates of channel and river contributions.

West: The fry-clipping was used for fry-to-smolt survival, but was inadequate for monitoring adults.

Mahnken: Do you routinely look at parasite levels? Do you look at anything besides growth and condition index to judge smolt quality?

Groot: There were 2 layers of smolts at about 70 and about 90 feet found during the day, and they migrated upward at night. Sampling at those two levels found some differences in parasite loads—top layer had more euphausiids.

Williams: Used swim tunnel testing to test smolts, but the only real differences found were reduced swimming ability in those fish that had been run through a 5% sampling separator.

Groot: We have a good idea of the lake parasite structure.

Tim Bodurtha: It's been pointed out that we'll need 20 years of data to get a good idea on success of the channel. But for mitigation assessment, when can we know whether the mitigation has been successful?

Groot: After 2-3 years, you'll have an idea, with good monitoring, about what's happening in the lake environment to the fry. It will take longer to get an idea of what's happening in the ocean environment, and in that case time works against you because climate changes in the next 10 years may be dramatic and unpredictable.

Bob Gerke: We need to produce fry quality equivalent to wild fry. There are two schools of thought: evaluate fry themselves, or evaluate the smolts. Which would be the preferred route to take?

West: You should probably look at fry-to-smolt survival and quality, because if you just look at fry, you won't know what it means to the whole system.

Gerke: How narrow can experimental channels be, and does water depth need to be the same in all of them?

Groot: Keep them as similar as possible. You may want small experimental channels separate from the production channel if combining them will compromise experimental design.

Schroeder: Big Beef has 3 parallel channels, two 5-ft. wide and one 10-ft. wide. They are 600 ft. long and can be divided into 36 experimental units.

Wilde: Experimental fish at one site could effect downstream production fish. If placed downstream, production could effect experiment.

Schroeder: An upstream experimental chamber would be better because the water situation would be degraded downstream.

Ernie Brannon: (Comments) He would have been surprised if Groot hadn't seen differences in the fry-to-smolt stage between populations in the Babine system, because that's a small population and each develops optimal migration routes that take advantage of food availability. If food is not limiting, those differences may not show up. If a population is built by several

times due to spawning channels, it may act evolutionarily still as a small population, and not distribute itself optimally. In that case, predation effects may show up quite a bit for the first few years. In the Medina system, a channel has sustained a population that was in trouble.

Williams: The Medina had silty banks, and there's some evidence that shifting substrate may have been detrimental to stocks.

Brannon: In the Cedar River, sockeye fry survival has been correlated with flood years, so it seems logical that the channel should show some success, hopefully better than Medina. We need to make sure our channel can be responsive to change. There may be long-term genetic influences, selecting inadvertently for certain stocks. It's not known what mechanisms will be influencing fry-to-smolt survival in the lake, and whether those are compensatory or compensatory. A channel is only charged with producing more fry. Success of the channel isn't necessarily shown in fry-to-smolt survival. The University of Washington, the City of Seattle, and Washington Department of Fisheries should be able to put together a package with all those interests. Impacts of trout and squawfish predation need to be looked at more carefully.

Williams: The Cedar River is more similar to Weaver Creek than to Medina and Gates, which are only small parts of big systems. Input from the small part of the system may be quite overestimated. Weaver Creek is close to the mouth of the Fraser, but Medina and Gates are several hundred miles upstream. Weaver Creek and Cedar River both have isolated commercial fisheries and can be compared most readily.

Wilde: Problems of upstream rivers have to do more with low flow than with flooding, which is the problem in the Cedar, so there are more things going for success of a channel here than at Medina.

Jay Rusling: Fry survival and fry-to-smolt survival were apparently linear. Are there any situations on the Fraser where this equivalency didn't happen?

Williams: There is little information on fry-to-smolt survival on the Fraser. The sockeye and smelt populations seem to have their own niches in Harrison Lake and don't exclude each other.

Groot: You must compare the advantages of a channel versus the disadvantages, such as shifting river populations to channel ones. Biologically, it's not good to create a homogeneous population. There's some evidence that fringe populations maintain heterogeneity more than main populations in the face of rapid change such as putting in a channel.

West: Gave an example for Groot's point, and said that other species may be part of the big changes. The lower Babine population, which is the largest, is affected by the pink salmon spawning.

Brannon: Smelt in Harrison Lake are 1/2 the size as those in Lake Washington, and smelt may be predators on newly emerged sockeye.

Dennis Moore: Are there disease considerations for monitoring a channel?

Evelyn: In-redd monitoring as well as channel monitoring are needed. You would also have to do comparative monitoring in the wild system. Money must be set aside for diagnosing any disease problems.

Ron Mayo: What evaluation has been done on interactions between channel spawners and river spawners? Are there influences on river spawners?

West: I can think of nothing that would suggest that there is an effect.

- Groot: You have to watch for an increase in jacks. That may have an impact on the wild population.
- Hilborn: Displayed a table that shows ocean survival has decreased for the Babine system, and that probably has an influence on wild survival as well.
- David Parkinson: Are there differences in fish due to flow levels between outlet and intake?
- West: Nothing indicates that there is a problem.
- Wilde: The 50% diversion rate is very high. We seem to be able to divert 20%-30%.
- Mayo: Is river production lost due to fish coming out of a channel, or is increase a net increase over natural production?
- West: The Babine system is very complex. Sockeye evaluation is different because fish aren't marked. All we can do is look at the net difference.
- Groot: I don't know how to factor out differences in what might have happened without enhancement, compared to what actually occurred with enhancement.
- Hilborn: In one experimental situation sockeye production increased in two lakes: one that was fertilized and one control.
- Mayo: The Canadian's data is split into "before" and "after." Is there baseline data from Lake Washington to help in our evaluations?
- Groot: You definitely want detailed pre-spawning channel information.
- Hilborn: Let's talk about that in the next session.
- Mayo: Anything we should know about establishing sample size that we won't find in the literature?
- Groot: Most is published. Only advice: go to a statistician before you start.

Hilborn ended the evaluation session.

## WRAP-UP SESSION

Several speakers gave summary presentations.

### *CEDAR RIVER EXPERIENCE: JIM AMES—WDF*

Ames assesses sockeye stocks in Lake Washington. When fish come into the Strait of Juan de Fuca, a test fishery gets the first samples. They take scales and do age analysis. As fish enter Puget Sound, his agency doesn't do much. The sockeye are enumerated as they come into the Ballard Locks, before they hit a fishery. There aren't fisheries every year, so samples are sporadic. Scales and age data are taken when there is a fishery. Seven to 10 day samples are taken to estimate escapement. No sampling is done during incubation. Past experience showed that sampling is difficult and interfered with steelhead spawning. Fry sampling done at out migration is done from February through June. Since 1982 most of the presmolt estimates have come from hydroacoustic data. WDF told the city that the pre-smolt stage is a good point on which to concentrate population estimates.

*STEVE SCHROEDER—WDF*

For fry numbers and quality, it's difficult to determine whether there are differences between channel and river fish. Some method is needed to mark the fish. A diagram for evaluation strategy to estimate fry-to-smolt survival with multiple marks was shown. From a mitigation perspective, the question is whether the channel fry are performing well. Schroeder thinks a method needs to be developed to mark fry within the 24-hr time period at emergence. Tim Mulligan at Nanaimo has done a lot of work on incorporation of rare elements into calcified portions of fish. This can be introduced through feed or into water to be absorbed through gills. Strontium is distributed into bones over a 14-day period. Schroeder hopes that this may be a way to mark channel fish. To test the method, some fish will be dehydrated in a saline solution, then held in a strontium bath. Control fish won't be dehydrated first. NMFS will help raise the fish and evaluate success of the marking.

Others have used tetracycline compounds (fluorescing) to mark calcified tissues.

It would be nice to collect marked tissues without killing fish, and they will experiment with scale platelets and fin rays for reading marks.

WDF may also use temperature manipulation to mark otoliths of fish. Experiments will expose fry to 24 hr of chilled water to see if otoliths are dependably marked. All this will be in cooperation with NMFS, WDW, and the City of Seattle.

*COMMENTS:*

West: Remember to look at other species. Riprap lining will produce coho fry.

Williams: He reinforced including a research component in the operation. Evaluate the natural system very carefully and get good numbers for the Cedar. In the Fraser, the flooding problem was avoided by having floating traps near the mouth of the river for trapping fish.

Groot: If you can get more incubation data, it would help. Try to get estimates of predator populations such as squawfish, and perhaps instigate a control program.

Evelyn: From a disease agent standpoint, keep your eyes open for diseases other than IHN, although IHN will likely be the main disease problem. Need to monitor any IHN problem in the wild stocks as well as on the channel stocks. Need to look at possibility that there are abiotic reservoirs of IHN as well as biotic ones. IHN virus may be tightly bound to particulates. Preliminary data on disease problems in the wild are needed so that any spawning channel effects can be judged.

*TOM QUINN—UNIVERSITY OF WASHINGTON*

As a UW professor who studied in British Columbia, he knows the Canadian systems as well as Lake Washington. Some points to consider: In Lake Washington, there is a diversity of spawning areas in addition to the Cedar River, including beach spawners as well as spawners near Issaquah. Thus wild stocks include stocks other than Cedar River non-channel spawners. In flood situations, the channel can act as a buffer. If there is an IHN problem in the channel, there are several wild stocks that can act as a buffer.

Lake Washington also has kokanee, which often coexist with sockeye populations. They have approximately equal fitness, though fecundity of kokanee is lower and eggs are smaller. But the mean reproductive success between the anadromous and non-anadromous populations may be

similar enough that studying the kokanee as a mirror image of the sockeye may give some extra perspective.

The sockeye population in Baker Lake is similar to that in Lake Washington in their early migration and long spawning period, and much research has been done on that population. Baker Lake adults, eggs and fry could be monitored as a good control for changes in Lake Washington.

## SUMMARY

- Wilde: You don't have a lot of the Canadian problems here, such as multiple fisheries. There is still a sizable run here, which is a good starting point. A terminal fishery is a good situation for sampling. There are no serious low water problems now. Siting shouldn't be a problem, but the squawfish problem needs to be looked at. You don't have enough time to get the project completed by the anticipated date of Oct. 15 1991, as legislation wants. Permit problems will hold things up, so pick a site as soon as possible, and design intakes as the site is cleared. For general layout, incorporate an experimental chamber with the outflow as near the intake as possible. Size of the channel doesn't need to be finalized yet. Build 1/2 or 3/4 now, and evaluate that for 8 years. Find out what full channel will do with hard numbers. Spread the fish out, and keep a low density. Have three loops for early, medium and late spawners.
- Evelyn: Not much to add. Different waves of spawners would be accommodated in different loops of the channel to reduce disease problems.
- Groot: Raising fish is still an art, not a science. Make sure the design is open to changes. Work with the university, and bring in students to do graduate projects—that way you get professors thinking on your problems as well. Also good for outside perspective.
- Williams: Design the channel with a slope near that used by sockeye in the natural environment. This seems to be a good project, with many similarities to Weaver Creek. Good opportunity to get more good information on spawning channels.
- West: We're now beyond early experimental stages of channel technology. Keep an open mind. There's good opportunities for gathering information.
- Mayo: Thanks to Canadians for all their input.
- Davidson: You've helped bring answers to a complex situation. What is the need for screening the intake?
- West: Needs to be screened if intake is from the river.
- Parkinson: Has learned a lot, thanks to Canadians.
- Moore: Nothing more will surprise him.
- Rusling: Two prime sites have been identified for the channel. The lower site will probably see increased urbanization, and also has a higher temperature. Water quality at the upper site may be more predictable and the IHN titer may be reduced. If the channel does its job, there would be a majority of adults returning to the channel.
- West: Its normal behavior for fish to spread themselves out. Upstream/downstream is a trade-off. Upstream concerns would include getting fish up into channel.
- Groot: That was a holding question. Fish seem to prefer to go to the portion of the river where they were born. It has to be played by ear—learn as you go. The situation probably can't be predicted.
- Brannon: Thanks to all. The emphasis on risk is good, and that's why we've concentrated on negative impacts of a spawning channel in this conference. There are also positive aspects though that we'll find out as we go.  
(To Davidson) Yes, screen water.
- Schroeder: Thanks to Canadians.

Mahnken: Maintenance of genetic integrity of stocks is important. In chinook populations, there is extreme variation between streams. But allozyme techniques haven't shown as much difference in sockeye, although this doesn't mean there's not heterogeneity. Any genetic integrity needs to be preserved.

Ames: Thanks to Canadians.

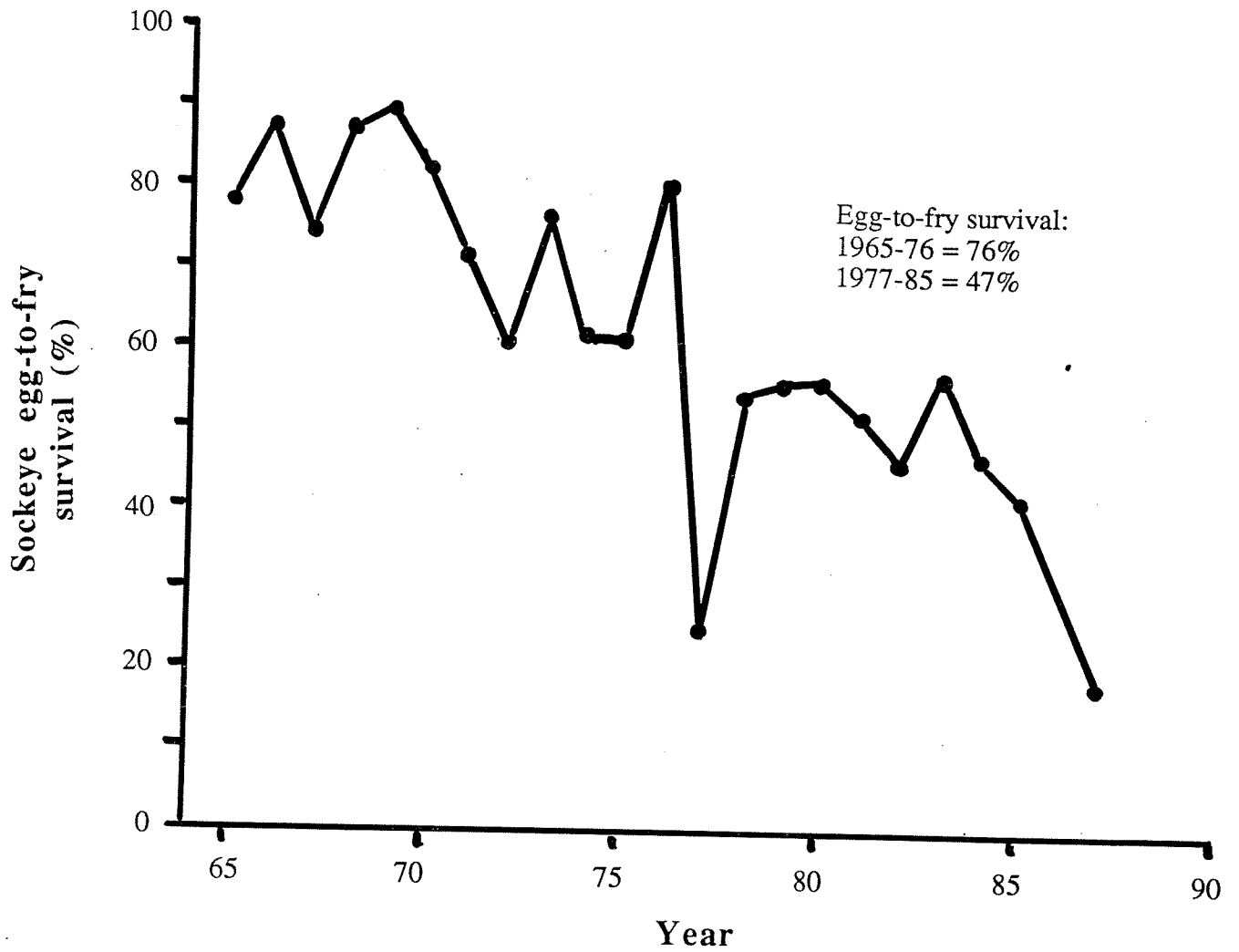
Gerke: Responsibility for the channel lies with the City of Seattle and WDF, as charged by the legislature. Experience with spawning channels isn't good in the state, but there's been lots of good information from the Canadians, both here and there. Thanks.

