IMPROVING HATCHERY EFFECTIVENESS AS RELATED TO SMOLTIFICATION

Proceedings of a Workshop

held at

Kah-Nee-Tah Lodge

Warm Springs, Oregon

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i. INTRODUCTION

As part of its responsibilities under the Notthwest Regional Power Act, PL 96-501, the Bonneville Power Administration (BPA) is responsible for funding activities which protect, mitigate and enhance fish and wildiife to the extent affected by the development and operation of any hydroelectric project of the Coiumbia River and its tributaries in a manner consistent with the [Fish and Wildlife Program] plan. Priorities identified in the Columbia River Basin Fish and Wildlife Program (the Program) of the Northwest Power Planning Council (Council) include research on hatchery effectiveness, smoltification and other related subjects. In this workshop, the emphasis was upon smoltification which is the physiological transformation that allows and prompts juvenile anadromous salmon and steelhead to move fdrom freshwater to seawater.

This is the Region's program, and BPA wished to develop a smoltification research effort that would have broad support among the interested parties. For this reason, EPA sponsored a workshop on smoltification and related research, held at Kah-See-Ta Lodge, Warm springs, Oregon, or. May 20-23, 1385. The workshop's purpose was to gather leading technl:al experts in the field in smoltification, permit them to exchange information about the state of the art of smoltificaticn research, and allow them to identify and rank high-priority projects relative to Section 73&(h)(2) of the Program. Primary emphasis was on Section 70h(h)(Tj(F), whirh addresses the need to develop a sensitive, relia'oie index for predicting smolt quality and readiness to migrate.

BPA formed a steering committee of regional experts who developed an agenda and invited 25 fishery scientists and other experts to participate. The workshop was opened to the publec and another 26 persons attended all or part of the sessions. The participants included wide representation from the fishery agencies, Tribes, Electric Utilities, Nordthwest Power Planning Council, Regional Universities, private consultants and other interested parties listed in Appendix B.

The workshop schedule (see Appendix C) included keynote speeches, technical papers, and ether sessions that were intended to summarize both what is known and what information is needed. Informal work groups drafted research-project "need statements" (see Appendix E), and then participants ranked the resulting "project needs"(see Appendix A). The results of the ranking process were made availabie at the end of the workshop. The structure of the workshop was described in a summary given to all participants at registration and it is presented in Appendix D. Copies of the revised project need statements and results of the balloting were sent to all participants. A "Proceedings" of the workshop (this report) was to be published immediately after the meeting. Regretfully, the development of the "Proceeding" was delayed beyond BPA's intention.

Unlike a formal report, this manuscript retains the flavor of the workshop's informal and creative atmosphere. Most of the "Proceedings" were developed from actual transcripts of the speakers, albeit, some participants provided written manuscripts. The transcripts were edited and re-edited to enhance brevity and clarity. Editing was not intended to alter the author's meaning, and if this occurred, BPA hopes that the altered meanings were insignificant.

BPA gratefully acknowledges the contributions and assistance by all who helped make this effort successful.

2.1 INTRODUCTORY AND KEYNOTE ADDRESSES

Welcoming Remarks (G. Drais)

Purpose of Workshop (G. Bouck)

Smolt Quality and the Effectiveness
of Columbia River Hatcheries (J.D. McIntyre)

Implementation and Management Issues (D. Evans)

WELCOMING REMARKS

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Welcome to the workshop. By way of introduction, I am the Chief of the Biological Studies Branch for the Division of Fish and Wildlife at the Bonneville Power Administration. Some of you have been involved in things that we have been doing in the past three or four years since the Fish and Wildlife Program was developed, but some of you have not, so I think it is appropriate to spend a little time talking about the Fish and Wildlife Program.

In December 1980, Federal law 98-501 was passed, and this was entitled the Northwest Power Planning and Conservation Act. There were two primary elements to that act, but its main purpose was to deal with the prospect of energy deficits in the region. The Regional Power Act called for a power plan to be developed which would look at the energy future of the Sorthwest. The lesser portion of the Regional Act dealt with fish and wildlife, and it called for the protection, mitigation, and enhancement of fish and wildlife impacted by hydroelectric development in the Columbia River Basin. I have said "lesser" because that portion was included at the urging of the fish and wildlife community in this region, but it was not the primary purpose of the law. Just about the time the Regional Act passed, many things changed. The economy slumped, and the forecast energy deficits became an energy surplus. Suddenly the energy plan (which was to bring stability to the region by providing a reliable, equitable future for power production in the region) took a back seat to a fish and wildlife program (previously only a small part of the law itself).

In November 1982, the Northewest Power Planning Council, a body consisting of two representatives of each of the four Northwestern states, was in the process of adopting the Fish and Wildlife program (Program). At that time we recognized that the Program was comprehensive, but I don't think we recognized what it would mean in terms of fish and wildlife resource protection, not only to the region, but also nationa ;ly and even internationally. The Program was amended in 1984. it is now composed of more than 200 measures which are intended to enhance, protect, and mitigate those fish and wildlife resources of the Columbia River Basin which were adversely affected directly or indirectly by hydroelectric develcpment.

One part of the Council's Program deals with hatchery effectiveness, smolt quality, and various other segments (Section 704 [h][2]). BPA was given the authority to use funds that were developed from the sale of energy to imlement the program. BPA was not given a role as manager or a regulator of the fish and wildlife rescurce. Our Administrator, Peter Johnson, who created the EPA Division of Fish and Wildlife in 1982, coined a phrase that has been hanging over our heads ever since--that we would be a "small, elite staff". We know we are small. We don't know what the "elite" means. But we know the that Administrator also said, "BPA is not going to be the fishery managers. You're going to nave to rely on the people in the fishery agencies in order to develop the projects that BPA will implement." The Administrator also told us that we would only implement projects that were adequately defined, evaluated, and assessed. We have seen over the last three years that BPA cannot be very successful if We try on our own, that is independently, to define, evaluate, and assess the various measures of the Program.

Over the last three years, BPA has tried numerous ways to define and understand the Fish and Wildlife Program Measures, to bring some consensus on what the measures are intended to do, and to scope out things that need to be done. We have met with varying degrees of success. This is the first major group effort at trying to define section 704(h) of the Program. We are trying to plan and bring some direction to what projects should be done, via this workshop.

I would like to identify the participants in this workshop. Primarily, we have regional fish and wildlife experts--both managers and scientists. We have also involved some national fishery experts who are here to help U.S. These people all deal with fish quality and hatchery effectiveness throughout the United States. We also have some international fish experts present, primarily from Canada. To help us facilitate the workshop, BPA has employed the service of EA Engineering, a consulting firm out of California and Dr. Jim Creighton of Creighton Associates, who is working for EA. This firm is to facilitate the workshop and we expect to go away from here with a direct product at the end of this week and indirect products later on.

How will BPA use the results of this workshop? We will use it primarily as a budget planning and scheduling tool. We have to be able to ensure that BPA funds will carry out only the things that are identified as being necessary. Our budgeting cycle is at minimum a two-year process. We add generally three years on top of that, so we're dealing with things which may be five years out into the future. That is pretty hard to do in a scientific field such as fisheries where the results of one year's efforts may dictate what you do the following year. But it will be useful as a budget planning document.

The results of the workshop will also help us develop project plans for implementation, and we will present these to the Northwest Power Planning Council (Council). The Council developed the Fish and Wildlife Program, and is a very important player in this Program. BPA has interchanges with the Council on nearly everything that we do. We go to them when we start to implement something, to see if what we are proposing is consistent with the Program. The Council is represented at this workshop by Dr. Mark Schneider, a well-known fishery scientist in his own right.

Another use of this workshop is to help bring some order to BPA's project implementation process. In the past, this has seemed almost a hit or miss process, or at least the order has not always been obvious. Planning through a process of this type will foster that order and make it more apparent to all concered.

Finally and most importantly, this workshop will focus on problem-solving. Using the minds collected here, we will identify the major problems and determine what is to be done in those problems. That focus is obviously very important.

What is expected of you? Well, I hope that you will have an opportunity to relax here. But at the same time, you are here because of your expertise and knowledge, and we want to use those talents. While you are relaxing, I hope we tire you out mentally. We want to pick your brains; we want you to open up and provide us with your knowledge, expertise, and ideas. We are going to do a lot of brainstorming. Again, we want to go away from here with something important, and you are the people who can allow us to do that.

Finally, there is a motto which you should keep in mind: "The opoortunities of today are found in our vision of the future, not in the what-could-have-beens of the past." Please keep that in mind constantly. Avcid the tendency to dwell cn the past. I encourage you to consider where we want to be, not where we have beer?.

PURPOSE OF WORKSHOP

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I would like to introduce the workshop steering committee: Ed Donaldson (Canadian Fisheries and Oceans), Doug Arndt (Corps of Engineers), Carl Schreck (U.S. Fish and Wildlife Service/Oregon State University), David Ransome (Oregon Aquafoods), Einar Wold (National Marine Fishery Service), Mark Schneider (Northwest Power Planning Council), and myself. To the extent that good things come from the workshop, 1'11 give them the credit; to the extent that anything goes wrong, I'll take the blame. The purpose of the workshop is purely technical--the result will be a recommendation to BPA which will be advisory and will be reviewed at a quasi-political level. That is, BPA will send out the workshop results and ask the Tribes, the Agencies, and other publics, "Are these the right projects?" Clearly there will be opportunity to impact the direction of proposed projects later, but the concern here is to identify the technical needs in smoltification and perhaps hatchery effectiveness in general.

The workshop's initial purpose was to determine which projects were needed to cover program area 704(h), i.e., smolt quality indices, readiness to migrate, and so on. BPA tried to identify needed projects in previous years with technical workgroups, and like so many things that seem relatively simple, the result turned out to be very complex. Among other things, we found that proposed projects often duplicated other previous projects or represented little more than "wish lists". In other cases, projects were proposed which were unlikely to be successful, or if successful, would produce products (results) which were unlikely to be used. The latter is important because the time and money used to develop a "result" would be wasted if no one is willing to use it.

BPA encountered considerable “uncertainty” regarding which projects are needed from a purely technical standpoint. For example, at breakfast this morning somone postulated that, "What we really need are high quality smolts." Someone else asked, “What is a quality smolt?“--and soon someone asked ‘What is quality and what is a smolt?” Thus, you can appreciate the uncertainty :hat exists. in summary, there is a mix of opinions and a lot of technical uncertainty, but there is also a fair amount of socio-poiitical uncertainty. These factors interact and generate priorities, which perhaps only Diogenes and his iamp could analyze accurately.

It also became obvious that “life-stage emphasis" could become a problem. That is, smoltiflcation research seems to be an entity unto itself and in some cases, without regard for the continuum in the salmon’s life cycle. All of us need to focus on that continuum, not just one part of it. We have to view life stages in the proper context, and realize that smoltification cannot be divorced from events that precede it; that the objective is not merely smclt;fication, but survival through the !:fecycle. Thus, the overall goal is to produce more adult fish, and not just “better understood” smolts.