West: Thanks to Ray Hilborn and others.

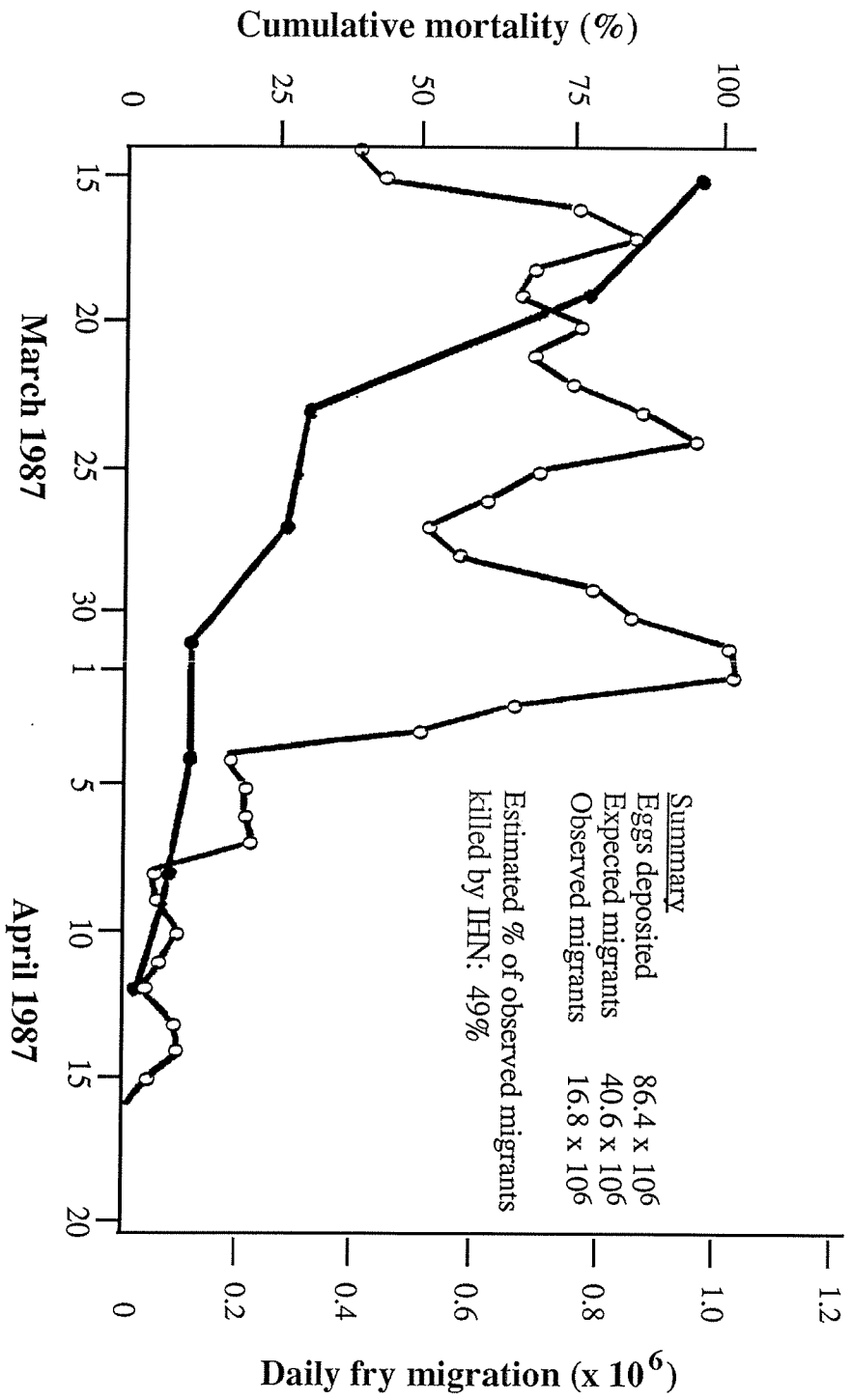
Hilborn: The spawning channel is a gamble, but we've got information to show that's its a reasonable gamble. We've learned that, for mitigation purposes, we'll know a little about success of the channel within about 5 years. It seems obvious that we should put plenty of resources into experimentation and monitoring. It will take a while longer to know whether fisheries will actually increase. See you later watching fish spawn.

Hilborn closed the conference.

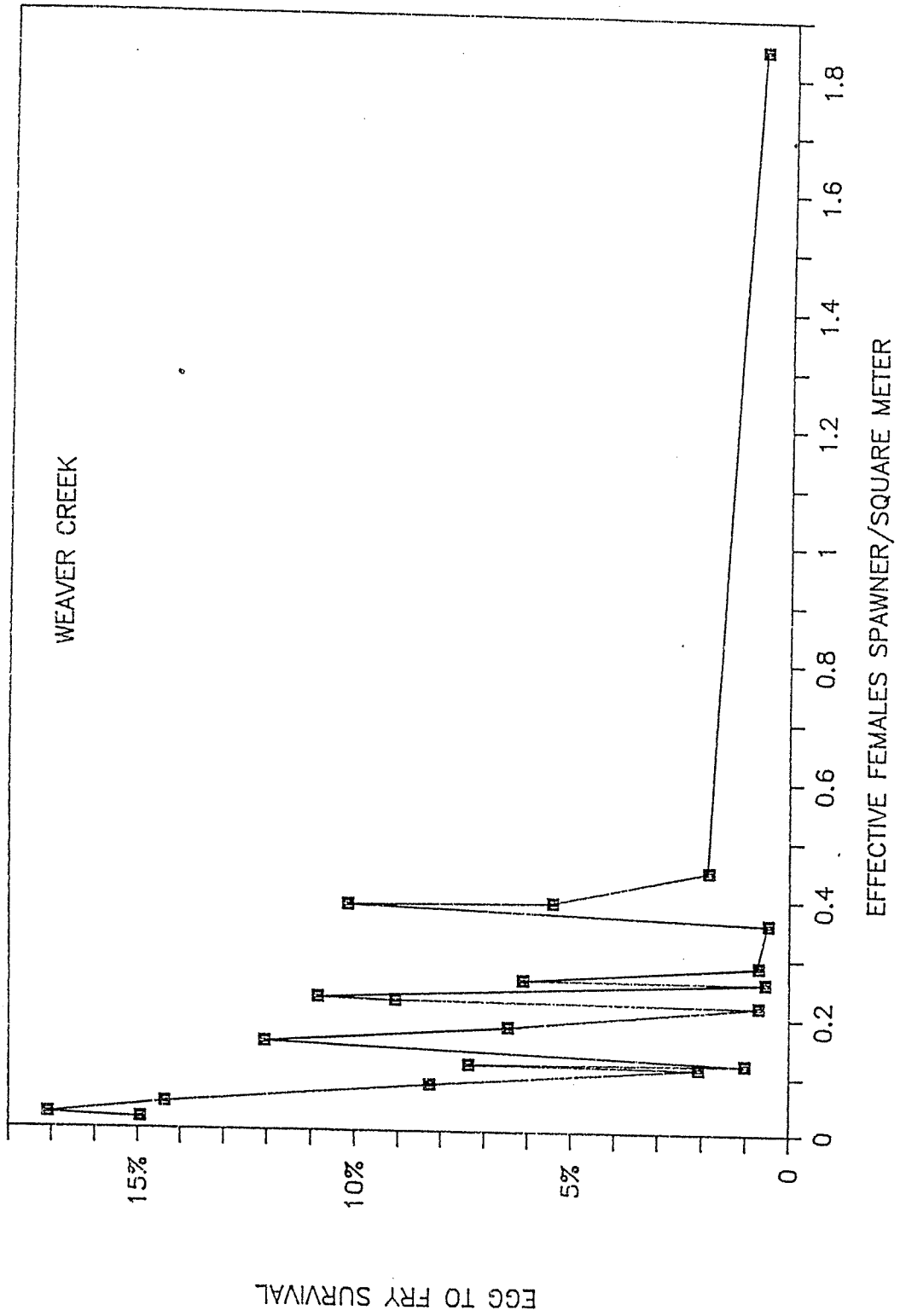
## **FIGURES AND TABLES**

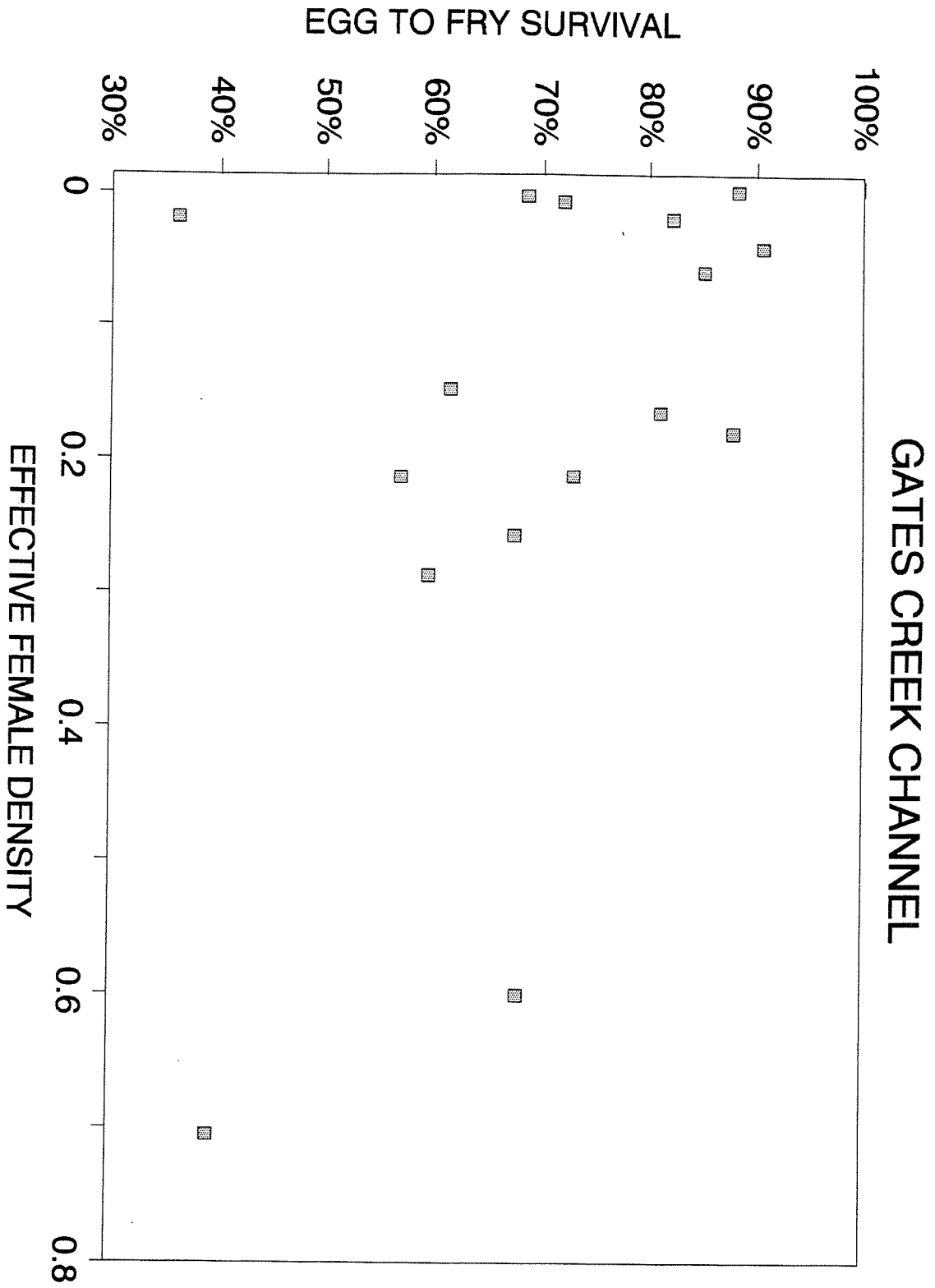


Egg-to-migrating sockeye fry survival in Weaver Creek spawning channel from 1965 to 1987.

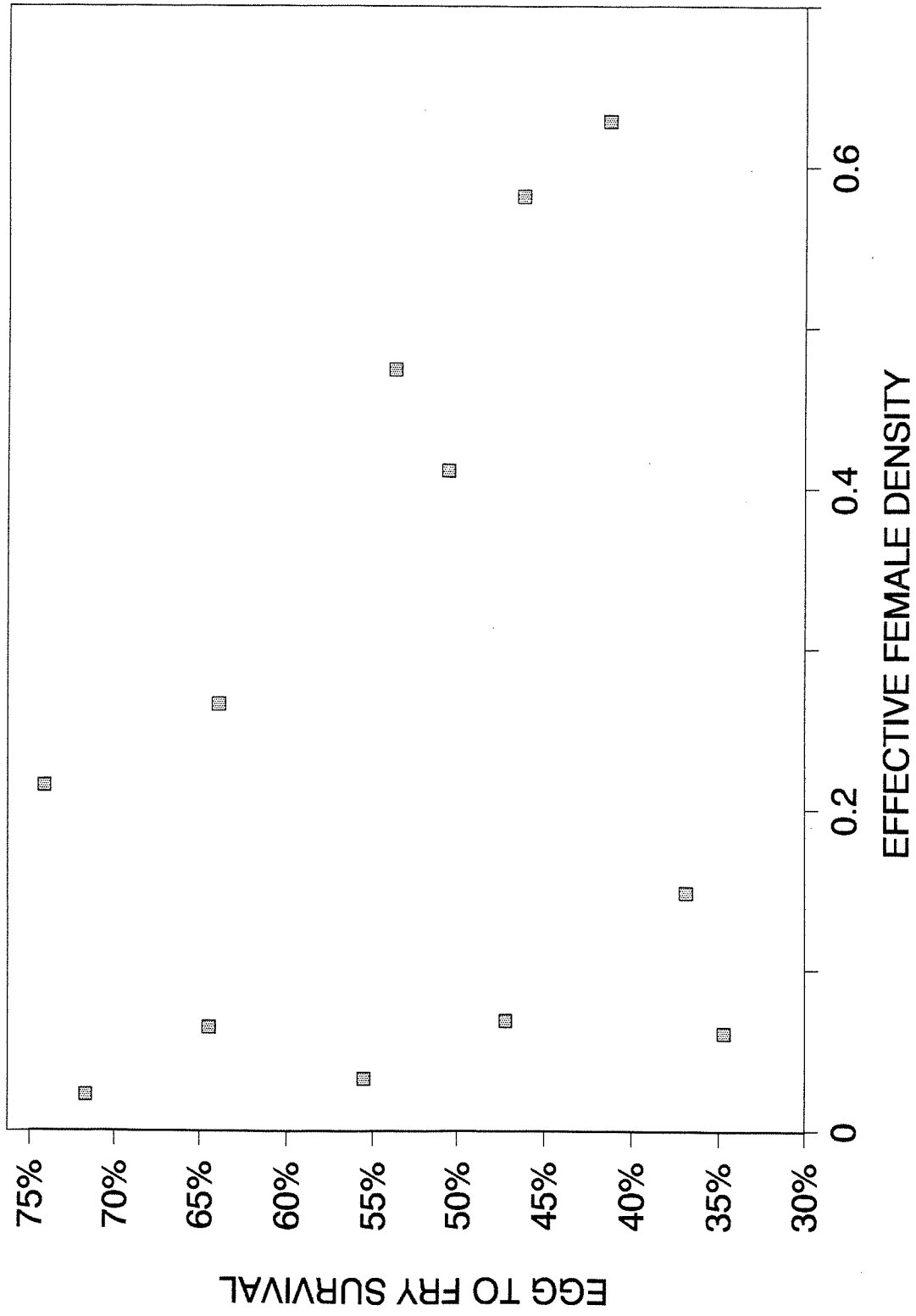


Weaver Creek spawning channel. Cumulative mortality in sockeye fry held for 4 days during fry migration (●), and daily migration of sockeye fry from the spawning channel (○).