The experience of many agencies and institutions clearly demonstrated that BPA needs the collective wisdom and support of a peer group, such as yourselves, to help identify the projects needs and establish priorities. This approach has worked very well at the national Institutes of Health and the National Science Foundation and, we thought, it worked well for BPA in identifying the projects that were needed in IHS disease research. We thought it could work well for identifying project needs in Measure 704(h)(2)(F) and if this workshop works out well, BPA is likely to have another in the future.

in setting up the workshop, we ran into a few Problems, and one was deciding whcm to invite. Selection of participants is a difficult thing--extremely difficult--when you have so many qualified peopie out there, and you can only pick a handful. Our approach was to use a steering committee that made most of the decisions and 3PA followed most of their recommendations. In a few Instances when recommended pecple couldn’t attend, I used executive privilege to quickly fill vacancies on short notice. I apologize to anyone who feels left out but this is an open public workshop. We did not take the time and effort to invite everyone--we thought if we had too many people here, we wouldn't accomplishes much. my worst fear was that there might he two hundred people in attendence, and I thought, "If that happens, we'll get nothing done."

There are three main goals for this workshop, and one goal is simply to complete it as quickly as possible-before summer--so that BPA can go forward with the funding of projects for FY 86[1]. One could have spent a lot more time planning the workshop, but we believed that it was better to have the workshop sooner rather than smoother. I think we are meeting this goal, since it is not yet summer.

The second goal, as Greg Drais pointed out, was to produce project titles and project descriptions of only the very, very, very top priority projects. This limitation is reasonable because BPA can fund probably less than 10 new projects per year in the 704(H) area in the immediate future. If there are only 10 projects, you do not have to worry about potential projects with a priority number of 12, or 20, or so forth. Thus, while planning is important, you should deal not just with the high priority, but rather just with the extremely high priority projects.

The third and last goal is simply to evaluate the workgroup approach as a means for doing this kind of work. We want the participation of experts, but only if it gets the job done and does it well.

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1 Subsequent resolution of the intent of the Northwest Power Planning Council's 1984 Fish and Wildlife Program, Action Item 39.1, lead to a moritorium against all new projects in Section 704(h), including smoltification. This moritorium continued until February 1987.

SMOLT QUALITY AND THE EFFECTIVENESS OF COLUMBIA RIVER HATCHERIES

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As I understand it, the purpose of the workshop is to identify information needed to satisfy Section 704(h)(2) of the Northwest Power Planning Council's (Council) Columbia River Basin Fish and Wildlife Program. This section of the Program includes several elements directed at increasing the effectiveness of existing artificial propagation facilities for anadromous salmonids. Elements include improved husbandry methods, improved rearing operations and release management, improved methods for gene resource conservation, and improved fish health. Experts in each of these areas have been convened to help BPA identify projects needed to complete these elements of the Program. The participants have been asked to consider primarily those elements associated with smolt quality and readiness to migrate--characteristics of a hatchery's "final product". Presumably because of my interest in fish population biology and aquatic ecology, I was asked to outline my view of the role that these fish are to fulfill when stocked into Nature, and the biological relations that may help the participants define the various project needs.

I concluded that my first task was to study the goal and objectives of the Council's Fish and Wildlife Program in an attempt to determine what they intend to accomplish and thereby identify what characteristics and "quality" of fish would be most likely to help them attain their goal. The first part of this paper describes what I concluded from the Council's Program document and my interpretation of their goal.

Section ;Gb(h)(Z) of the Program, the Section to which the Workshop is addressed, proposes that hatchery effectiveness is wanting and that the key to its improvement lies in the elements described previously, elements that, if accomplished, will make a significant contribution to the goal. In the second part, I discuss some questions concerning these propositions and reexamine the Council's goal within the context of these questions. The last two sections of the paper Inc-'ude my conclusions regarding smolt quality and a series of recommendations to the Workshop's participants.

COUNCIL GOALS

When I agreed to par..'icipate in this Workshop, my decision was based on the assumption that I could go to the Council's Program document (1984 Fish and Wildlife Prcgram) and find their specific goal and objectives. I intended to prcceed to an examination of some of the ecological relations that would determine the quality of fish needed to meet the Council's goai, so that the 'Workshop part Icipants could make recommendaLions fcr producing an appropriate product. Once involved in the development of this strategy, however, I found it difficults to progress in logical steps from the goal to these needs..

My prrmary difficuity was that the Council has no specific goals and object tives outlined for anadromous fish in their program document. They have init iated projects with some fish and wiidlife agency pesonnel to deve lop otential goals, but I found no existing numerical goals. Their general goal, however , is tc overcome adverse effects for anadroncus fish caused by hydro power development and operation in the Columbia Basin. The Council's directicns to those attempting to propose specific goals and cbjectives include, "Specific losses and goals will be provided for each stock and each signifi cant river basim." The council has also said that they I',... will take special care not to endorse any projects that would overccmpensate for fish and wildlife losses caused by the Columbia River hydroelec:ric system." futher guidance is provided by the Council's statement, "Hatchery propagation objectives must be integrated fully with natural propagation objectives." Perhaps we can also conclude that the Council's primary concern is with adult

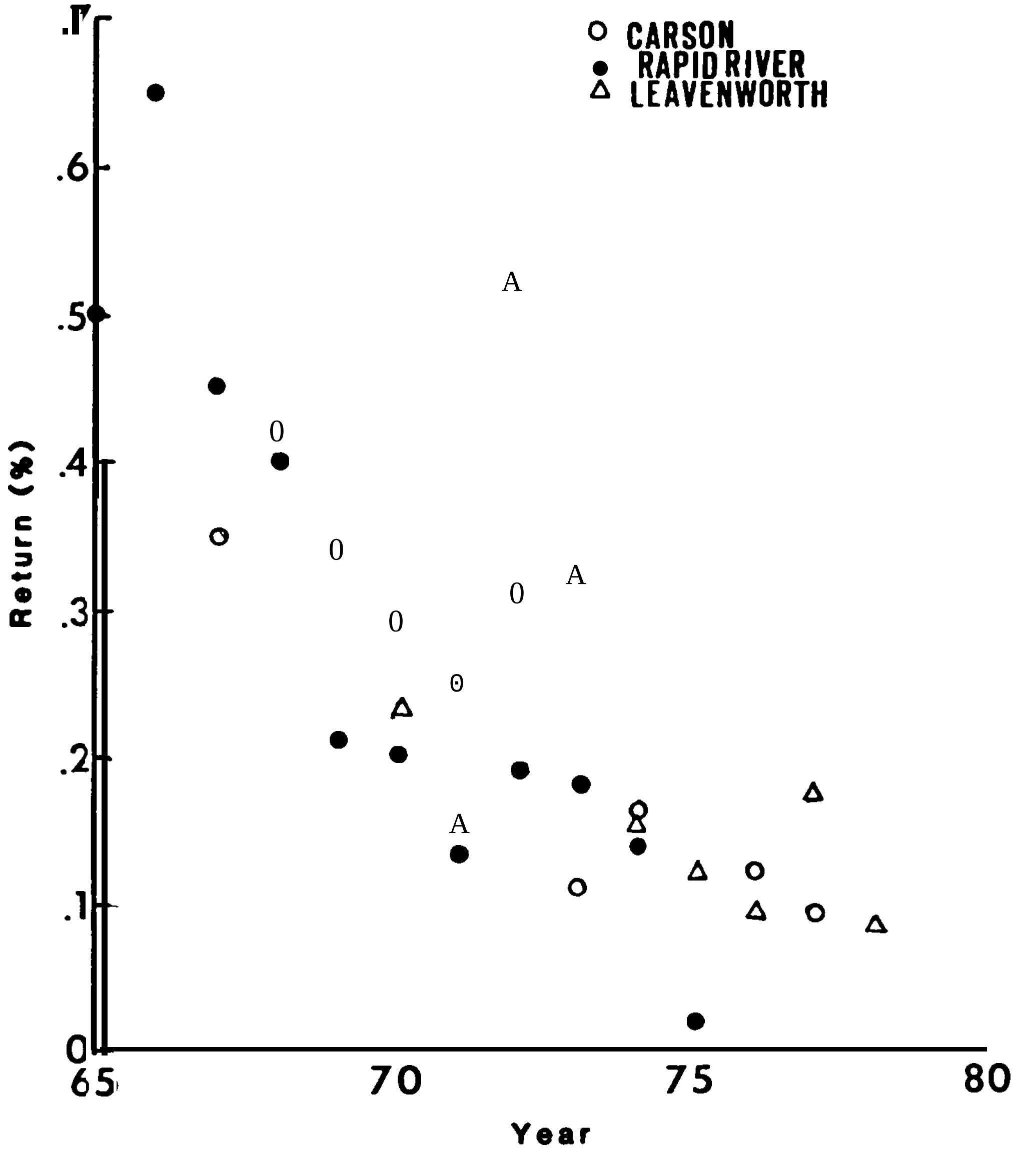

Figure 1. Percentage return (adults/smolts) x 100 for spring chinook salmon released from Carson National Fish Hatchery, Leavenworth National Fish Hatchery, and Idaho's Rapid River Hatchery.

fish escaping the fisheries, because they said ". . . . if the Council's fish prcpagation objectives are to be implemented successfully, they must be coordinated with harvest management."

Given these statements, my interpretation is that the Council wants to increase the number of adults returning to all parts of the river, and they have concluded that one way to do that is to improve the effectiveness of existing hatcheries by producing more smolts that survive to adulthood. The fish must be produced and managed so that they can be "integrated fully with natural productisn objectives" -- objectives that have not been developed beyond statements such as ". . . rebuild naturally spawning stocks..." and " maintain existing wild stocks . . ."

FACTORS LIMITING SMOLT SURVIVAL

One might conclude from the foregoing that because of the poor quaiity of smolts produced, survival rates for hatchery fish have been found to be wanting to such an extent that improvements in smots quality will make a significant contribution to the Council's program. To evaluate this assertion, I examined some of the trends that exist in present programs for spring chinook salmon at three Columniaa River hatcheries (Figure 1). The decline in adults returning tc each hatchery per unit of smots released certainly is a source of concern, but has the decline in adults been caused by conditions either in the hatcheries or by husbandry practices

Another obvious question arising from these data concerns the similarity in the apparent trends for hatcheries in the middle Colurbia (Carson National Fish Hatchery), the upper Columbia (Leavenworth Sational Fish Hatchery), and the Snake River (Idaho's Rapid River Hatchery). Experiments have shown that about 15 percent of downstream migrating smolts are killed at each dam that they encounter. The data in Figure 1 do not show this effect. I am aware of no explanation that might reconcile these differences.