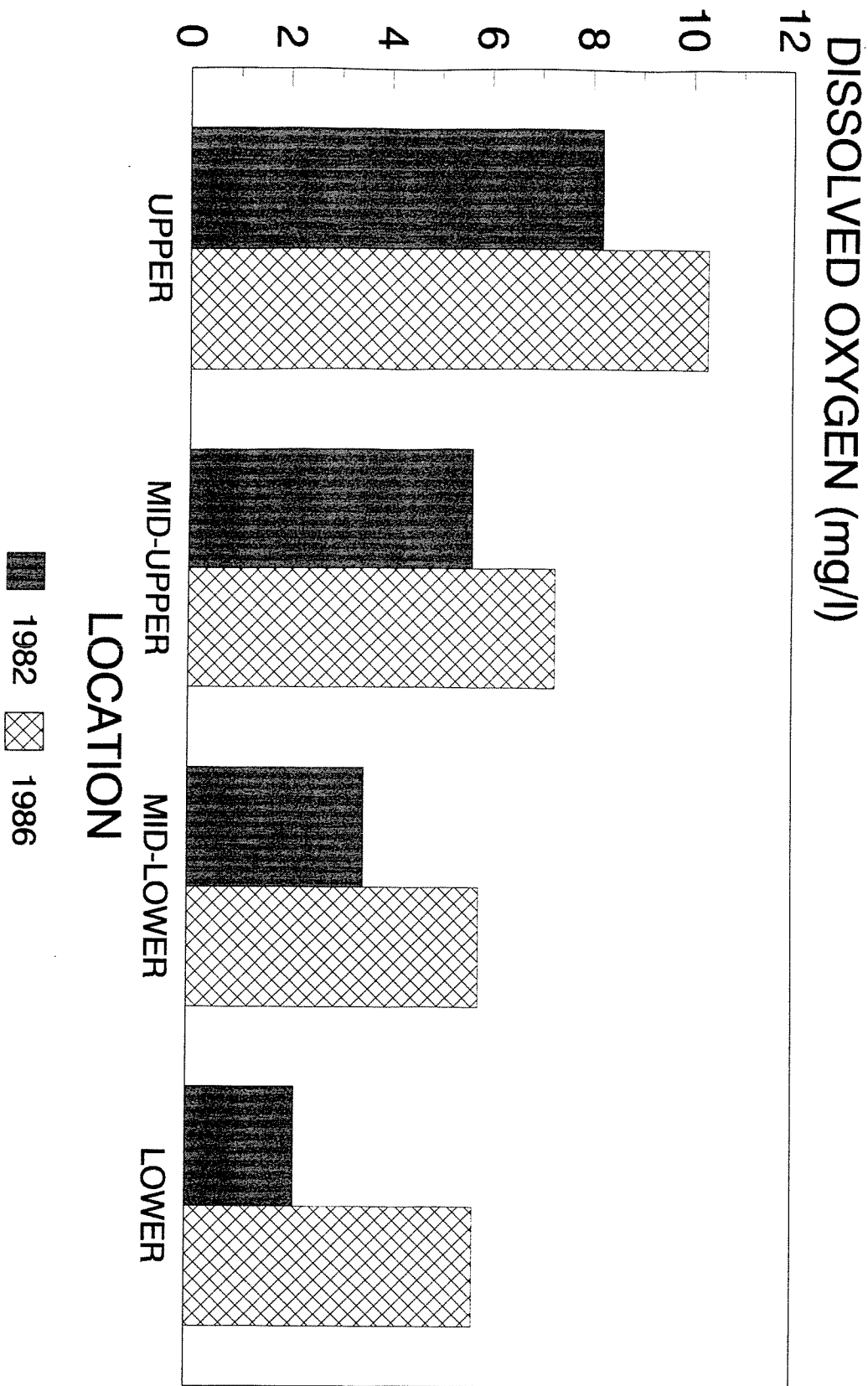


# NADINA SPAWNING CHANNEL

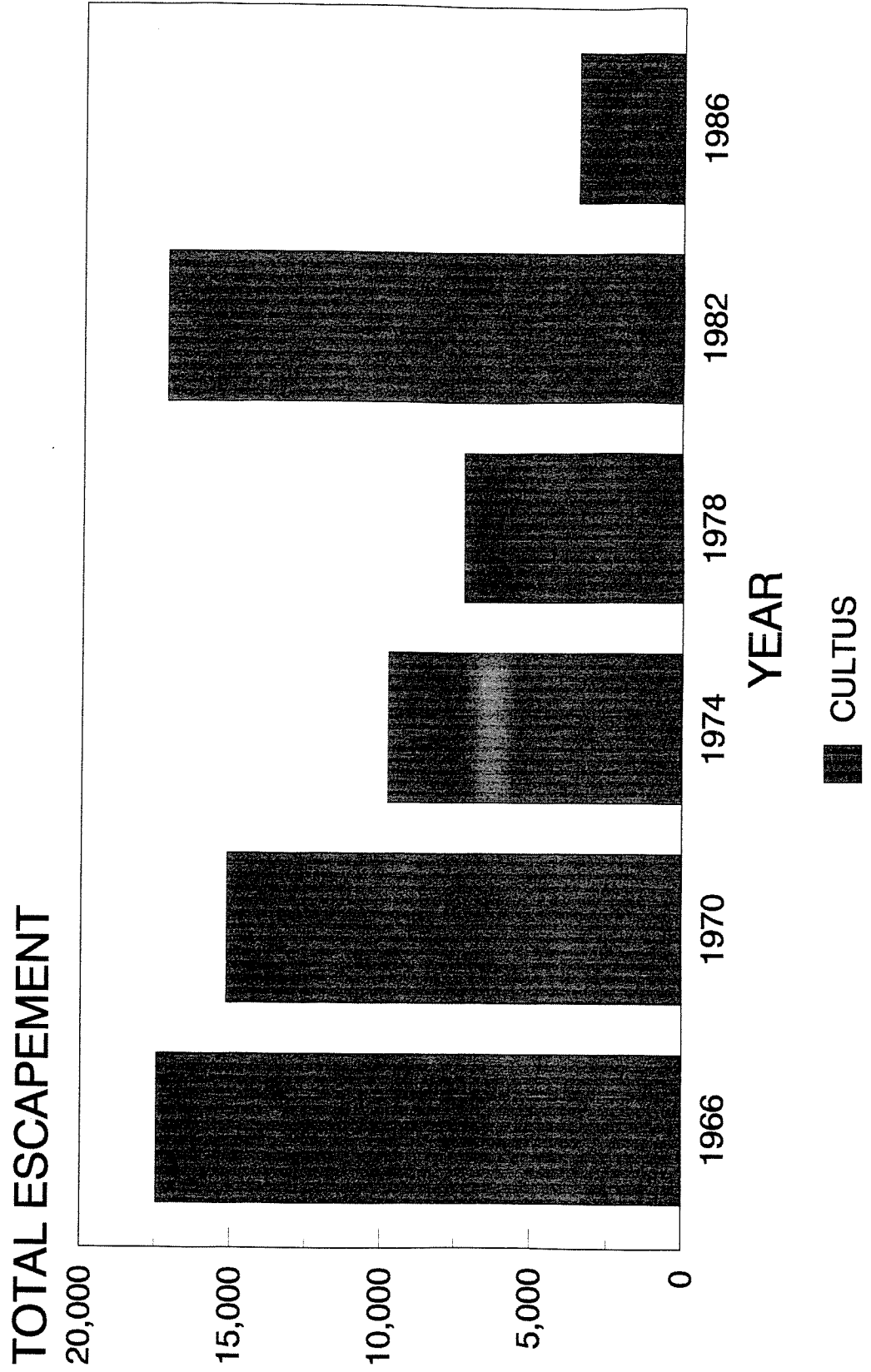


# WEAVER CREEK SPAWNING CHANNEL

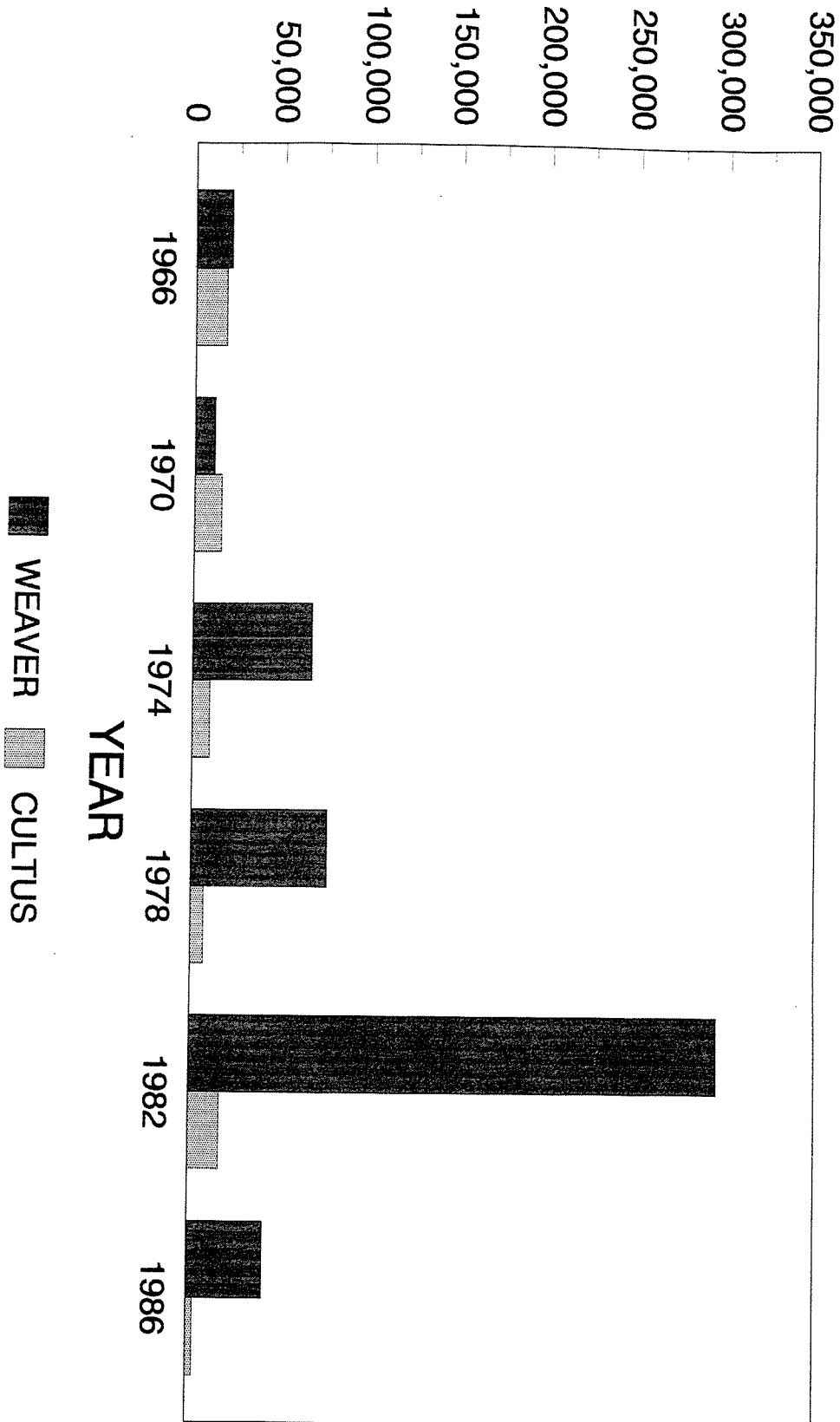
## DISSOLVED OXYGEN LEVELS



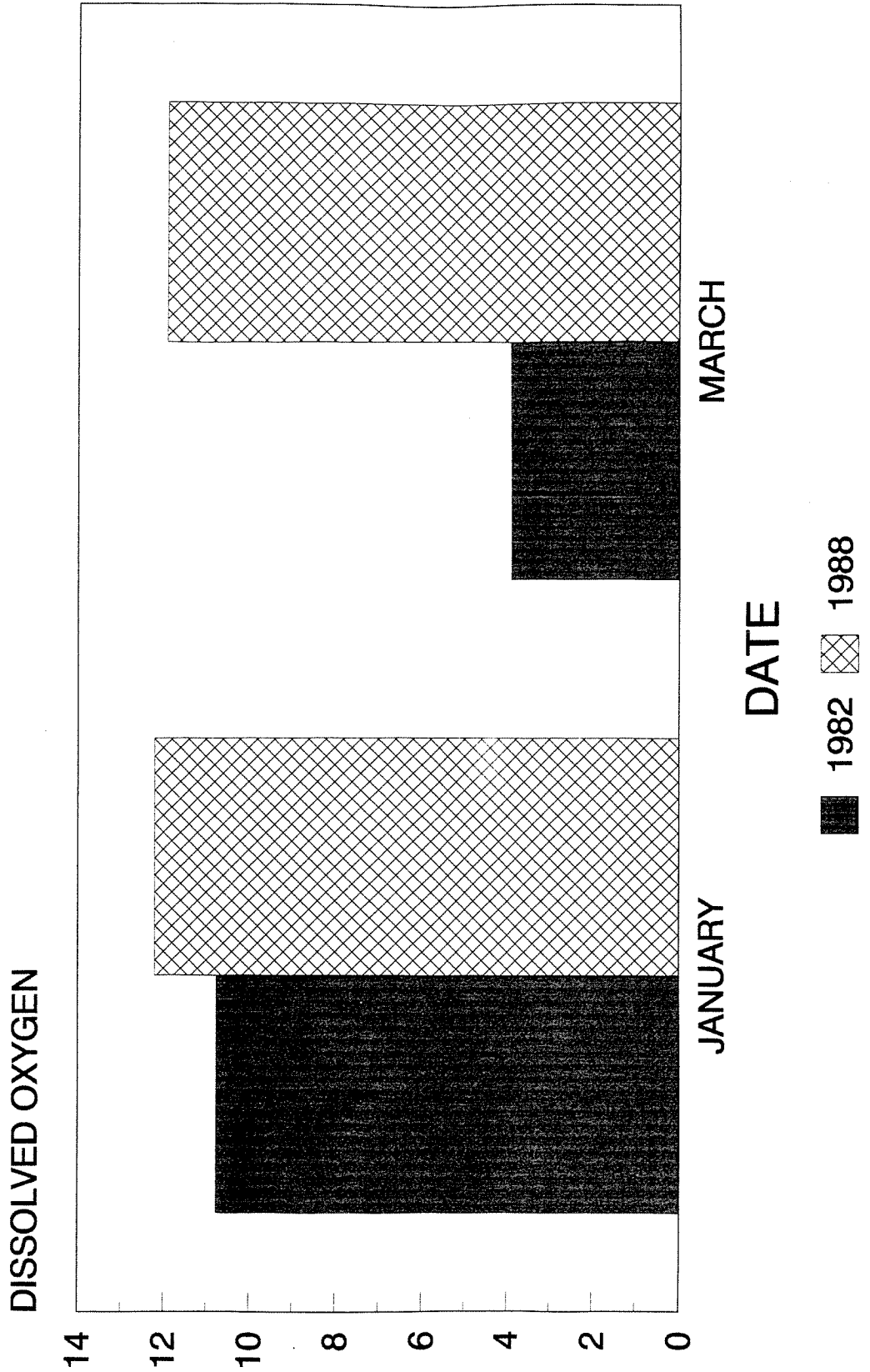
# SOCKEYE ESCAPEMENT CULTUS LAKE

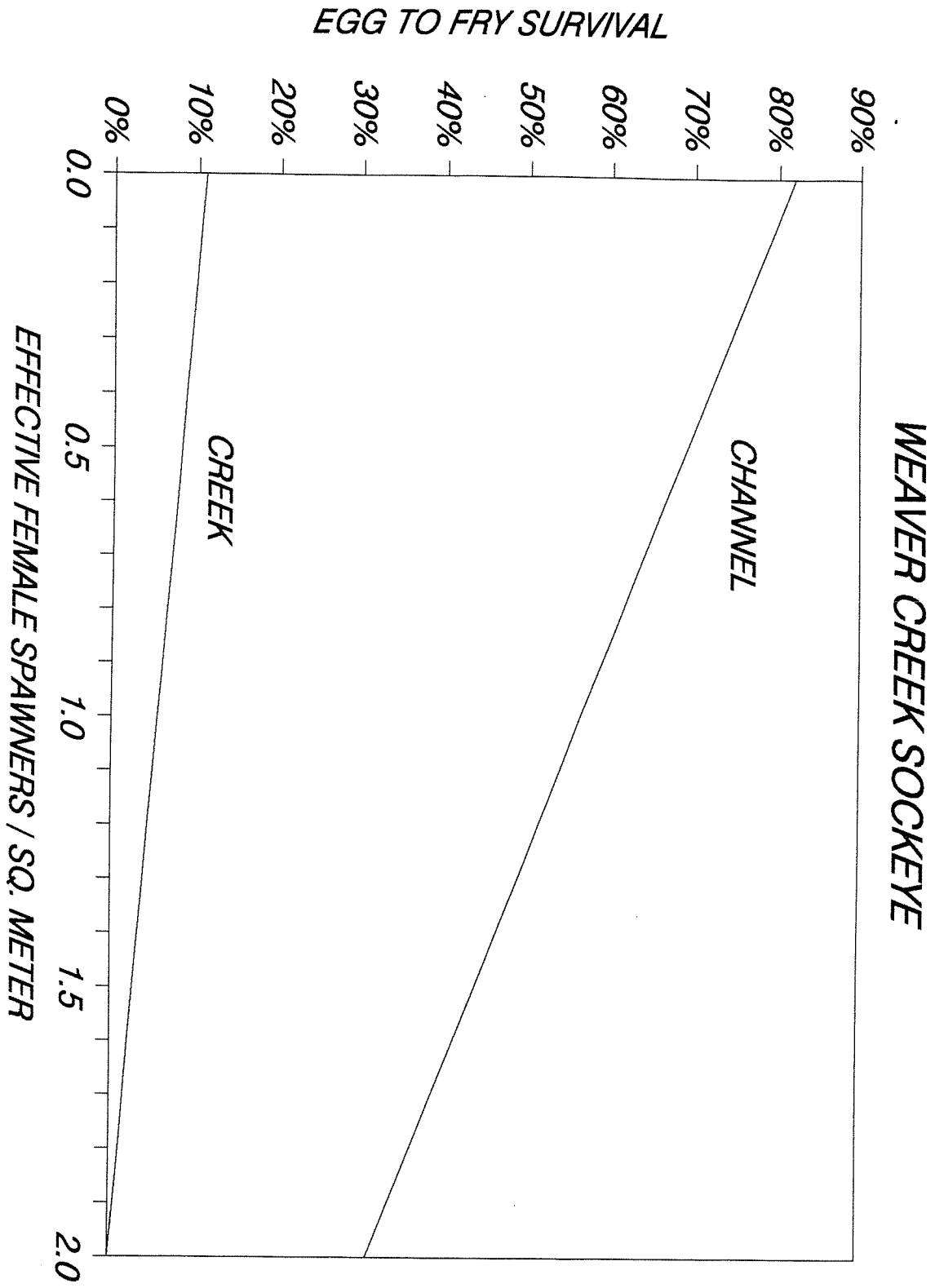


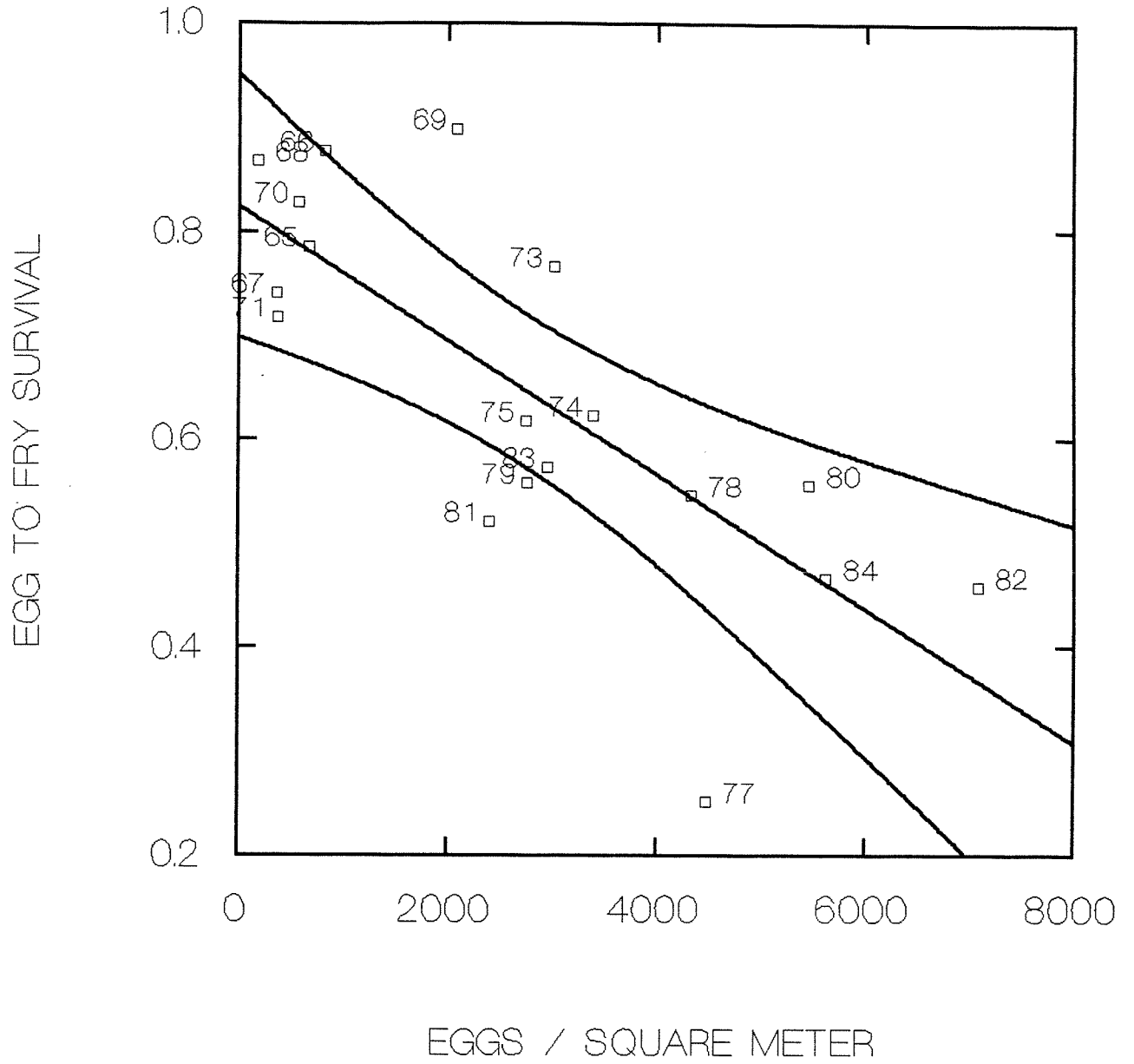
# SOCKEYE ESCAPEMENT WEAVER CREEK - CULTUS LAKE TOTAL ESCAPEMENT

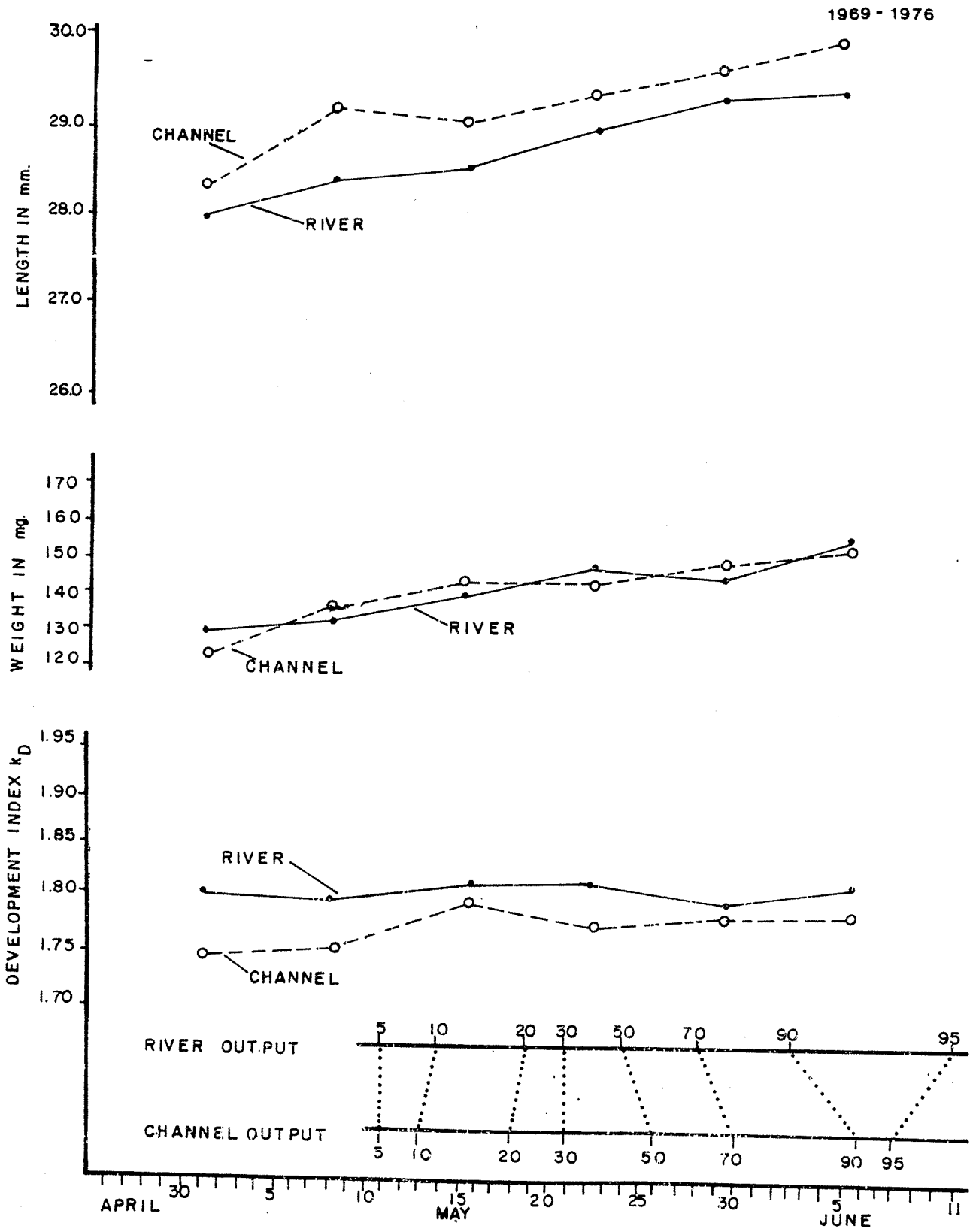


# WEAVER CREEK CHANNEL INTRAGRAVEL DISSOLVED OXYGEN

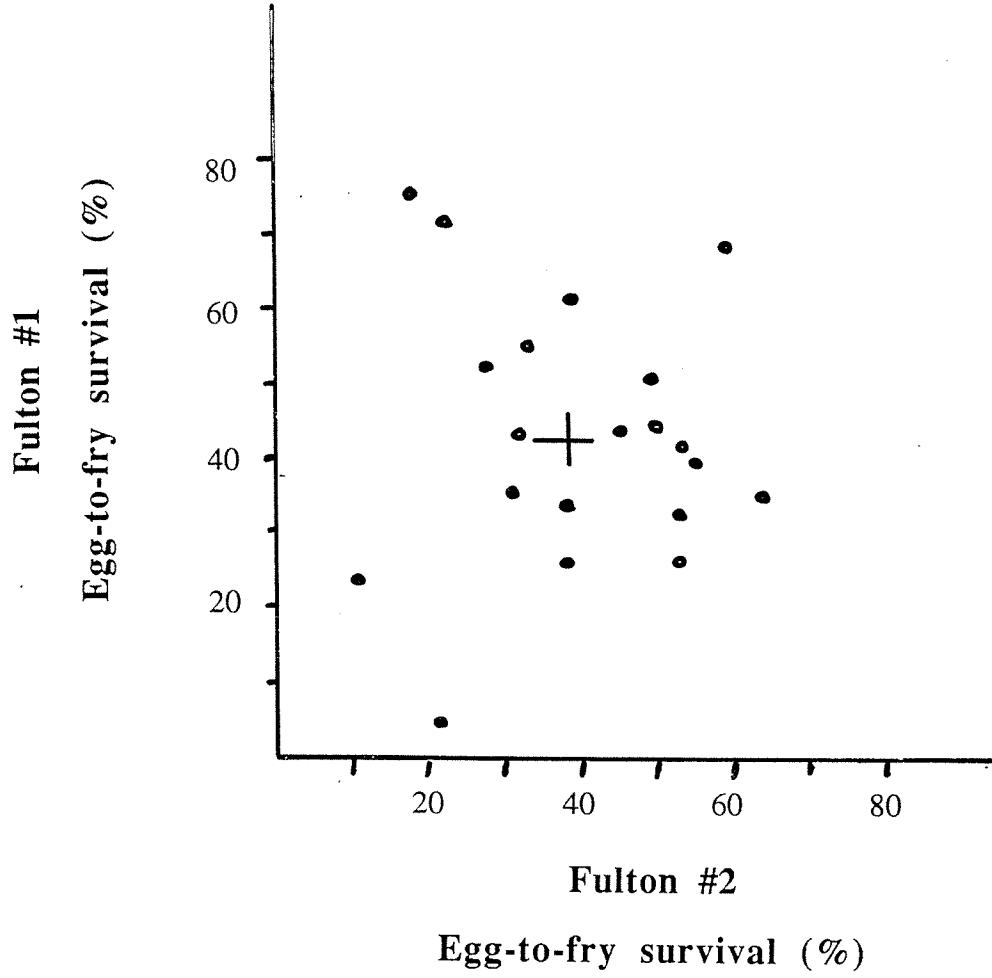




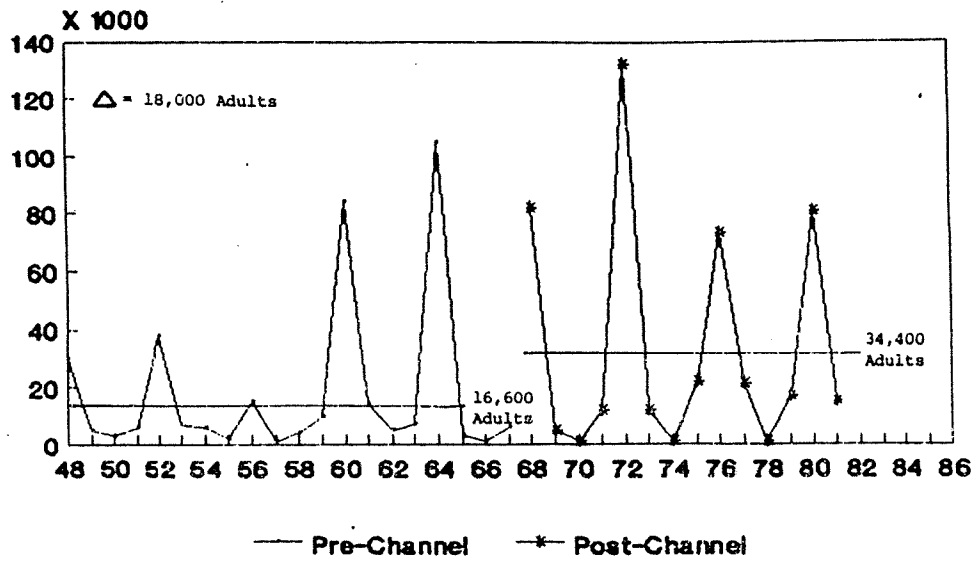




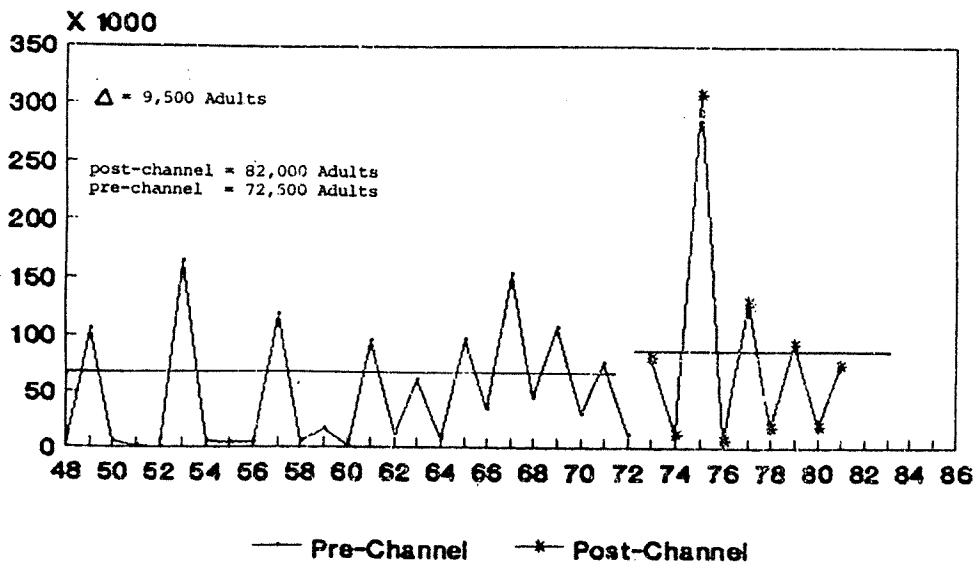
Average lengths in mm, average weights in mg, and average developmental indices of Pinkut Creek and Pinkut Channel fry at intervals through the mean spring migration from 1969 to 1976. Also shown is the average progress of the runs in time.



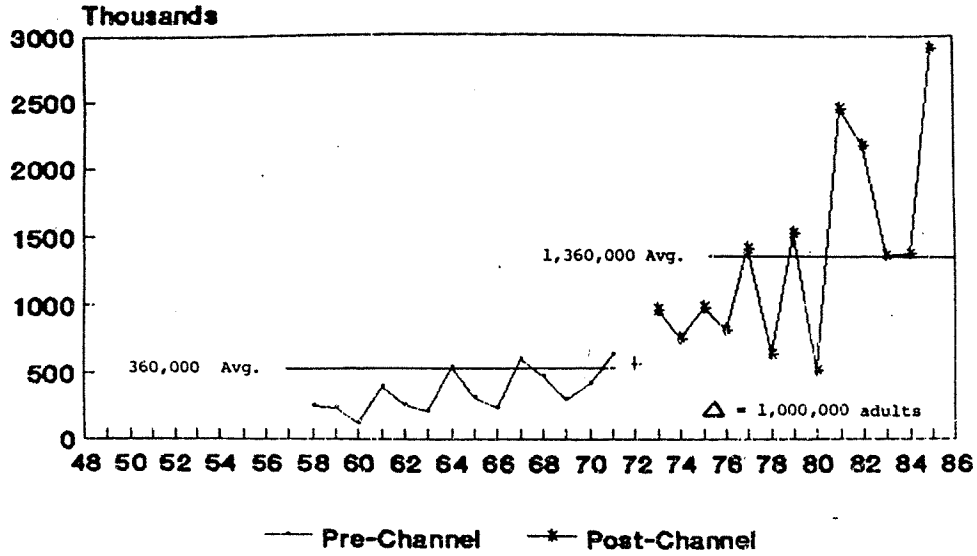
## Gates Creek Total Adult Sockeye Return