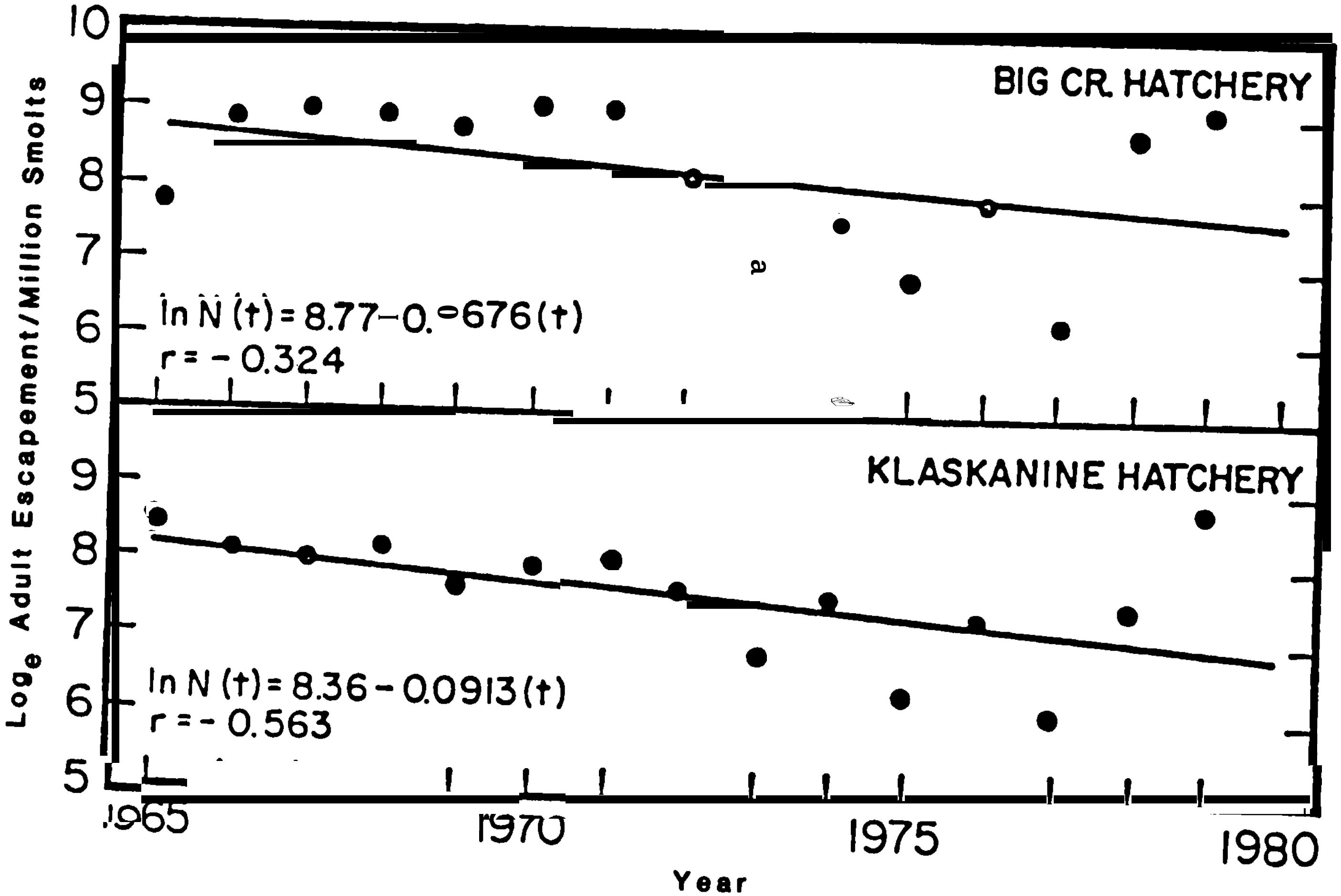

Figure 2. Trends in the escapement of adult coho salmon per million smolts to Big Creek and Klaskanine hatcheries, Columbia River, 1965-79 (from Oregon Department of Fish and Wildlife 1982).

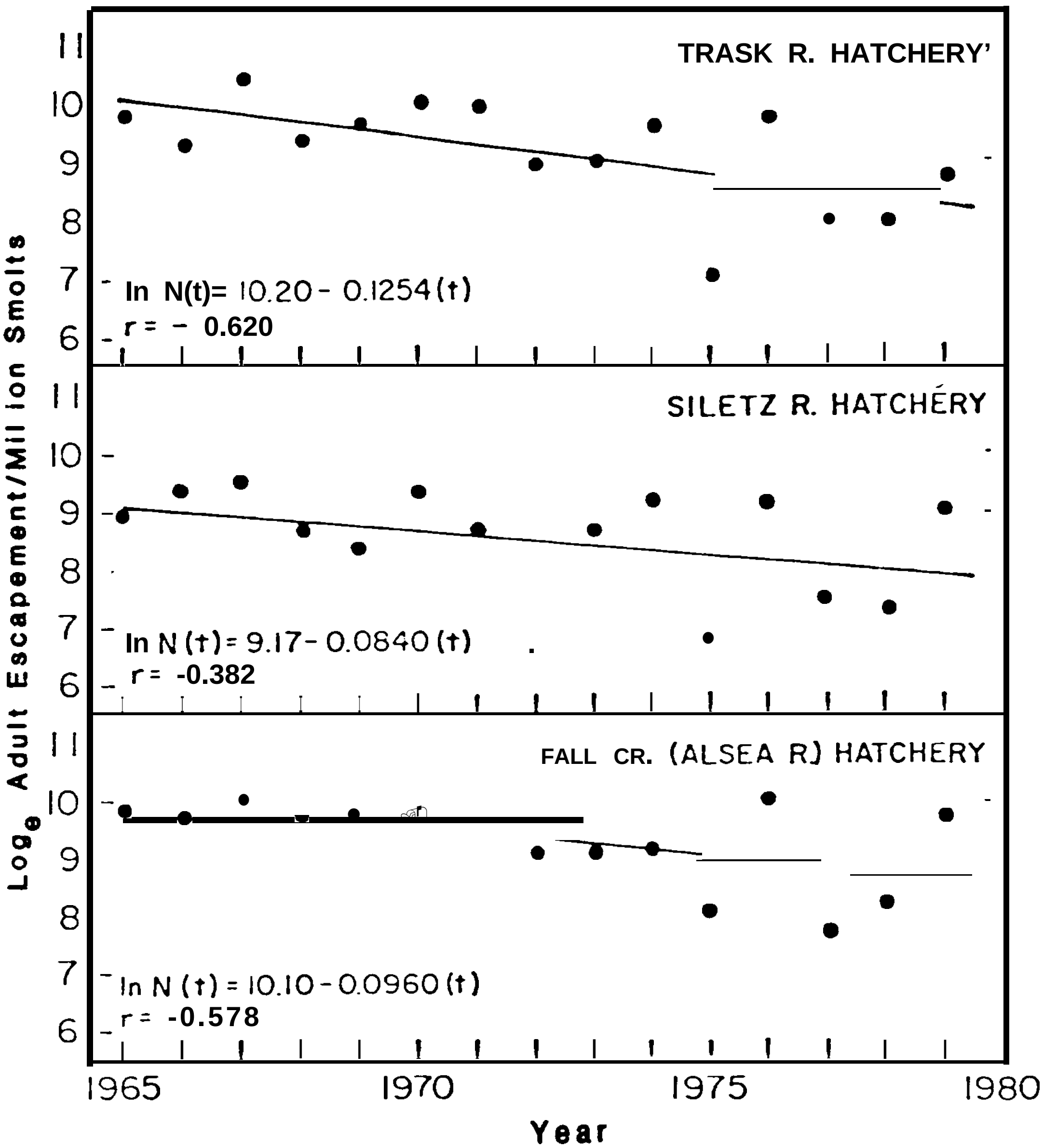

Figure 3. Trends in the escapement of adult coho salmon per million smolts to Trask, Siletz, and Fall Creek (Alsea River) batacheries, **1965-79** (from Oregon Department of Fish and Wildlife 1982).

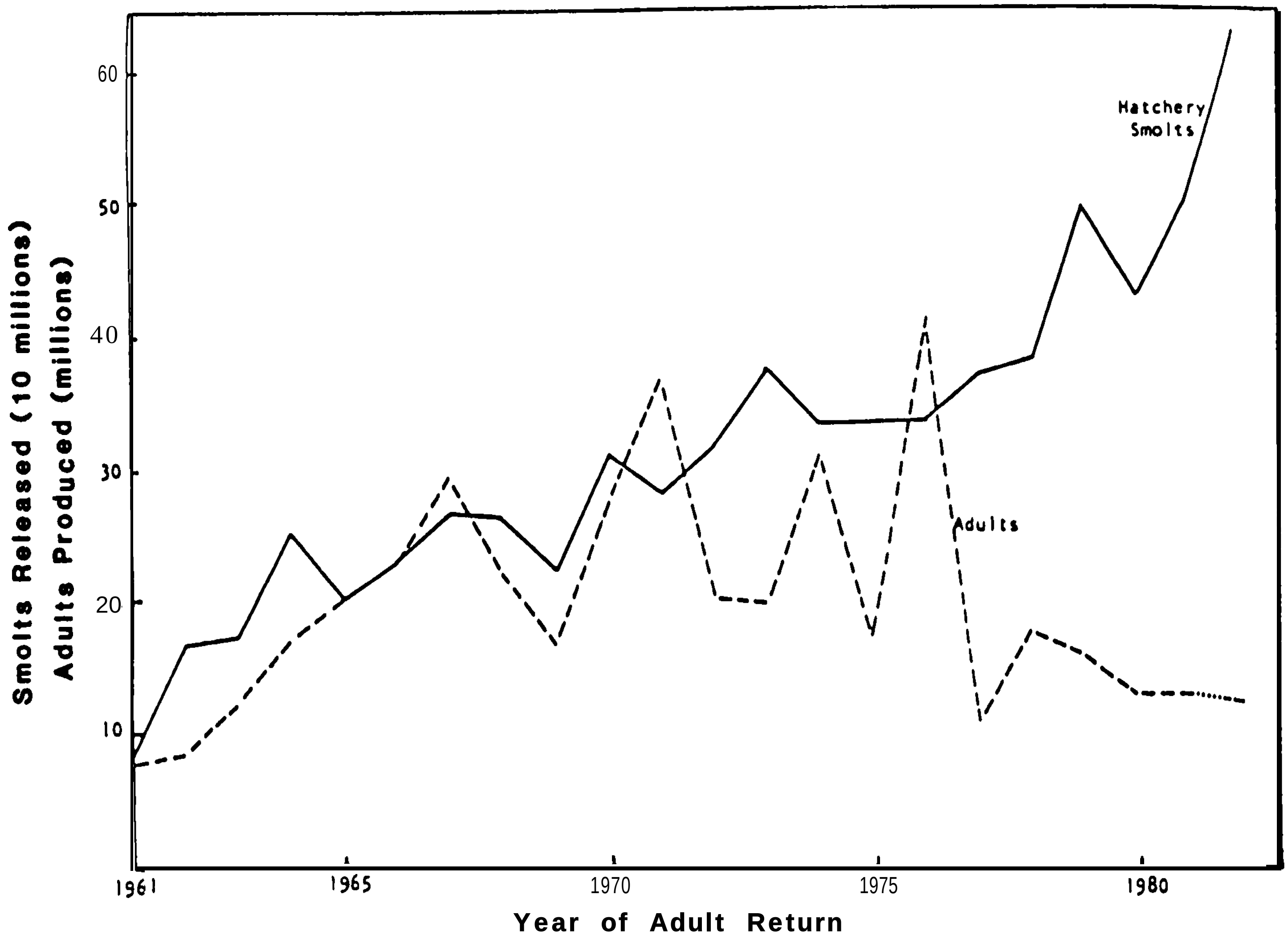

Figure 4. **Comparison** of coho salmon hatchery **smolts** released and wild and hatchery adults produced in the Oregon Production **Index area** 1 year later. Dotted line for 1982 is a preliminary estimate (after Oregon **Department** of Fish **and** Wildlife 1982).

The declining trends in return of spring chinook produced in hatcheries are similar to trends described for coho salmon, trends that have been the subject of intensive study by the Oregon Department of Fish and Wildlife (1982). Their investigations (see Figure 2) showed that the same trends existed for fish in coastal streams (see Figure 3) as well as for fish in the Columbia River. These trerds were occurring while the number of smolts being released continued to increase (see Figure 4), and in association with harvest levels that approached or exceeded the highest catches previously recorded (see Figure 5). Cregon researchers set out to test several hypotheses that were proposed to explain these trends. They concluded that both density-dependent and density-independent control of numbers were occurring in the ocean. Hypcthests concerning smolt quality (including disease, nutrition, loading densities, time of release, genetic diversity, and quality control), loss of natural production, :he predominance of a declining Columbia River program, and density-dependent morrality in the river or estuary were a!! rejected as possible explanations for the declining trends when their analysis was complete.

Although there may be persistent doubt among some people ccncerr:Ing conclusior:s of lImited resources in the ocean for salmonids, and the sponsors of this workshop may has-e only minor interest in these probiems, the data provide no basis for confidence that programs to increase the number of coho or chinock smolts produced in the Columbia River are prudent actions. If Oregcn's researchers are correct, efforts to increase smolt quality may have to include production of fish that have a distinct advantage over fisn produced elsewhere, in order to obtain a disproportionate share of Limited resources. In this scenario, more fish would reduce survival of ail other groups, especially others from the Columbia River system, and may affest some grouos more than others. Thus, increased smolt production may result in no additional adults--but only a different distribution within the Columbia River system--and would decrease the survival of all smo!ts. Such a strategy for obtaining a dispropcrcionate share of available resources is not likely tc be acceptable, and it would not be consistent with the Councii's desire to ensure that artificla l propagatlan activities be fully integrated with natural fish production objecttves.

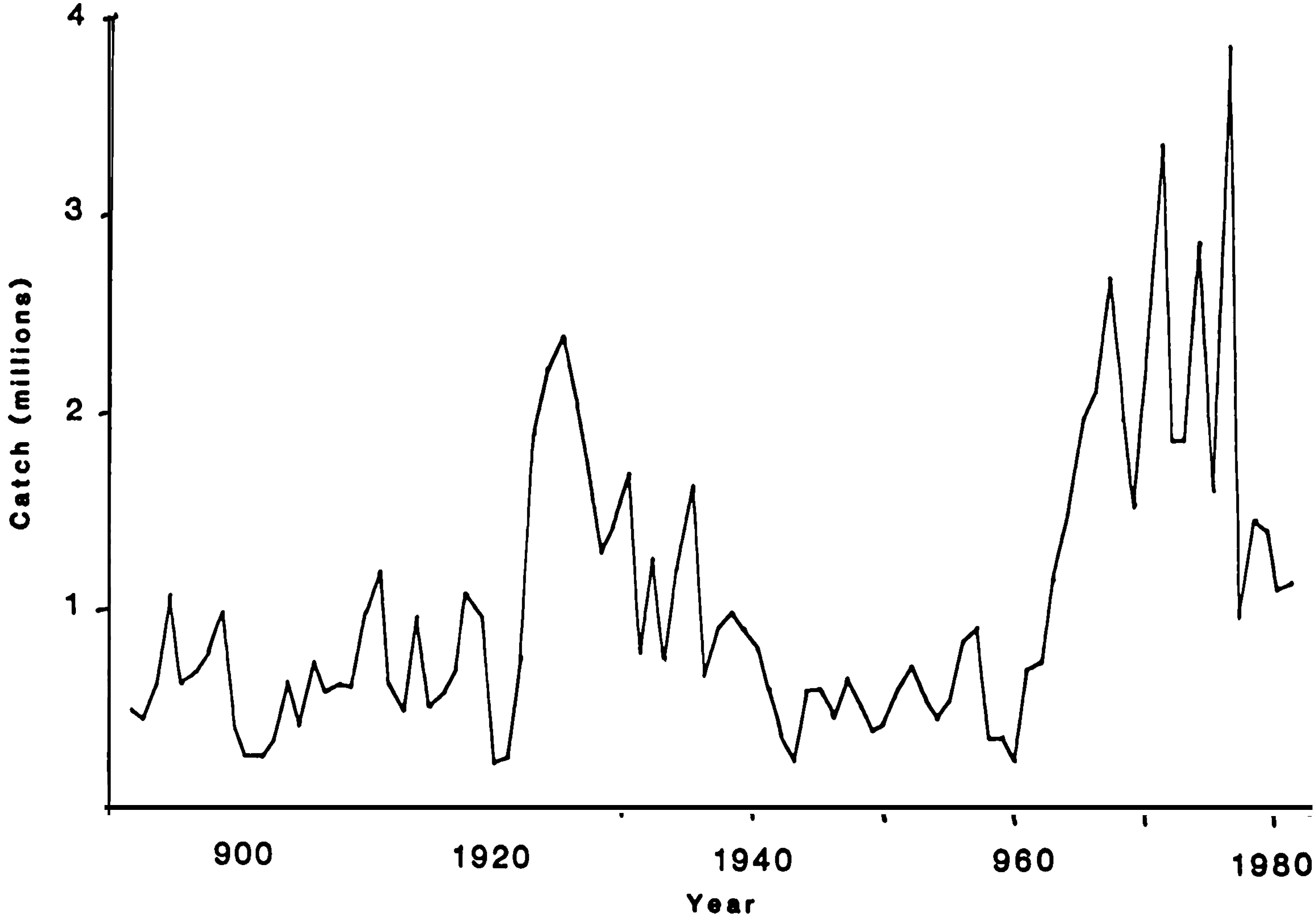

Figure 5. Catch of coho salmon from the Oregon Production Index area from 1890 to 1981.

What does such a scenaric leave open for the Council's Program? Three courses cf action seem apparent. First, the Council could ignore the trends that Indicate that the ocean is limiting production possibilities for at least some saLmonids and hope that continued investigaticn of hatchery practices and smolt quality will again Froduce the glories of the past. I think, however, that technical advisors to the Council have to be careful that they are not encouraging what Richard Feynman, Nobel prize winner from California Institute of Technology, recently referred to as "cargo-cult science" (U.S. Sews and World Report, March 18, 1985). Dr. Feynman's story was:

> "in the South Seas, there is a cargo cult of pecple. During World War II, they saw airplanes land with lots of goods and material, and they want the same thing to happen now. So they've arranged to make things that look like runways, put fires along the runways, made a wooden hut for a man to sit in, with two wooden pieces on his head like headphones and bars cf bamboo sticking out like antennas--he's the contoller They wait for the airplanes to land. They're doing everything right. The form is perfect. But it doesn't work. so I call these things "cargo-cult science" because they follow all the apparent precepts and forms of scientific investigation, but they're missing something essential ."

Secondly the Council could; (1) put a moratorium on all actil:ities that depend cr. whether production possibilities are limited; and (2) reprogram their resources to finding out what the management possibilities really are. Such an effort is likely to require several years tc acccmpllsh and probably depends on unprecedented interagency cooperation.

Thirdly the Council could conc lude that as many or more smolts enter the oceam mow from the Columbia River as at any time in the past, and direct its at tent ion tc redistributing the smelts produced in the system. It will be difficult to obtain generally acceptable estimates of previous smolt production by each stock in each significant basin and equally difficult, to make reasonable estimates of the natural productivity that remains therein.

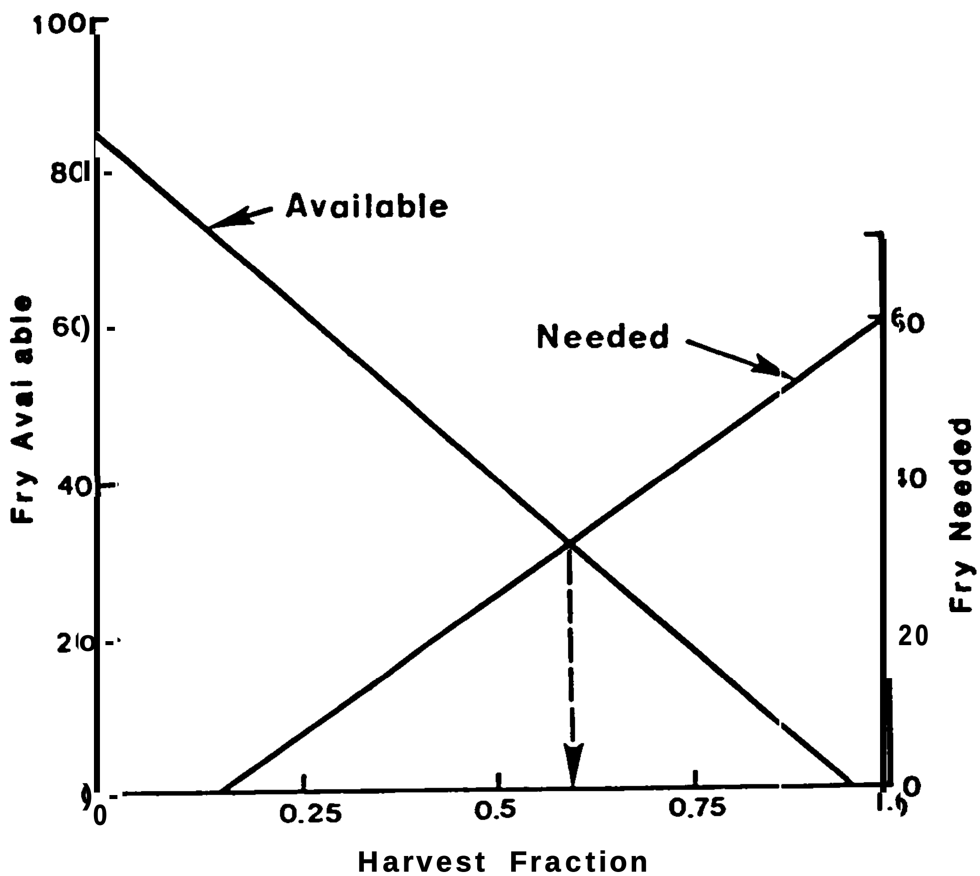

Figure **6.** Conditions for equilibrium **between** fisb available **and** fish needed for **outplanting.** Units are arbitrary. Figure is from **McIntyre** and Reisenbichler 1985.