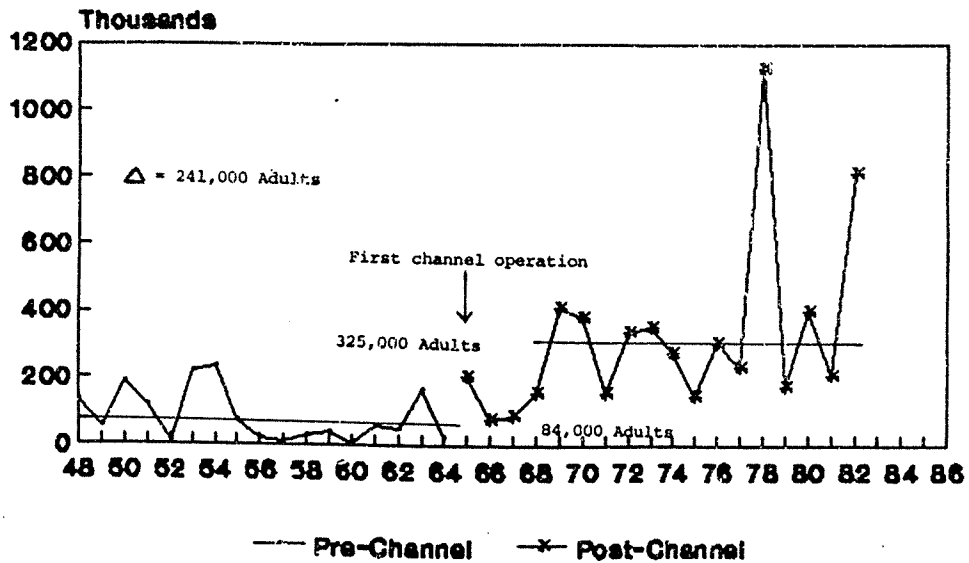
## Nadina Total Adult Sockeye Return

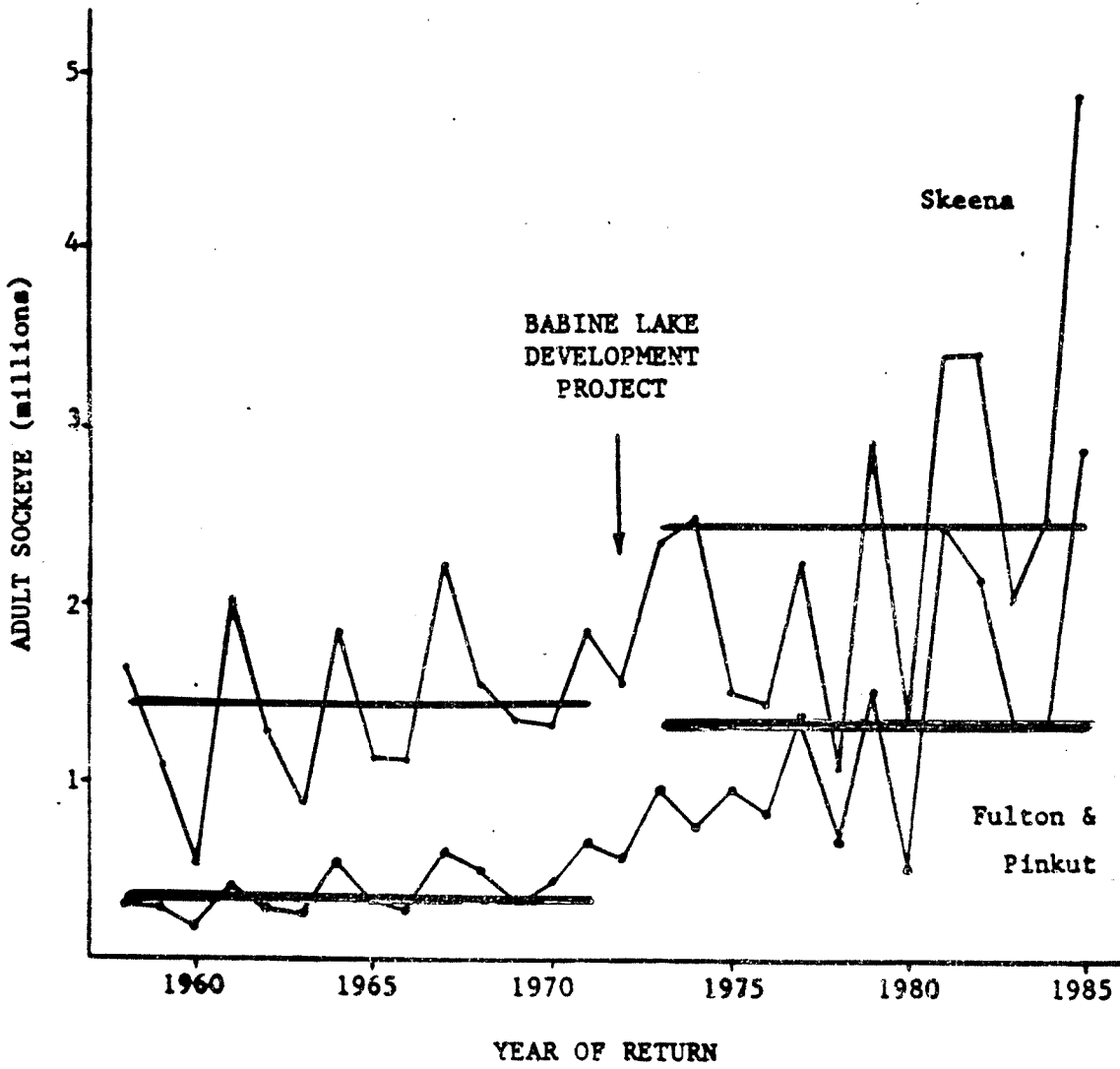


## Fulton & Pinkut Total Adult Sockeye Return

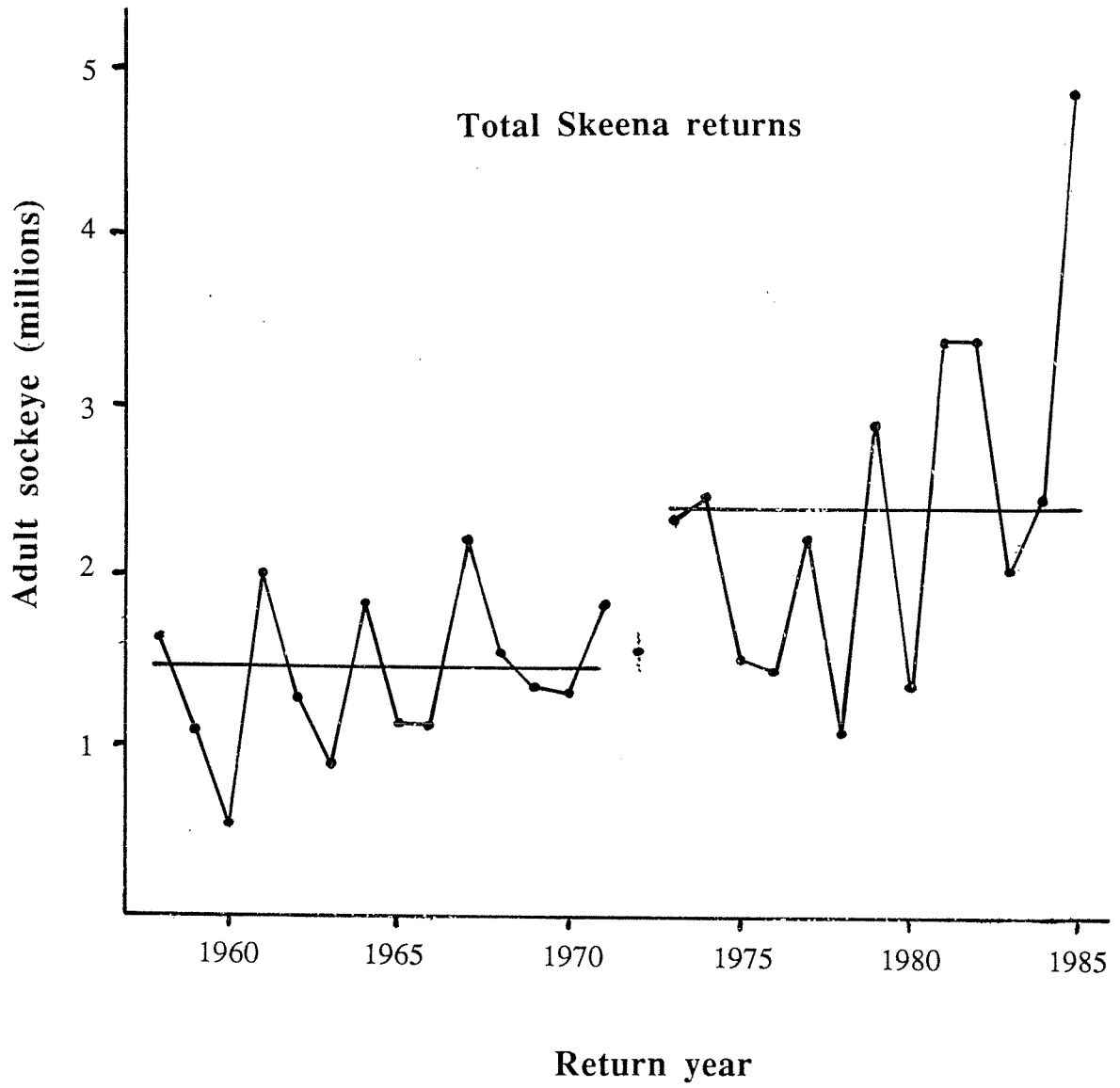


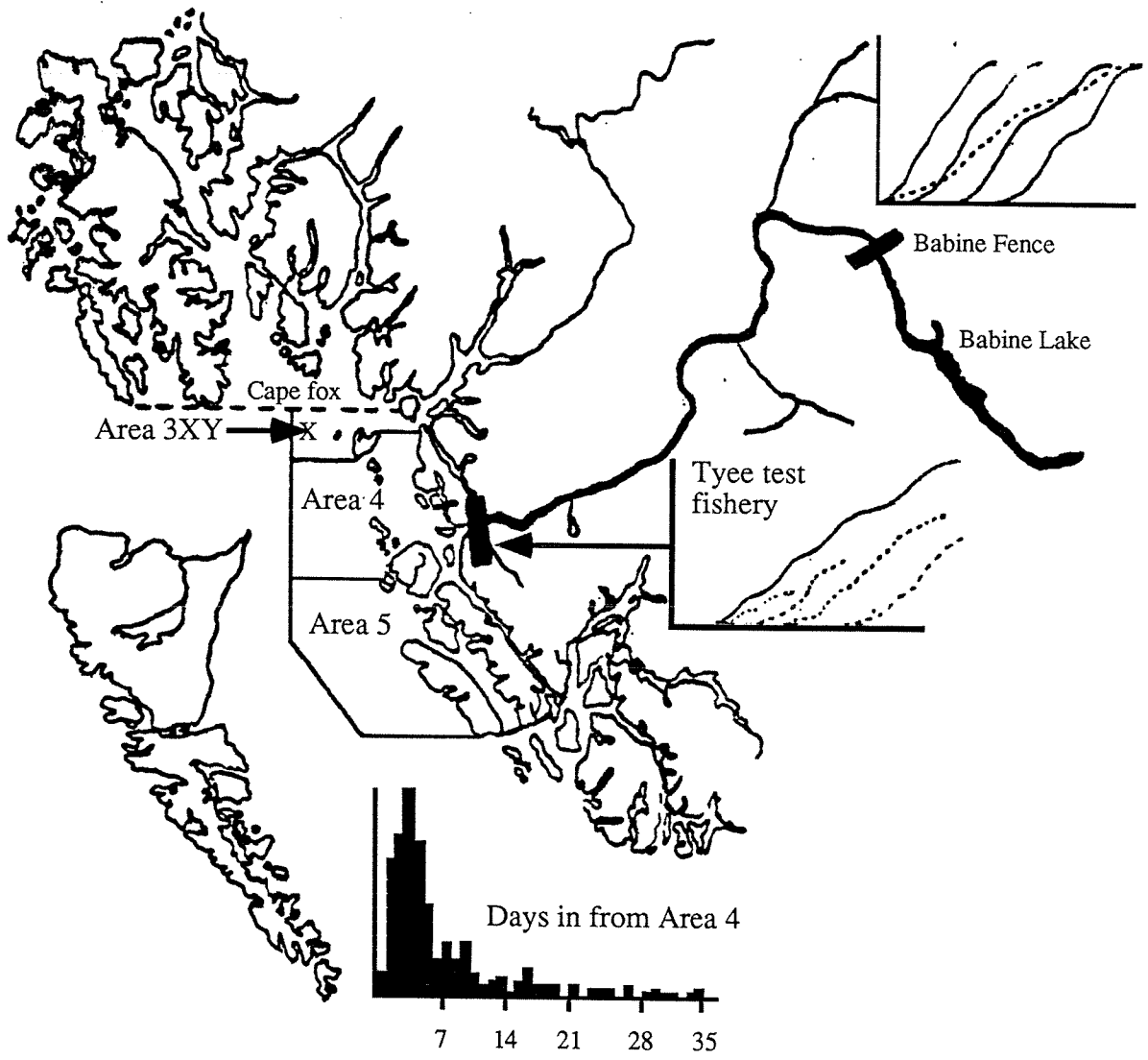
## WeaverCreek Total Adult Sockeye Return

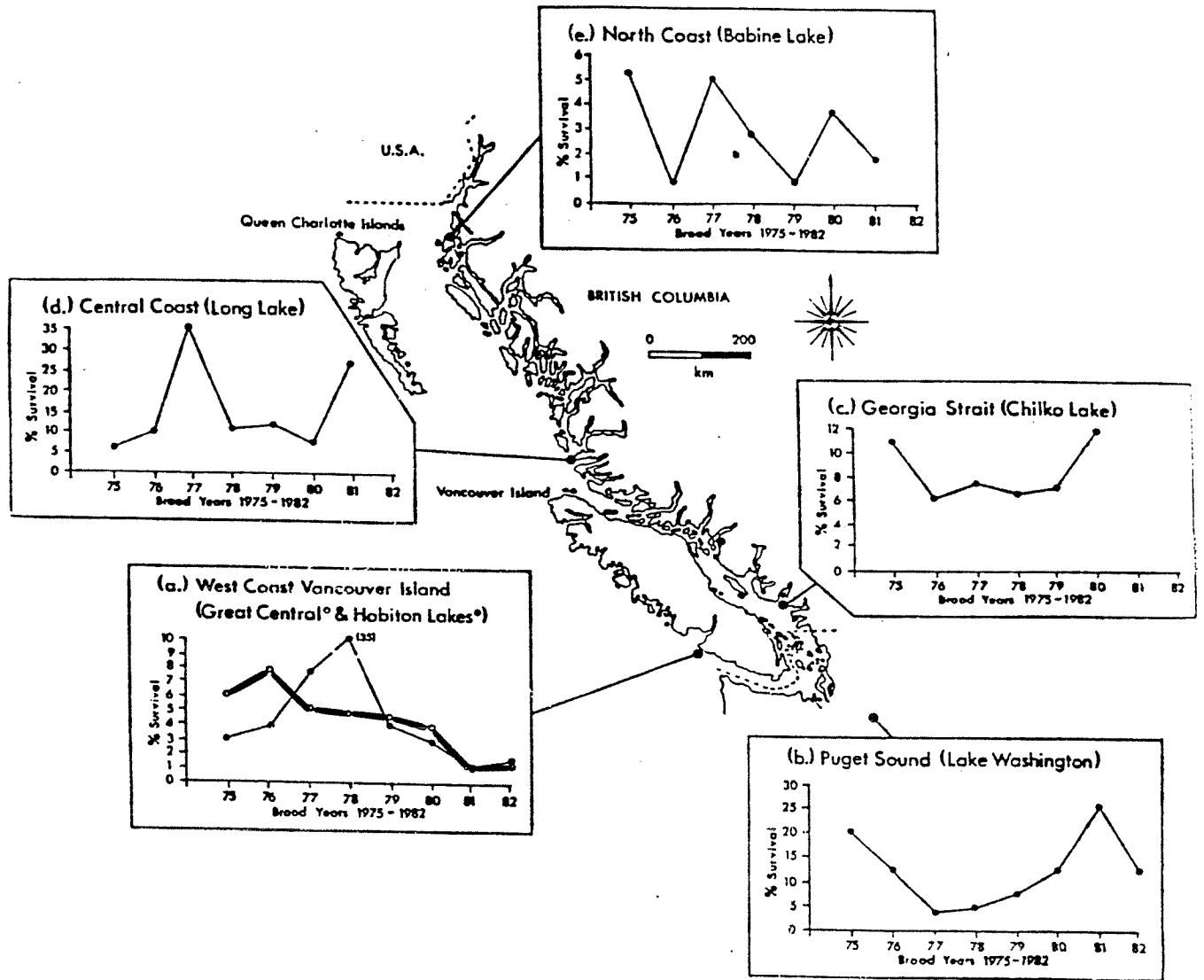




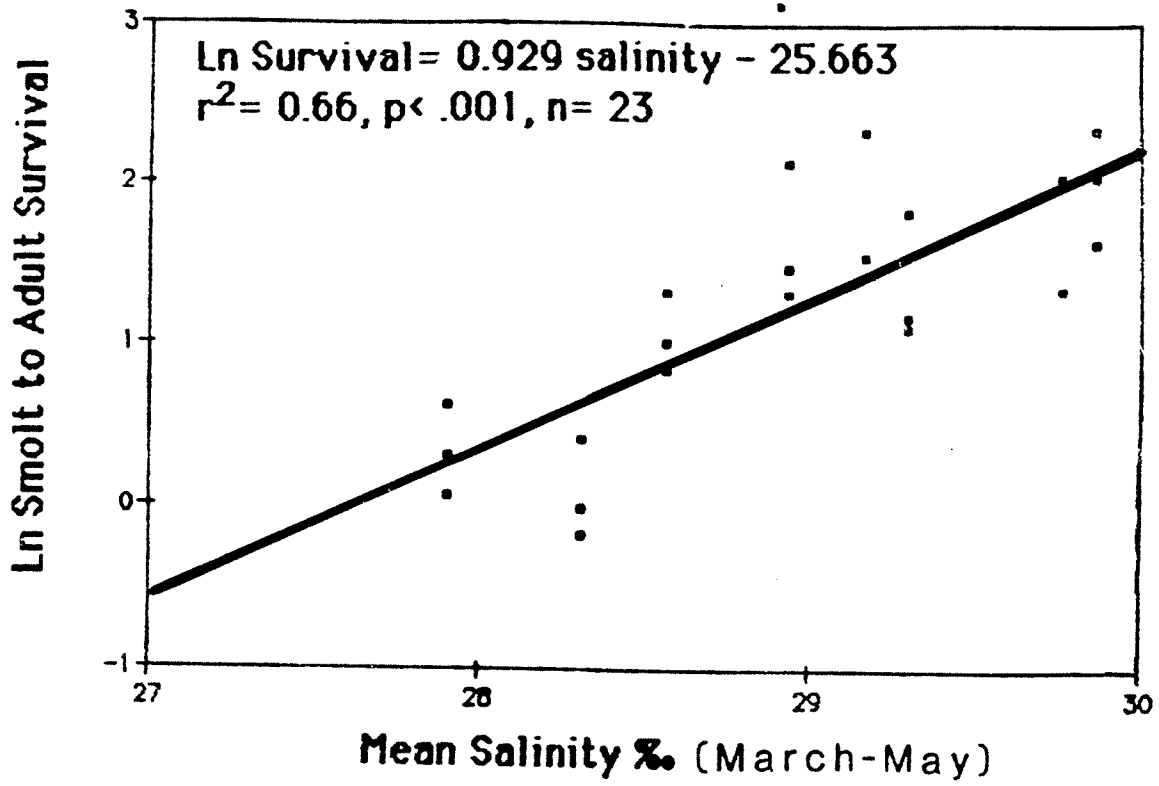
Total adult sockeye returns to the Skeena River system (1958-1985) and to the Fulton River plus Pinkut Creek systems, with pre- and post-development averages shown.