Unfortunately an extraordinary feat of diplomacy would be required to reduce smolt production in lower river hatcheries and to reserve the unused capacity for propagation of upper river fish. Yet this seems to be the strategy both in the Council's Program and in the guidelines that the Council has developed relative to natural production and overcompensation.

Since there has been no apparent commitment by the Council to one program direction or another, I am going to proceed on the assumption that the third option, or some variation of it, will be the direction that the Council finally adopts. This assumption gives me a basis from which I can attempt to identify some of the program needs, and thereby identify the qualities that hatchery produced fish should exhibit.

My hypothetical version (third option above) of the Council's Program requires a reduction in smolt production from lower river stocks and reallccation of the space for production of juveniles from upper river stocks (including the Snake River). Actions in each "significant basin" of the upper river would include outplanting of fry to bring natural production up to, or near, levels needed for maximum production. Smolts from the appropriate stocks that are produced in new or reprogrammed hatcheries would also be stocked in the waters of each basin. Smolts would be stocked in quantities sufficient to ensure that the basin's contribution to the total smolt population entering the ocean is that which would be possible at present if there were no hydroelectric facilities.

Outplanting need and hatchery capacity requirements can be estimated frcm the capacity of a basin for producing fish and from the expected number cf recruits from the spawning population (see Figure 6, from McIntyre and Reisenbichler 1985). Successful integration of artificial and naturai production systems requires production of hatchery fish that can be substituted on a one-for-one basis for fish produced in nature. This is because hatchery fry used to supplement natural spawning will increase density-dependent mortality rates and displace the fry from natural spawning. Smolts produced in hatcheries will also be expected to return and become part

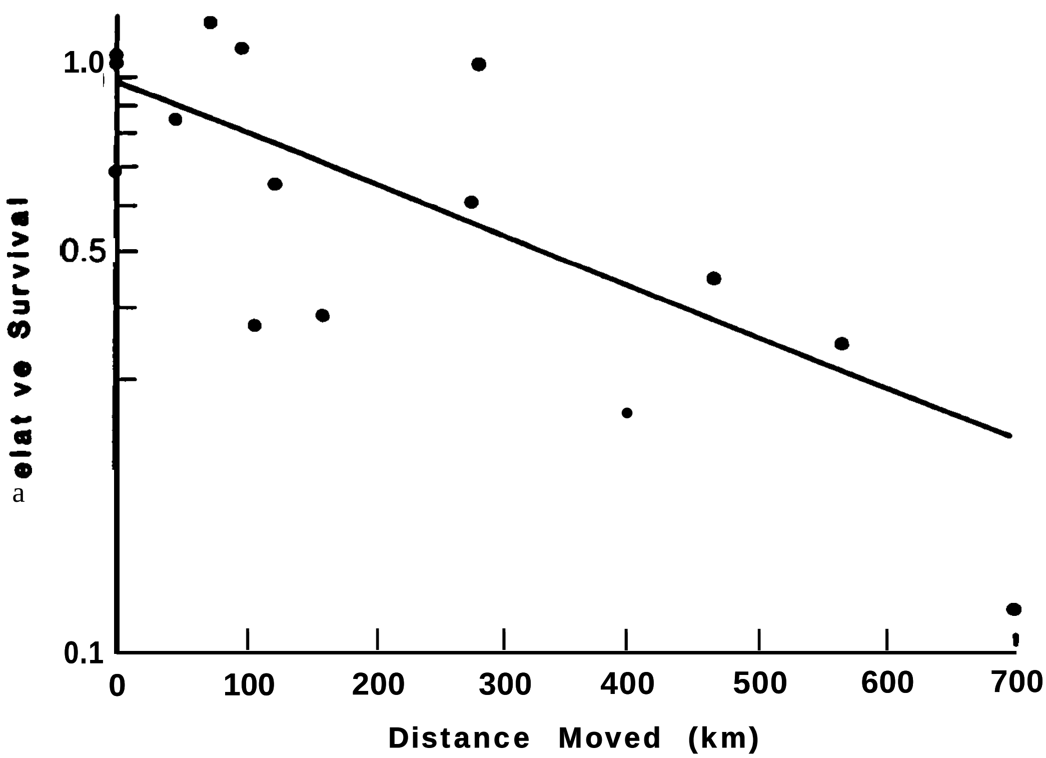

Figure 7. Survival of transferred coho salmon divided by survival of local salmon reared in the same hatchery and released at the same time and location vs. distance between stream mouths for transferred and local stocks.

of the natural spawning stock. All of the smolts produced from this integrated production system will enter harsh and variable environments, both in the river and in the ocean. My view of the task confronting this Workshop is to outline the information needs for producing fry and smolts that can meet these requirements effectively.

SMOLT QUALITY

Smolt quality, it seems to me, is generally thought to be a characteristic of individual fish. I'm sure that release of healthy, strong smolts enhances their probability for survival in nature, but quality is more. Quality can also be viewed as a trait of a population. A population is a collection of individuals, each with its own genotype. In an environment such as that which the Columbia River or the ocean provides, variable conditions are the rule rather than the exception. We should also expect variation in the gene pool among the adult fish produced each year. If ocean conditions in recent years have resulted in density-dependent mortality, there has probably been a natural selection for individuals that tend to be aggressive, and compete effectively for the available food or space resources, or otherwise make effective use of marginal habitats. In ocean conditions that apparently existed in the 1960s) natural selection favors individuals that tend to flourish when resources are abundant. Unless environmental conditions are harsh enough to threaten the existence of a population, there is a tendency to "reshuffle the genetic deck" during spawning and to replenish the diverse gene pool that characterized the parental spawning population. Because we cannot predict the conditions that smolts will encounter, a population of smolts has to be "ready for anything". The populaticn should include a diversity of phenotypes which have not been affected either by artificial selectin of :heir parents, or by husbandry practices that have seiectively removed some phenotypes. I know of no way to measure this aspect of quality prior to their release.

Although we may not be able to measure this kind of quality, brood fish from the local stock can be used to ensure that gene complexes produced from adaptation to local conditions are present in the hatchery stock. When local fish are not available, fish from locations in the immediate area should be obtained so as to minimize the costs associated with the use of remote stocks (see Figure 7).

Many methods, both qualitative and quantitative, have been explored to determine whether the individuals in a population are "strong and healthy". The logical strategy here is to provide a rearing habitat that results in strong and healthy smolts, who have not been subjected to selective breeding or non-random mortality factors.

Under the scenario described earlier, smolt quality cannot be evaluated in terms of some preconceived standard of survival to adulthood unless the effect of density can be removed. Smolt quality in one hatchery, however, can be evaluated by comparing its production rate for adults to those of other hatcheries managed by similar criteria.

RECOMYENDATIONS

I encourage the participants of this Workshop to keep the Council's intentions clearly in mind as you progress in your deliberations. Although the Council has not presented any specific goals, their intention is to develop a program to compensate for fishery benefits lost because of hydropower development and operation. This does not necessarily mean that they want to increase the total number of smolts produced from the system. An increasingly stronger case is emerging that it may not be possible to increase the population of adults even if this were desired. Also, the Council has made a commitment to integrate natural and hatchery fish. That fact alone provides direction regarding the nature of the smolts which should be produced to assist their Program.

Smolts produced from a system which is managed both for natural and for artificial production, should be poorly adapted to conditions in the hatchery environment (Reisenbichler and McIntyre 1985). Adult return rates from fish managed to prevent adaptation in the hatchery, may not be as high as those which may sporadicaliy occur when adaptation to the hatchery (for part of their life-history) is permitted to occur. But hatcheries managed according to the latter strategy cannot be considered to be gene conservation hatcheries and should not be viewed as sources of fish for effective supplementation of naturally spawning stocks.

The following is a series of recommendations that I encourage you to consider during the workshop.

1. The Council's program refers to "increasing survival to adulthood" in several of the elements associated with Section 704. Your findings may be taken as recommendations that will produce increased survival unless you are careful to state otherwise. Unless you have a data source to show that it is possible to increase survival to adulthood, without having a negative influence on fish produced elsewhere, I encourage you to counsel the sponsors that survival rates appear to be limited primarily by factors remote from the hatcheries.

2. I encourage you not to get trapped into thinking that some (yet-to-be-announced) goal stated in terms of escapement or recruitment can be attained by producing a greater number of smolts.

3. I encourage you to consider that the fish to be produced in hatchery outplanting programs will be replacing and displacing fish from natural production. The "optimum" fish, from a genetic perspective, in a smolt program that is not gene conservation-oriented (i.e., one that produces fish that are highly adapted to a hatchery) are not the fish to be used in outplanting programs.

4. In that it may be possible to produce the same number of smolts from fewer eggs, I encourage you to consider the issue at hand as one of increasing efficiency, and attempt to develop recommendations for obtaining information to improve egg-to-smolt survival by means that are non-selective and that do not inhibit the migratory responsiveness of the smolts produced.

5. I encourage you to consider that smolt quality is, in large part, a population trait, and smolts have to be "ready for anything"--that gene complexes in favor this year may well be in disfavor next year.

REFERENCES

McIntyre, J.D. and R.R. Reisenbichler. 1985. A model for selecting harvest fraction for aggregate populations of hatchery and wild anadromous salmonids. (In press). American Fisheries Society.

Northwest Power Planning Council. 1984. Columbia River Basin Fish and Wildlife Program. Portland, Oregon.

Oregon Department of Fish and Wildlife. 1982. Comprehensive plan for production and management of Oregon's anadromous salmon and trout. Part II. Coho Salmon Plan. Fish Division, Anadromous Fish Section. Portland, Oregon.

Reisenbichler, R.R. and J.D. McIntyre. 1985. Requirements for integrating natural and artificial production of anadromous salmonids in the Pacific Northwest (In press). American Fisheries Society.

IMPLEMENTATION AND MANAGEMENT ISSUES

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It is a pleasure to be at what has already been described this morning as a rather important workshop. It is important to researchers and fisheries managers for some obvious reasons. But I also think it is important because we are describing some of the reasons why we, the fishery agencies and tribes who have resource responsibilities, need to get our act together a bit more. We need to improve the way that we deal with Bonneville and the Power Planning Council, entities that clearly are becoming major actors in the whole arena of salmon and steelhead management and restoration.

This is an important workshop because fish culture practices are going to have an important effect on how runs are rebuilt and how wild fish survive in competition with other stocks produced through new hatchery development. Most of the smolts leaving the Columbia River are now produced in hatcheries. I think it is likely that hatchery production is going to increase faster in the Columbia Basin in the next few years than is wild production. For example, Jack McIntyre mentioned this morning that the Lower Snake River Compensation Plan is scheduled to begin producing very substantial numbers of new stocks of hatchery fish in the Upper Basin.

The first salmon hatchery was built in the Columbia River in 1876, and in the next year produced about 300,000 chinook fry. By 1918, the hatcheries in the Columbia River broke the 100 million fry release barrier, and by 1919, total harvest of fish in the Columbia Basin had reached its peak. I think when you average out all the peaks and valleys since then, harvest has been on a rather steady decline to the present day.

Columbia River hatcheries for the past 25 years or so have produced from one half to two-thirds of the total releases of hatchery fish on the Pacific Coast, and this situation prevailed, I think, until production began at the large-scale aquaculture facilities in Alaska. So for 100 years, hatcheries have been a very important part of fish management in the Columbia Basin.

I want to read a paragraph out of a July 1937 report by Frank T. Bell, Commissioner of the Bureau of Fisheries, reporting to the U.S. Senate on problems with adult passage at Rock Island Dam and discussing some of the fish facilities planned for Bonneville Dam, which was then under construction. He said that in 1885, G. Brown Good, the second united States Commissioner of Fisheries, expressed his confidence in artificial propagation in the following words:

> "Here the fish culturist comes in with a proposition that it is cheaper to make fish so plentiful by artificiai means that every fisherman may take all he can catch than it is to enforce a code of protection laws. The salmon rivers of the Pacific Slope, the shad rivers of the East, and the white fish fisheries of the lakes are now so thoroughly under control by the fish culturists that it is doubtful if anyone will venture to contradict his assertion.

Commissioner Bell then went on to say:

> "How ill-founded was his [Gocd's] faith in the all-effectiveness of fish culture in maintaining or restoring the fisheries in the face of ail possible destructive influences may be seen by the fate of the three great fisheries he chose as illustrations. The salmon fisheries of Puget Sound have decreased alarmingly, and even the Columbia River fishery has been affected, as we have already seen. The shad fisheries of the East coast have declined on the whole to one-fourth of their abundance in 1896, and the white fish fisheries of the Great Lakes are facing certain ruination from overfishing.

Well, clearly by 1937, hatcheries were not the cure-all for overfishing or loss of habitat.

The essential feature of the workshop, I think, is to set some priorities for how to use fish hatcheries to contribute to the restoration of runs in the Columbia Basin. The careful selection of the attendance at this workshop, I suppose, has weeded out those who would say the best option is "none of the above". But in my view, the potential we have with hatcheries is certainly so great that we cannot afford not to look carefully at what we can do with them. For example, the 1978 brood of fall chinook released about 90 million fish. Three years of harvest data that we have on those releases shows an average of about 2.7 per thousand contribution to the fishery. There were about 23 hatcheries cooperating in those releases. The average contributions to harvest ranged among hatcheries from 0.1 fish per thousand released to 8.4 per thousand. The range between individual groups released was from 0 to 16.3 per thousand. So we have a very wide range of performance within which we can work. We know that some hatcheries and some stocks of fish, for some reason, perform much better than others. I think it must be within our capability to understand what the reasons are for this variability, and to develop the means for improvement.

So, what would it take to double the harvest of fall chinook from the Columbia River? Well, there are two approaches: First, we can double our hatchery capacity. If we added 5 1/2 Spring Creek hatcheries, we could just about double the releases. Spring Creek was reconstructed in 1970 at a cost of about $8 million. If we multiply $8 million by 5 1/2 and multiply the product by the construction cost index since 1970, we'd have about a $150 million investment---not considering land and water acquisition.

Or, we could double the efficiency of the existing hatcheries. That would only require that we increase the average contribution of hatcheries to about 1/2 of 1 percent. I can't imagine that it would take $150 million worth of effort to do that. But then, maybe even $150 million wouldn't do it. Maybe money is not the problem. My own view is that it should not take a great deal of money to improve hatchery efficiency, because I’m not convinced that we’re effectively using the knowledge and data that we already have.

What are some of the things that cause some hatchery releases to contribute more efficiently than others? For example, we have 13 releases of upriver bright fall chinook scheduled this year. Some of these are yearlings ranging from 7 to 20 to the pound scheduled for release over a period of about 80 days. Some are sub-yearlings expected to be 60, 70, 85, and 120 to the pound, scheduled for release over a period of about 40 days. In total we have more than a dozen releases of upriver brights, totaling 17 million fish, and it would be a very powerful experiment if all of those releases and all of the differences in fish culture leading up to those releases were organized in a thoughtful, carefully prepared experiment. Our tule fall chinook are scheduled for release over a LOO-day period this year, and it would seem that with 100 years of experience with tules, we should be targeting on a set of conditions a little bit .more specific than what occurs over a LOO-day period.

So what really determines what we are looking for in terms of time and size of release? It has been a long time since I’ve heard anyone admit to a “thinning release”, but is there still a subliminal drive to maximize production from our hatcheries in terms of numbers or pounds of fish released? How does this drive for quantity, if indeed I’m not being overiy cynical, affect survival of fish after release? Well, I’m just asking questions. Obviously, if I had the answers, I’d be in a different part of the program. As Jerry Bouck said, I was to be the “designated rabble rouser,” and I’ll do my best.

I don't know whether we're making a regular use of hormone injections to advance the spawnign time of spring chinook both to reduce mortality in the adult pond, and to increase the time availab!e for rearing the offspring from those fish. I don’t know whether after experiments have shown improved survivai with salt additives to the diets of fall chinook, if those stations are continuing to use it on a regular basis. I don’t know whether ponds are not covered with caaouflage netting because it interferes with feeding, or because the evidence showing that there was a reduction in stress when the fish were afforded some kind of cover was found to be flawed, and that therefore providing shelter is not good hatchery practice.

From the management point of view, it is very important to know whether or not we are making the best use of the data that we already have. Are we fully exploiting information that suggests--or sometimes shows clearly--that we can make improvements in the return of fish? Perhaps we should not measure success of a hatchery solely by its contribution to a fishery, but somehow that still seems to me to be the bottom line--especially if we are going to be looking at cost effectiveness as one of the parameters of the Fish and Wildlife Program. There is a larger problem than just the availability of data or the completeness of the data, and that is how well we are using the data. One of the important criteria for prioritizing program initiatives has got to be whether or not we're able to ensure the utility and the applicability of the results of the projects that are funded. You've got to consider all of the aspects of the problem that you're proposing to address, and not all of it has to do with fish biology.

At the Marine Recreational Fishing Symposium last month, there was a panel on certain aspects of this question--on policy and implementation. Fisheries management in the Northwest was described by one speaker as being poorly coordinated, ineffective, and fraught with intra- and inter-agency breakdowns in communication. He suggested that a top priority in any effort to improve fisheries management, would be an interjurisdictional information system that could bring operations and the results of operations into the sunshine. That seemed to me to be a reasonable point to make. It's certainly not the only thing that needs to be addressed, but it's a good place to start.

In order to get the best utilization of our findings, the information has to be readily available to everyone. The results of using those findings in a hatchery on a production scale has to be readily available, along with all of the parameters that were adjusted or that affected the life history, the rearing, and the release of those fish. There has to be follow-up to evaluate whether the translation from the experimental regime to the production regime gave the same kind of results. Now that's just common sense.

We need a common data base on all of the brood stocks in all of the hatcheries. We need carefully recorded, consistent data on disease, diets, a variety of physiological parameters, and the contributions of each stock to the fisheries. We need financial data on what it is costing us to produce these fish.

A full array of hatchery environmental data has to be recorded, and then we need a somewhat equal array of data on the river and the estuary, and the near-shore ocean environment where there is a lot of evidence that something happens that affects our returns. If we had some predictive capability on things that affect survival during early ocean life, perhaps in time we could become sufficiently sophisticated in our hatchery management practices that we could adjust the time of arrival at the estuary of at least some of the fish so that they will hit those optimum conditions out there.

Agreeing on a definition of smolt quality and some of the measures of smolt quality is a fundamental step that we have to take, in order to set up an information system that's going to be so crucial to making the whole thing work.

Before I close and we get on to the next stage of the workshop, I want to leave you with a note of caution. I think you have to recognize that this workshop is simply one step in a process. I don't think we should approach what we're going to do here just in terms of finding short-term or long-term solutions to problems. We should realize that this is part of a continuum--a process--and the objective really is to improve our capability as researchers and managers to participate in a very complex resource management process. We've got to recognize that as always we'll be discovering more questions than answers to questions, and so it's important that we begin here in a very thoughtful manner and build a good foundation for continuing in this process. I think that concludes all that I can do here to help get you started.

2.2 USE OF SMOLTIFICATION INDICES

Seawater Challenge Test/Time of Release Studies (W.C. Clarke)

Smolt Indices and Migration (W. Zaugg)

Smolt Indices and Adult Survival (R-D. Ewing)

Endocrine Testing (W. Dickhoff)

SEAWATER CHALLENGE TEST/TIME OF RELEASE STUDIES

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This paper will present some of our results with a smolt indicator, the seawater challenge test, and its relationship to the results of a time- and size-of-release experiment conducted by Tom Bilton and Bruce Morley. The experiment was conducted in a production hatchery, the Capilano Hatchery, just outside of Vancouver. I will talk a bit about the seawater challenge test and about the experimental design of the time and size to release studies, and also about the way that these data have been analyzed using response surface analysis. I want to emphasize this approach more than the conclusions. The response surface analysis is preliminary, since the tag return data are incomplete.

Figure 1 shows Vancouver Island and the two production facilities used in the work, Capilano and Quinsam, and also the Rosewall Creek Hatchery, our research facility. Bilton first started working on the time and size question at the Rosewall Creek Hatchery, and after finding an interesting result--that the size of coho at release and the time at which they are released had an important effect on adult survival--he then extended the work to regular production facilities to get an idea of the variability involved.

This paper will present only the experiment that was done at Capilano Hatchery. The types of information that were collected at the time this experiment was done are presented in <u>Canadian Data Report of Fisheries and Aquatic Science No. 347</u> (1982). This does not include the return data, but it includes the various measurements that were taken on the fish prior to release, and describes how the experiment was conducted.

Figure 1. Vancouver Island, British Columbia, with hatcheries where snoltificatioo research has been conducted.