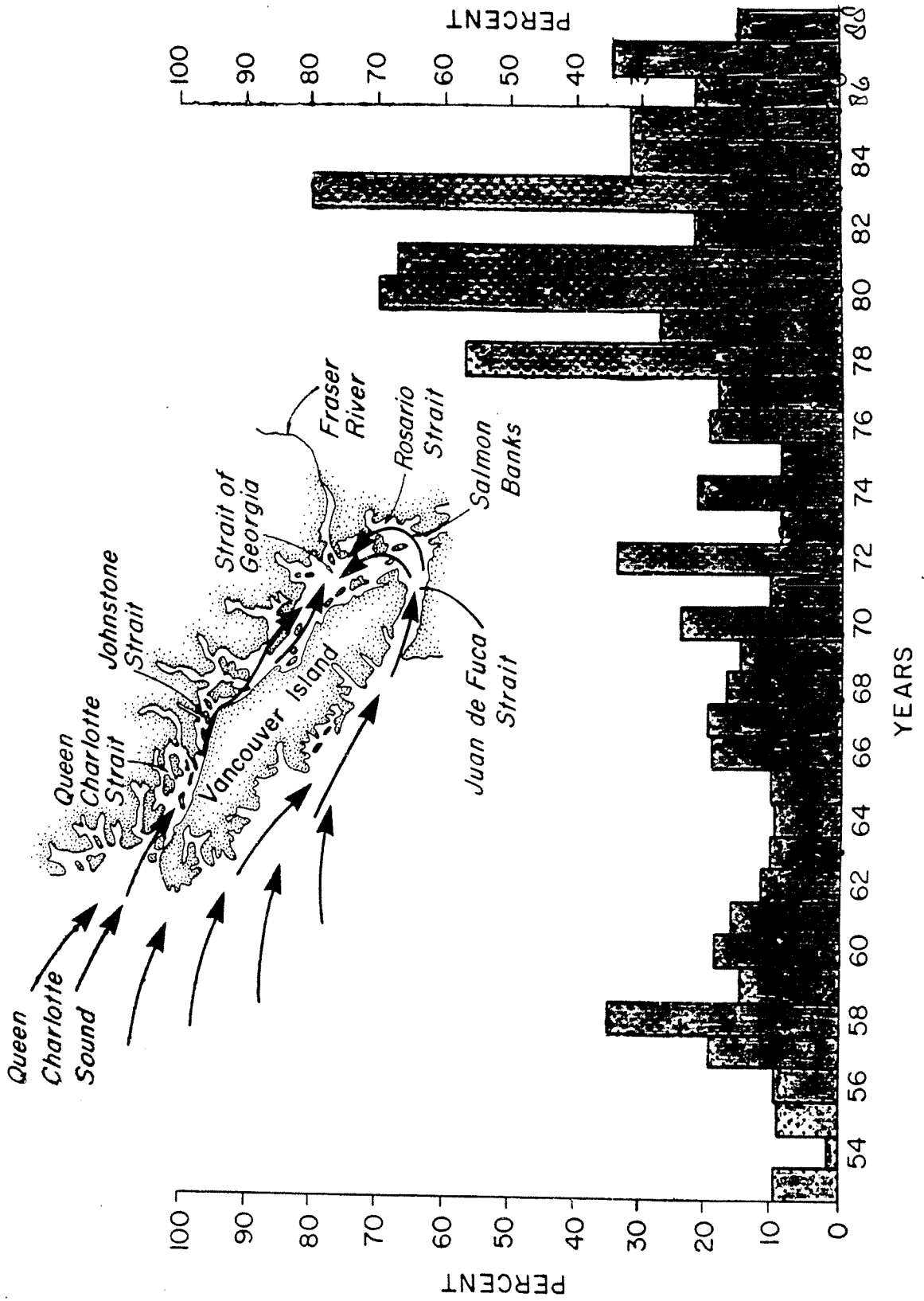


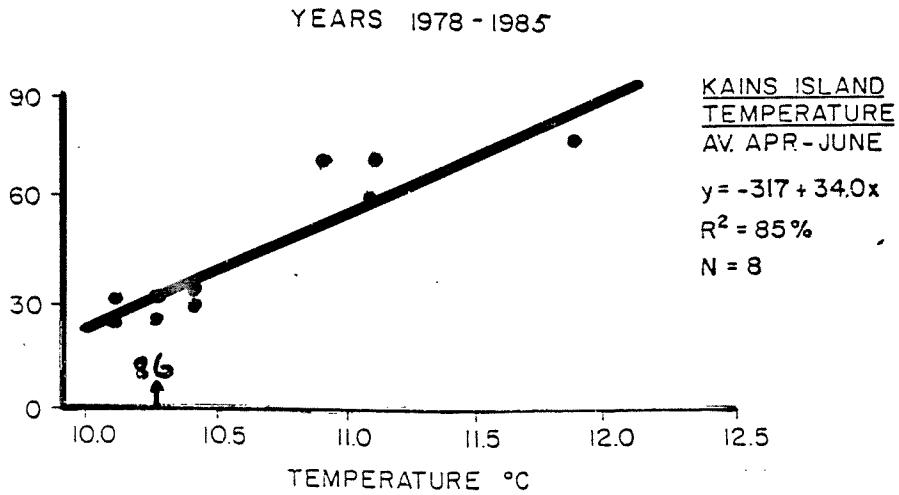
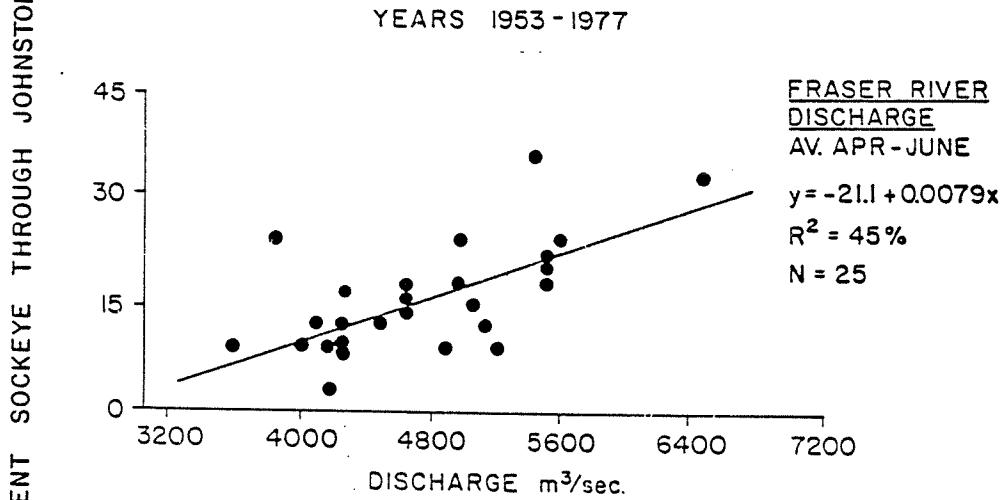
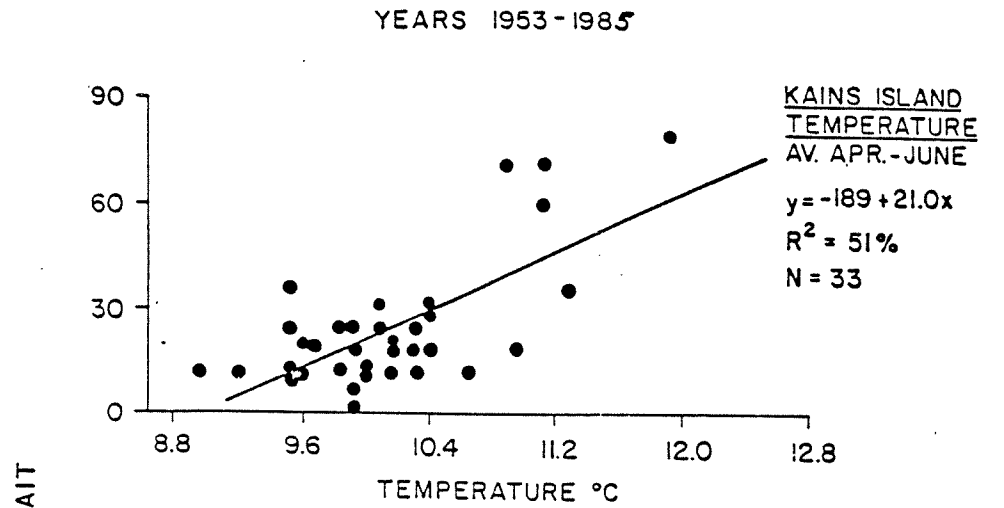
Marine survival patterns for several sockeye stocks that have different locations of marine entry.

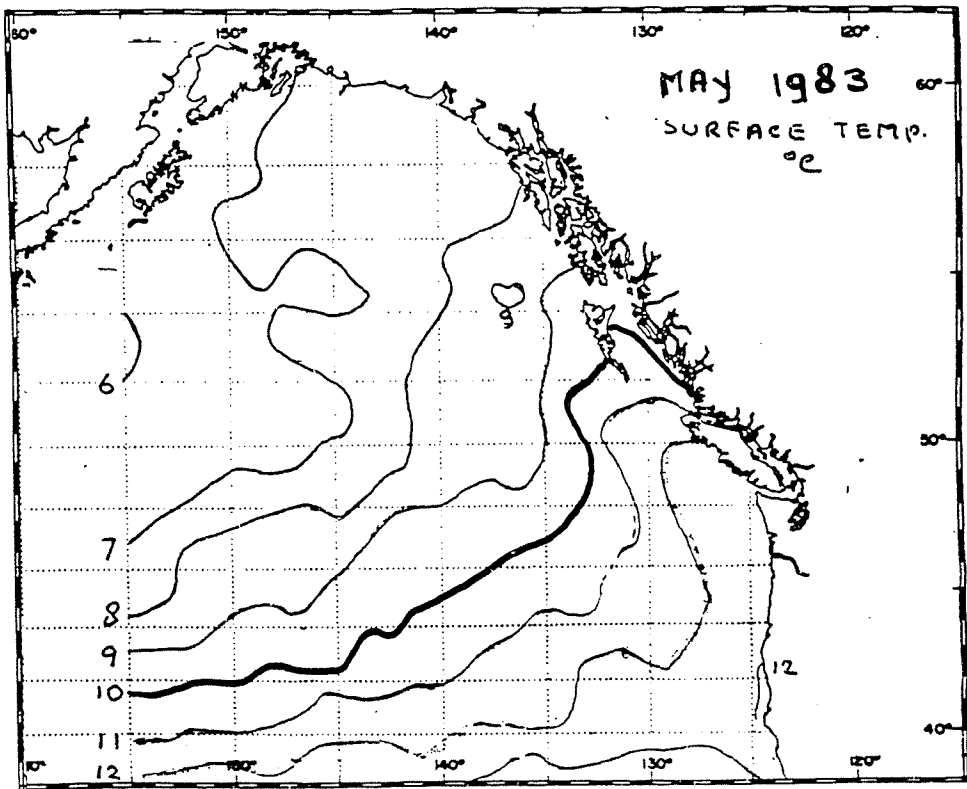
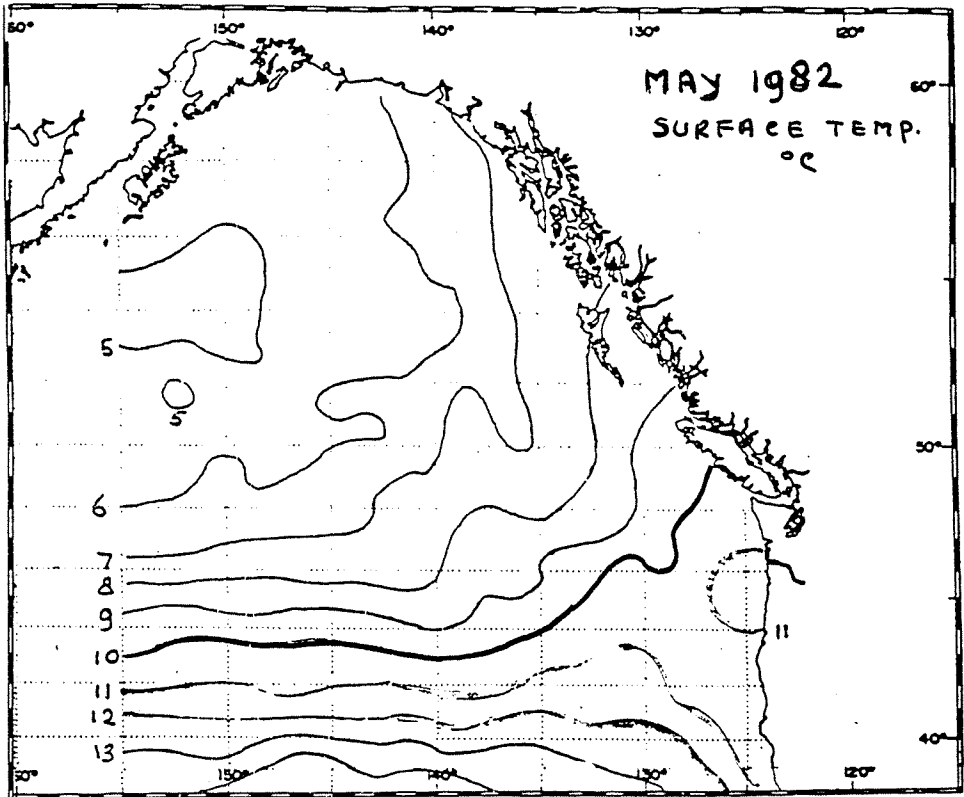


The relationship between smolt-to-adult survival and sea-surface salinity variations at Amphitrite Point during the months of smolt migration for sockeye salmon originating from Great Central, Sproat, and Hobiton lakes.

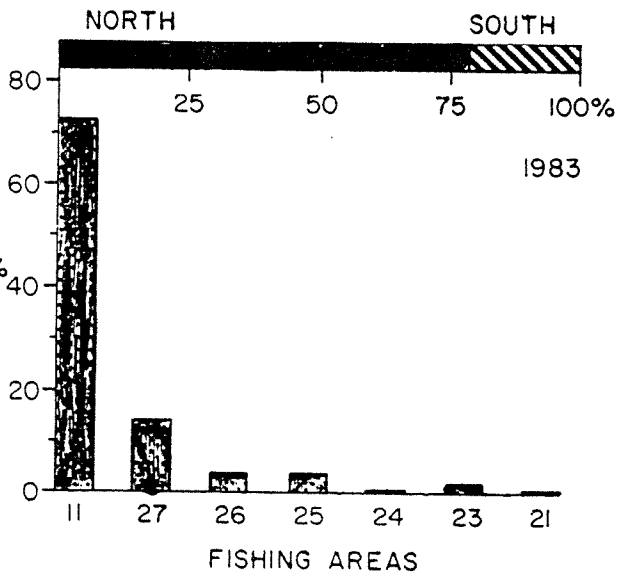
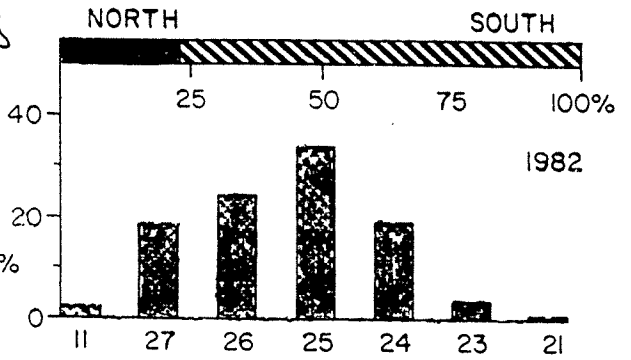
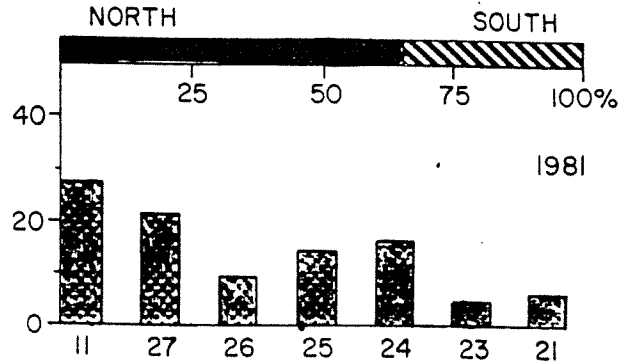
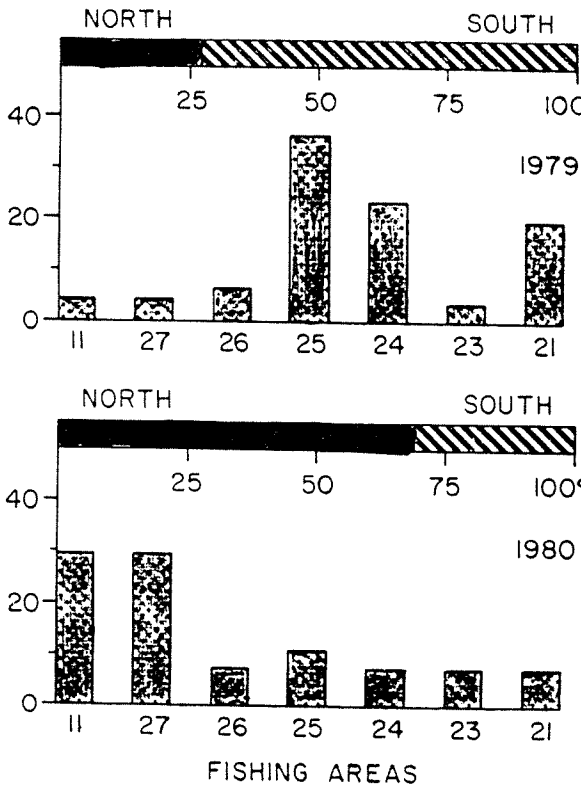
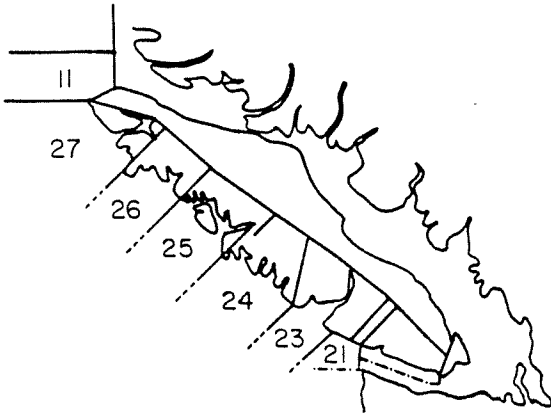
PERCENT FRASER SOCKEYE USING NORTHERN PASSAGE







RELATIVE NO'S SOCKEYE CAUGHT IN % OF TOTAL FOR YEAR



FISHING AREAS

FISHING AREAS

Estimated in-lake losses of sockeye fry attributed to  
IHN virus (IHNV)—Babine system

Year	% egg-to-fry survival (range) <sup>a</sup>	Fry production (x 10 <sup>6</sup> ) <sup>b</sup>	Estimated in-lake fry loss to IHNV <sup>c</sup>
1984	45 (15-64)	198	30
1985	37 (20-54)	178	14
1986	44 (29-59)	190	30
1987	16 (5-24)	77	41
1988	33 (10-76)	183	34

<sup>a</sup>Role of IHNV in observed survival rate is unknown. Values are based on data for Fulton River, channels 1 and 2, and Pinkut Channel.