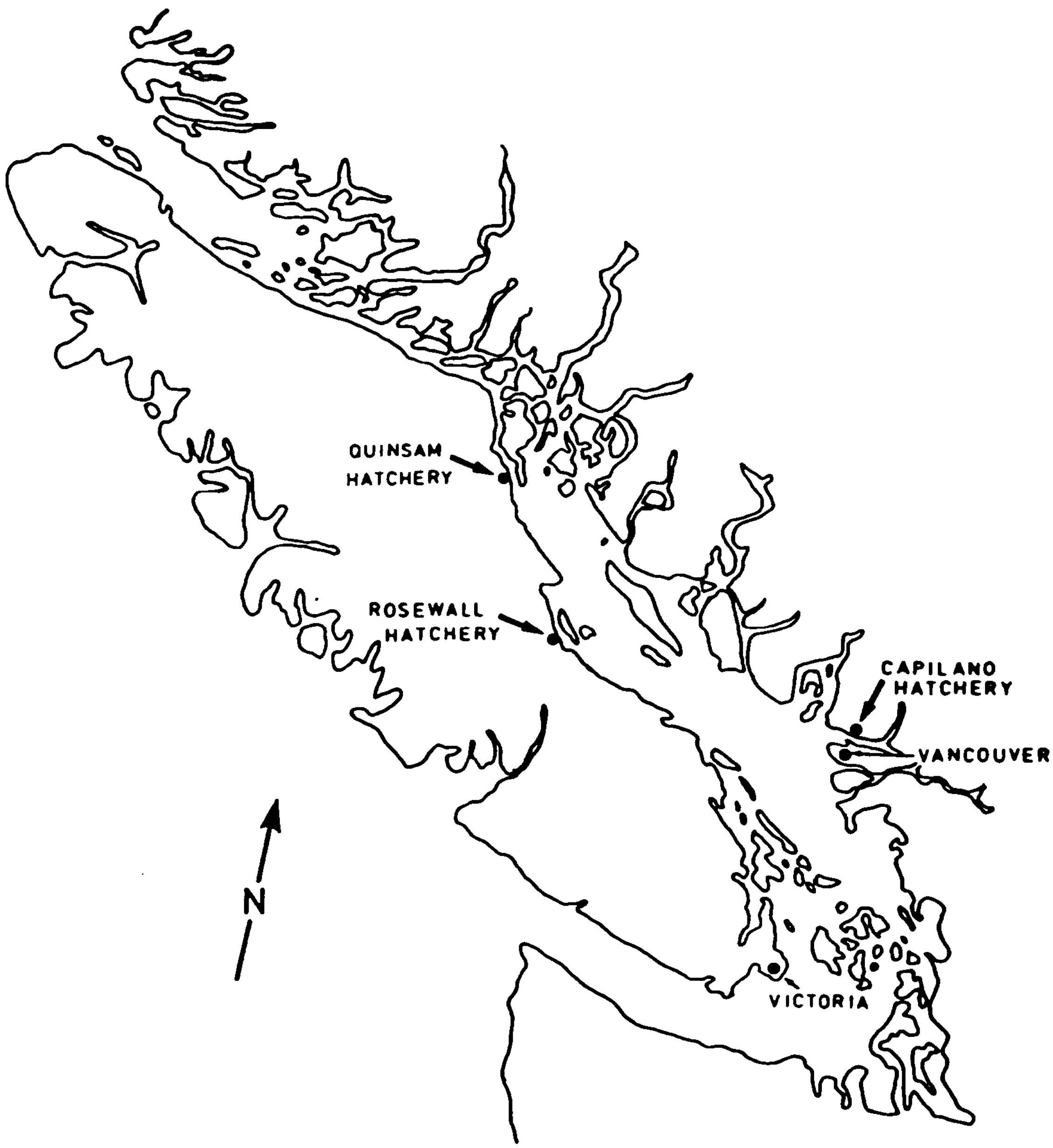

QUINSAM
HATCHERY
ROSEWALL
HATCHERY
CAPILANO
HATCHERY
VANCOUVER
VICTORIA
N

Figure 2 is an outline of the experimental design used in these time and size studies. There is a matrix of four release dates and three release size categories. The specific dates vary a little between studies: April 14 to July 9 is the range for all of the studies, but in this particular study, there were four releases: May 7 and 28, June 18, and July 9. In this experiment, the three sizes were achieved by rearing three groups at different temperatures during incubation from the eyed egg stage through to hatch. Beyond that, they were fed more or less on a routine feeding schedule with Oregon Moist Diet. This resulted in a different mean size in each of the three Burrows ponds. Three tag codes were used on each size category to provide replication on estimates of survival rates.

The experiment was also used to get some information on our smolt indicator. We've done a lot of laboratory work on the seawater challenge test, and we've also used it in conjunction with our pilot-scale net-pen culture studies. In this work, it is possible to see a correlation between the ability of, for example, coho salmon to osmoregulate when given an abrupt challenge in seawater and their ability to grow subsequently in seawater. Of course, in a hatchery release situation, there are a lot of other variables involved. It is appropriate to ask whether something that provides a reasonable index in the more controlled situation is of value in the highly uncontrolied situation of releasing fish into a river for subsequent ocean migration. we undertcok to sample fish from Bilton's release groups through the period leading up to release, as well as for some groups beyond the time of release, in order to get a seasonal pattern of seawater adaptability.

Table summarizes the mean fork length in millimeters, the weight in grams, and the sodium concentration in milliequivalents per liter after a 24-hour challenge. The challenge is carried out using a sample of fish transported back to our lab, where they were held for a few days in fresh water to recover from the transportation and then transferred abruptly to seawater by changing a valve. We used seawater of the same temperature as their acclimation temperature. After 24 hours in seawater, we cut off the tail and took a blood sample and diluted the blood plasma for sodium determination.

TABLE 1 PLASMA SODIUM LEVELS AFTER 24 HOURS IN SEAWATER IN COHO SAMPLED FROM CAPILANO HATCHERY, 1981

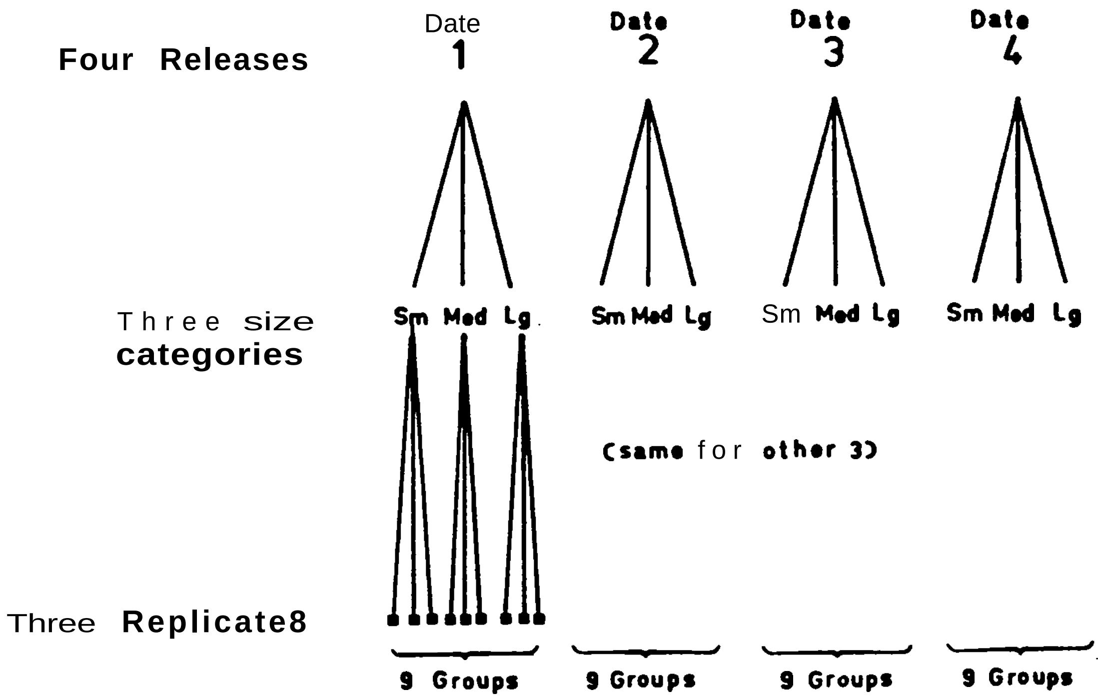
Date	Number	Fork Length (mm)	Wet Weight 63)	Plasma Sodium (meq/L)
30 March	30	112.9 ± 1.7	15.0 ± 0.7	176.8 ± 1.4
	30	114.6 ± 2.9	16.4 ± 1.3	172.6 ± 1.2
	30	119.4 ± 3.5	19.3 ± 1.5	175.9 ± 1.1
24 April	36	106.8 ± 2.2	12.5 ± 0.7	173.1 ± 1.4
	36	123.8 ± 2.8	18.9 ± 1.1	171.3 ± 0.9
	36	133.2 ± 3.2	24.9 ± 1.9	166.7 ± 0.5
15 May	36	110.0 ± 1.8	13.0 ± 0.6	167.9 ± 1.0
	36	117.8 ± 2.8	16.8 ± 1.2	167.5 ± 1.5
	36	137.3 ± 3.6	26.8 ± 2.2	164.0 ± 0.7
8 June	36	115.8 ± 2.4	14.6 ± 0.8	173.3 ± 1.9
	35	126.5 ± 2.9	20.0 ± 1.3	168.9 ± 1.3
	39	145.2 ± 3.4	30.6 ± 2.2	170.8 ± 1.0
23 June	33	123.2 ± 2.4	17.7 ± 0.9	174.3 ± 1.3
	36	134.3 ± 2.5	24.0 ± 1.3	174.5 ± 1.3
	25	155.3 ± 5.2	37.9 ± 3.6	168.9 ± 0.8
LO July	36	130.9 ± 2.2	22.5 ± 1.2	171.6 ± 1.2
	36	143.4 ± 3.6	31.5 + 2.1	170.6 + 1.2
	36	158.9 ± 3.0	39.1 ± 2.2	169.9 ± 1.0
10 August	35	136±1 + 2.9	25.4 ± 1.6	180.2 ± 1.2
	34	148.1 ± 3.6	34.9 ± 2.4	175.0 ± 1.1
	36	158.9 ± 3.8	40.4 ± 2.6	173.7 ± 1.2

Note: Values are mean ± SEM.

In this test, a fish that has a low blood sodium concentration is considered well-adapted to sea water. From Table 1, it is evident that the blood sodium tends to be lower after transfer for large fish than it is for small fish, and there is also a seasonal trend, so that the minimum of blood sodium which represents the best seawater adaptation appears to be the sample during the middle of May. Then the performance deteriorates again. We were fortunate in this case to have had the cooperation of the U.S. National Marine Fishery Service, and at the suggestion of Conrad Mahnken, we took some gill samples, froze them, and sent them down to Dr. W.S. Zaugg for analysis of gill sodium-potassium ATPase. We were able to obtain that information along with our challenge results.