<sup>b</sup>On the basis of counts of fry migrating to Babine Lake.

<sup>c</sup>On the basis of % migrating fry with IHNV titers  $\geq 10^4$  pfu/g whole fry.

Great Central Lake sockeye “returned” adults

Year	Freshly returned	% $\bar{c}$ IHNV	Post-spawners	% $\bar{c}$ IHNV
1975	91	0	24	96
1976	95	0	82	87
1977	153	0	170	59
1978	135	0	72	76
1979	101	0	42	74

Summary

None of the freshly returned fish with detectable IHNV; infection rate in post-spawners: 59%-96%.

Great Central Lake sockeye “returned” adults (1989)

Sample	IHNV prevalence no. pos./no. tested	%
Trapped at lake entrance	0/40	0
Trapped as above and held in virus-free water to “spawning”	0/31	0
Spawned out adults on spawning grounds	5/53	9.4

## Evidence that IHNV in sockeye is not vertically transmitted

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In 6 years of study in the Babine system, there has been no correlation between IHNV infection rates of the adults and their progeny.

IHNV prevalence in adults has always been high (44%-88%), but prevalence in their progeny has been highly variable (3%-91%).

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## Evidence that IHNV is not vertically transmitted

---

1. IHNV prevalence in sockeye spawners:	57%-88%
2. IHNV prevalence in their eggs* (284 tested):	0%
3. IHNV prevalence in their progeny** (167 tested):	0%

---

\*Eggs were all in advanced eyed stage.

\*\*Yolk sac fry teased out of surface-disinfected eggs.

## Survival of IHNV in carcasses of spawned-out sockeye

---

Sample	Result
Kidney tissues from 16 sockeye, 1 month post-spawning*	All IHNV negative
Kidney tissues at 4°C from seven IHNV-positive sockeye spawners	6 of 7 were IHNV-negative in 72 hr

---

\*Samples were from a population with a high prevalence of IHNV.

## IHNV reservoirs in sockeye spawning grounds— search is now underway

---

Numerous samples of the following have proved IHNV-negative:

- sculpins and chub
- spawning channel silt
- algae on spawning bed gravel
- caddis and mayfly larvae
- snails
- earthworms

The following have proved IHNV-positive:\*

- leeches in Babine System (6/20)
- leeches in Weaver Creek (3/14)

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\*Leech is *Nephelopsis obscura*; IHNV titers ranged from  $10^2$ - $10^5$  pfu/g whole leech.

## Conclusions

---

1. Sockeye salmon probably do not carry IHNV to sea and return with with it to the spawning grounds.
  2. Sockeye spawners probably acquire IHNV on the spawning grounds and amplify it, thus infecting a reservoir also present at spawning time.
  3. Nature of reservoir uncertain. Not likely to be sockeye carcasses but might be salmonids or leeches.
  4. Sockeye progeny probably acquire their infections from the reservoir(s).
  5. Channels should be designed and located so that impact of reservoirs is minimized.
  6. Is item 5 feasible if nature/identity of reservoirs is not known???
- 

Channel	Start	Area	Egg-to-fry
Weaver	1965	17,430	65.28% ± 16.6
Gates	1968	11,280	69.84% ± 15.9
Nadina	1973	18,090	53.41% ± 12.5

## BABINE SPAWNING CHANNELS

### Basic Assumptions

1. Artificial spawning channel is an effective means of producing sockeye fry.
2. Fry produced are as viable as those from natural spawning beds.
3. Lake nursery area has the capacity to support juvenile populations.
4. Increased smolt outputs will result in increased adult returns.

### Monitoring Program—Evaluations

- Adults moving into channel and river (timing).
- Female/male ratio.
- Size-weight-age.
- Behavior in channel and river.
- No. eggs deposited (egg retention).
- Fecundity channel and river (females).
- Embryo-alevin development/mortality.
- Fry out of channel and river (timing).
- Juvenile distribution-growth-survival in lake of channel and river fish (I. June/early July; II. Aug/early Sept.; III early Oct. (15 days ea).
- No. smolts out of lake of channel and river.
- No. adults return to lake and to channel and river.
- No. eggs channel and river.
- No. fry channel and river.
- No. smolts channel and river.
- No. adults channel and river.

### Findings

1. Egg-fry survival channels  $\pm$  40%, as expected.
2. No substantial differences in
  - distribution
  - growth
  - survival in lake.
3. Fry increases resulted in smolt increases in
  - underyearlings in lake
  - smolts leaving lake.
4. No change in average size or survival in lake when population size increased.
5. Adult returns initially (until early 1980) did not meet expectations (first 10 years), but later . . . ?

## Expected Climate Changes British Columbia

McBean

Sea surface temperature	+1°C year 2000 +3°C year 2050	Winter +7°C ±3 Summer +4°C ±3
Sea level	+100 cm year 2050	
Precipitation	Winter—greater runoff Summer—less runoff	
Ocean currents	<ul style="list-style-type: none"> <li>• More El Niño-type years</li> <li>• Sluggish coastal circulation</li> <li>• Summer less strong upwelling</li> <li>• More frequent storms</li> </ul>	

### Pacific Salmon Development time egg-emergence

Species	No. days at:			
	4°C	7°C	10°C	4-10°C
	diff.		diff.	
Steelhead	150	95	64	
	\	/	\	/
		55	31	86
Coho	180	118	81	
	\	/	\	/
		62	37	99
Chinook	236	146	96	
	\	/	\	/
		90	50	140
Chum	260	128	105	
	\	/	\	/
		132	23	155
Pink	195	139	103	
	\	/	\	/
		56	36	92
Sockeye	213	150	109	
	\	/	\	/
		63	41	109

## Predictions—British Columbia Fishes

### Distribution Shifts

#### Pacific salmon

- |             |              |   |              |
|-------------|--------------|---|--------------|
| • Sockeye   | south. limit | → | north. B.C.  |
| • Pink      | south. limit | → | north. B.C.  |
| • Chum      | south. peak  | → | central B.C. |
| • Coho      | south. peak  | → | central B.C. |
| • Chinook   | north. limit | → | south. B.C.  |
| • Steelhead | north. limit | → | south. B.C.  |

### Populations Shifts

- |           |              |   |             |
|-----------|--------------|---|-------------|
| • Herring | south. limit | → | north. B.C. |
|-----------|--------------|---|-------------|

#### Migratory pelagics

- |            |              |   |                     |
|------------|--------------|---|---------------------|
| • Hake     | north. limit | → | central/north. B.C. |
| • Sardine  | north. limit | → | south/central B.C.  |
| • Mackerel | north. limit | → | south/central B.C.  |

#### Groundfish

- |               |              |   |             |
|---------------|--------------|---|-------------|
| • Flatfish    | south. limit | → | north. B.C. |
| • Pacific cod | south. limit | → | north. B.C. |
| • Pollock     | south. limit | → | north. B.C. |

- |           |                     |  |  |
|-----------|---------------------|--|--|
| Pathogens | northward<br>shifts |  |  |
|-----------|---------------------|--|--|

## Conclusions

Treat project as research project:

- test assumptions (hypotheses).
- controls
- proper evaluations
- experiments

Scientists as part of design and operation team.

Get best manager you can find and hire before construction and make him part of design team.

Understand ocean survival better, especially early seawater stages.

Seriously consider global climate changes.

## Babine Lake

Skeena River system:  $\pm 1.5$  million sockeye (catch + escapement)

Babine Lake: 90% of sockeye

Pre-channel escapement: 102,000-888,000 (average 668,000)

Spawning areas:

60 km <sup>2</sup>	- upper/lower river and north arm tributary	44%
18 km <sup>2</sup>	- Morrison Lake tributary	4%
400 km <sup>2</sup>	- Main lake tributary	52%
	- Lake spawning	20%

## Spawning Channels

Fulton 1 (1965)	1 mile	} 117,000 m <sup>2</sup> spawning area
Fulton 2 (1969)	3 miles	
Pinkut (1968)	2 miles	

All fully operational by 1971—78,000 females; 1.5m<sup>2</sup>/female

# QUESTIONS REGARDING SOCKEYE SPAWNING CHANNEL WORKSHOP

## DESIGN

1. What are the design elements that may be effective in maintaining good water quality and controlling IHN?
2. What are the factors that would require an impermeable liner for the channel? If required, what type is recommended?
3. What type of fish barrier rack is recommended for guiding/bypassing adult fish into or around the channel? Discuss construction and operating problems associated with barrier racks in large streams in Canada?
4. Where on the Cedar River should a spawning channel(s) be located?
5. What is the recommended gravel size, type, and depth for sockeye channels?
6. How should landscaping be designed and maintained to minimize organic input?
7. What style of intermediate channel fences are recommended for sockeye?
8. Are low drop structures necessary and effective in maintaining adequate dissolved oxygen through the length of a channel? What is the recommended design?
9. Can an artificial overhead cover (sail, mast, or fixed cover) be used in place of natural foliage to minimize litter fall and cleaning consequences?
10. Based on your experience, what are the most critical concerns and criteria for planning visitor facilities for spawning channels? What areas of the channel and operation facilities should visitors be diverted away from?
11. In general, are on-site residences or general staff facilities more practical for a spawning channel located in an urban area?
12. What are your recommendations for sediment and turbidity control for the channel water supply?
13. Have the Canadians investigated ozonation for IHN control at spawning channels? Has this been tested anywhere to your knowledge?
14. In terms of planning, designing, constructing and testing a spawning channel, what are the most critical scheduling items for a spawning channel? Is an

operational test period recommended for channels prior to directing fish into the channel?

15. What procedures have been used to maintain adequate dissolve oxygen through the length of the channel? Based on your experience, what do you recommend that we use?
16. What are the advantages/disadvantages of: (1) one large spawning channel system or (2) two or more systems?
17. What flows are needed for transportation; spawning and incubation?
18. What are the advantages/disadvantages of building a partially built channel versus a complete channel at the initial construction phase?
19. IHNV is known to be prevalent in naturally spawning sockeye with no apparent effect, what information is available that suggests the IHNV should be of major concern?
20. How do we evaluate the impact of IHNV (if any) or other diseases on egg to fry and fry to smolt survival?
21. Besides IHNV, what other fish health concerns should we be aware of in operating the channel? Please address adults, fry and eggs, and include possible impact on natural predation.
22. Will the channel design incorporate cobble or riprap sides to create new rearing habitat? The additional benefits could be substantial, but the presence of rearing species could restrict the option of drying the channel, eg. for gravel cleaning.

## **Operations**

1. How important is it to be able to totally dry the channel and gravel? What are the biological advantages and disadvantages of drying the channel and gravel?
2. How important, successful and practical is the measurement of interstitial gravel flow?
3. How important is it to monitor channel water quality for IHN density?
4. Can adult attractants be successfully used to divert a portion of channel adults away from the channel area?

5. What are the Canadian experiences in the redistribution of sockeye adults when they are barred from entering the channel?
6. In channel management, what portions of the natural river run should be encouraged to enter the channel?
7. What have been the water quality impacts of channel operation and cleaning on the river downstream of the channel?
8. What gravel cleaning methods are recommended to optimize production and control fish diseases?
9. What difficulties have been experienced in getting fry to leave spawning channels? What velocity is required to flush fry from the channel and how effective is it?
10. How should the channel be loaded?
11. What is the recommended spawning density?
12. What suggestions could you make regarding maintenance?
13. Which physical parameters should be measured in the channel and what sampling effort is needed to collect these data (i.e., how often should samples be taken and how should sampling stations be distributed throughout the channel)?
14. What are the primary factors influencing egg-to-fry survival?
15. What are the personnel requirements for operating a spawning channel?
16. If the Cedar River sockeye run is made up of one interbreeding, genetically identical, stock, then why not stock the channel with fish from the modal segment of the return?
17. If the Cedar River sockeye run is made up of discrete substocks who spawn at different times and different locations, how will it be possible to separate these fish at the rack?
18. Loading of the Channel over a two month or longer period is being considered.
  - A) Is this practical?
  - B) How would you design the Channel to accomplish this?

- C) Since maximum IHN virus shedding is at time of maturation, should we consider loading the channel from bottom to top in order to reduce the virus titre which green fish would be exposed to.

## Evaluation

1. What criteria/methodology should be used in evaluating the channel?
2. If a larger fry production does not result in more smolts, is there anything we can do about it?
3. Should parallel systems be utilized for experimentation?
4. Should the post fry stages of channel fish be monitored?
5. Should actions such as lake fertilization and predation control in Lake Washington be considered?
6. What methods are available for enumerating wild fry?
7. Should we evaluate spawning densities?
8. What measurements or evaluation procedures should be used at emergence (or shortly thereafter) to determine if fry produced from the channel are of compatible quality to those naturally produced from the river?
9. What steps are necessary to assure the continued production from the natural river? In particular can we assume that fish that are excluded from the channel will be viable natural spawners?
10. How could we determine if the channel production was impacting the natural production?
11. How do you explain the failure of the Gates and Nadina facilities to increase the adult population?
12. If morphological, behavioral, or physiological differences do occur between wild and channel fry, how do we determine if they are biologically significant?
13. How can we compute fry-to-smolt survival rates of channel fish?
14. How should we determine whether the channel has successfully mitigated for the production of 262,000 adult sockeye?

15. How do we appraise whether genetic differences have occurred in the Cedar River population due to channel operations?

# LIST OF PARTICIPANTS

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