We used the response surface analysis technique because our interest is really in defining optimum conditions. In this case, Bilton was trying to define the optimum size of fish at release and the optimum time of release. A paper in the Canadian Journal of Fisheries and Aquatic Sciences by Schnute and McKinnell (1984) outlines the response surface analysis program developed at Sanaimo and gives some examples of its application.

Figure 3 presents the response surface for the plasma sodium data from Table 1. The response surace is based on individuai values for body weigh: and plasma sodium, whereas the means are given in the table. The weight range, from 12 to 40 grams, encompasses the size range of the fish at release, and the time scale is from late April through early August. This surface is a minimum, with contours descending toward a center that is actually off the top of the graph. You see that the contours open to the top, indicating that after challenge, plasma sodium declines as fish get larger. That trend was evident from the raw data. The dashed line--shown off to the left there--is the date at which blood sodium is minimum. The trend for this line is to the right; release of 40-gram fish gives a slightly later date for transfer than with small fish. There are not many contours in this left hand area around that minimum line--it is rather flat. In other words, there is a broad period over which performance seems to be quite good. Julian Day 131 is May 12, and should give the best seawater adaptation. This may be compared with the



Approximately 4,000 fish released per group

Figure 2. Study design of a time and size at release study, Capilano Hatchery, British Columbia, 1981.

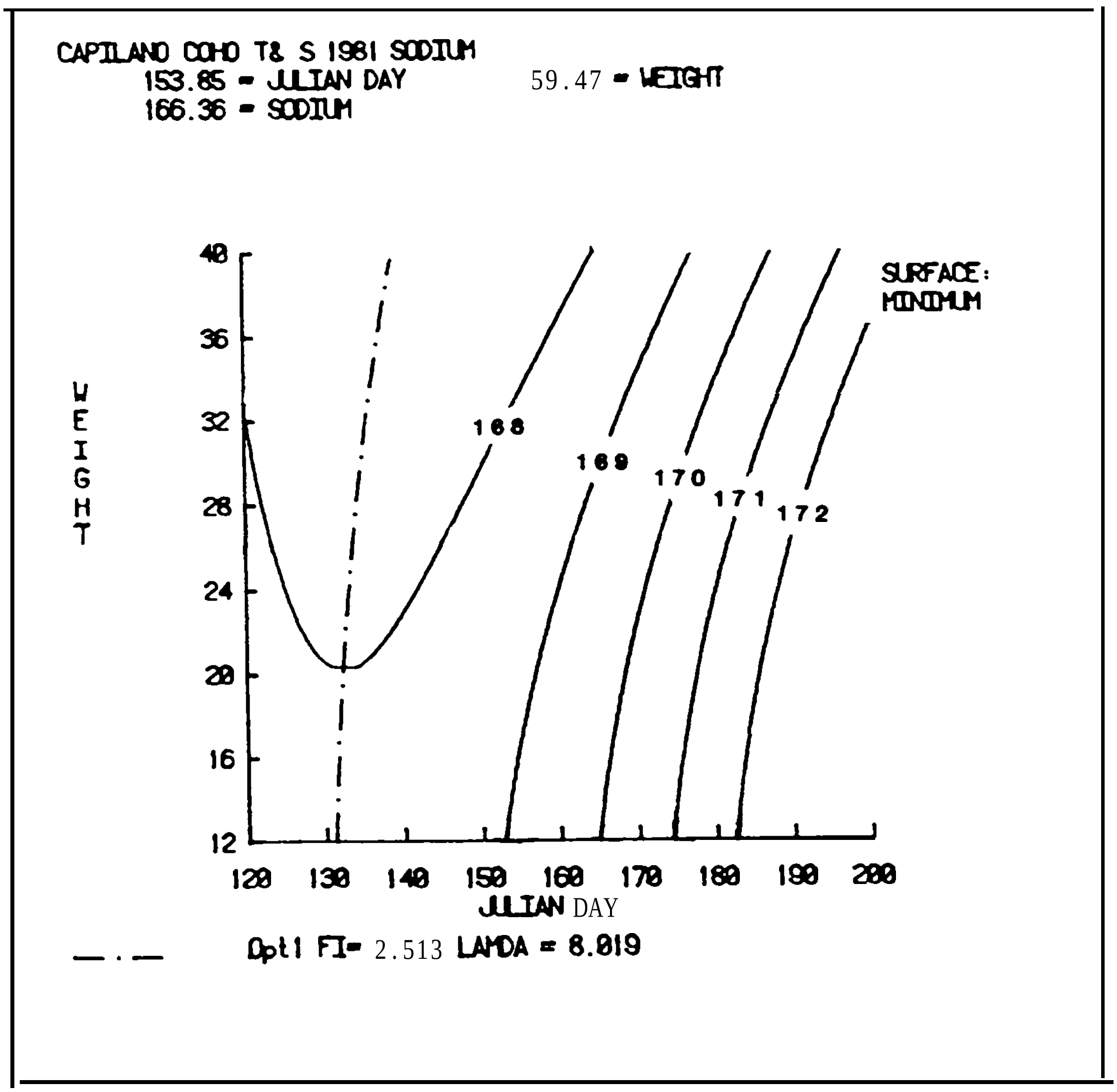


Figure 3. Response surface for plasma sodium concentration in coho salmon of differing sizes and times of release, Capilano Hatchery, British Columbia, 1981.

ATPase surface (Figure 4), which is on the same scale as the previous figure. Note that this shows a maximum rather than a minimum, since the gill ATPase activity is highest at the center. That is one difference. The other is that the contours open downward in this surface, indicating that performance is best in smaller fish. In fact, this suggests optimum or maximum ATPase in fish of 12.4 grams. The optimum transfer date is rather similar to that predicted for sodium. In this case, it was May 20th which the figure shows to be an absolute maximum. But you can see that there is a period of a week and a half on either side of that where it predicts good ATPase levels in smolts, The question then arises, if these are to be the indicators, how do they compare with adult returns? Figure 5 shows preliminary adult return data with a predicted maximum return of 14 percent. The U.S. return data will probably add only about one percent at most, and so should not affect the results appreciably.

The center of the surface is a maximum of 14 percent return on June 1 (Day 151) for fish of 19 grams. The area of 90 percent of maximum return encompasses releases from about May 20 to June 14. Thus, there is a fair period during which you expect to be within 90 percent of maximum return. The size range for 90 percent of maximum return is from about 15 grams to about 24 grams. My interpretation of the information provided by the indicators is that they are anticipating the optimum date of release by 10 or 15 days. In other words, if you release according to ATPase or sodium, you would have released about two weeks before the release experiment itself said that returns were optimal. However, a surprising difference between sodium and ATPase is that they seem to be rather far off the mark in terms of predicting optimum weight. I can't really explain that at the moment, because the sodium data predicted optimum size off the end of the scale while the ATPase data predicted an optimum weight well below the optimum recorded from Bilton's return data. This discrepancy will have to be resolved through further research.

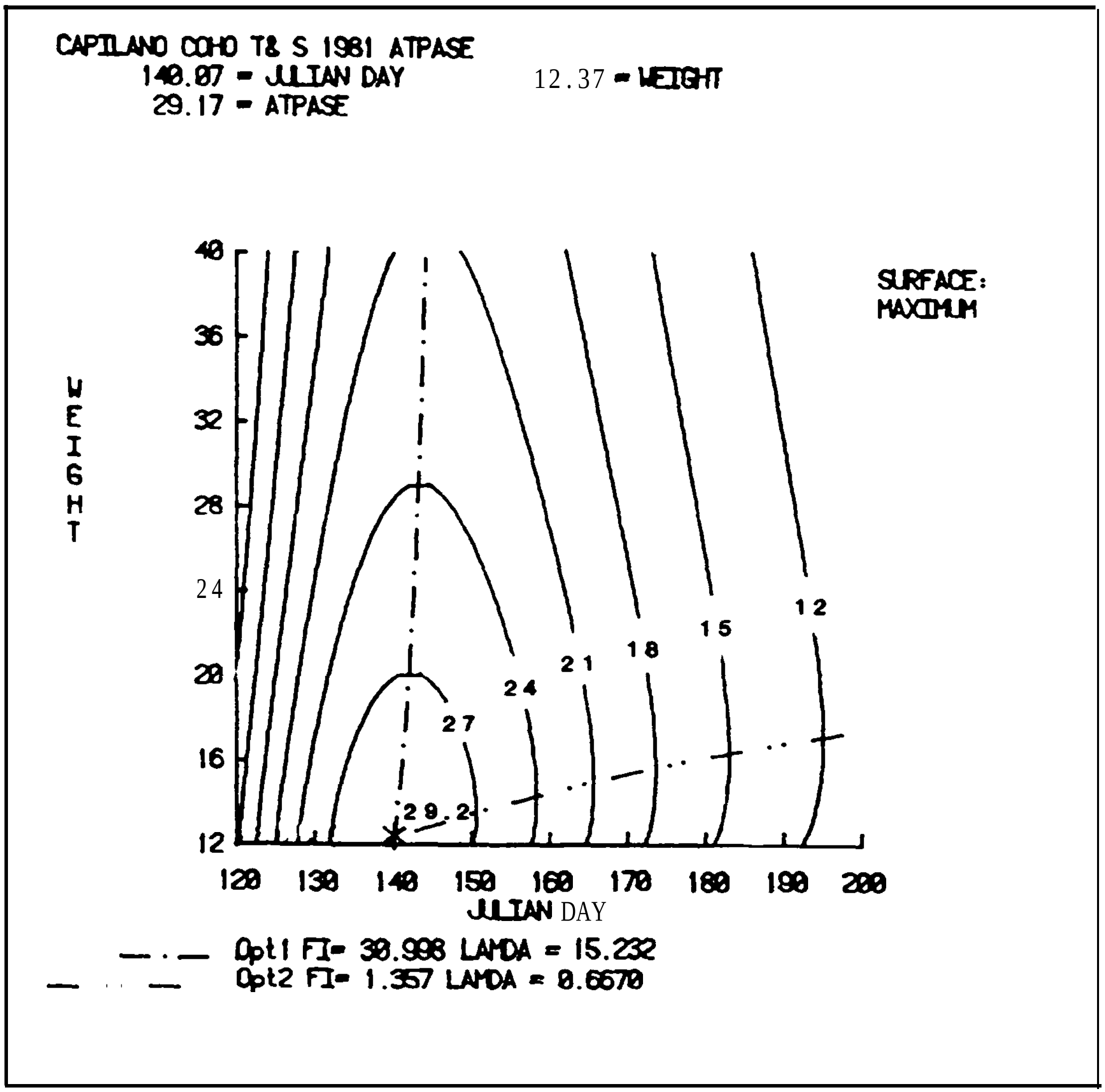


Figure 4. Response surface for plasma **ATPase** concentration in coho salmon of differing sizes and times of release, Capilano Hatchery, British Columbia, 1981.

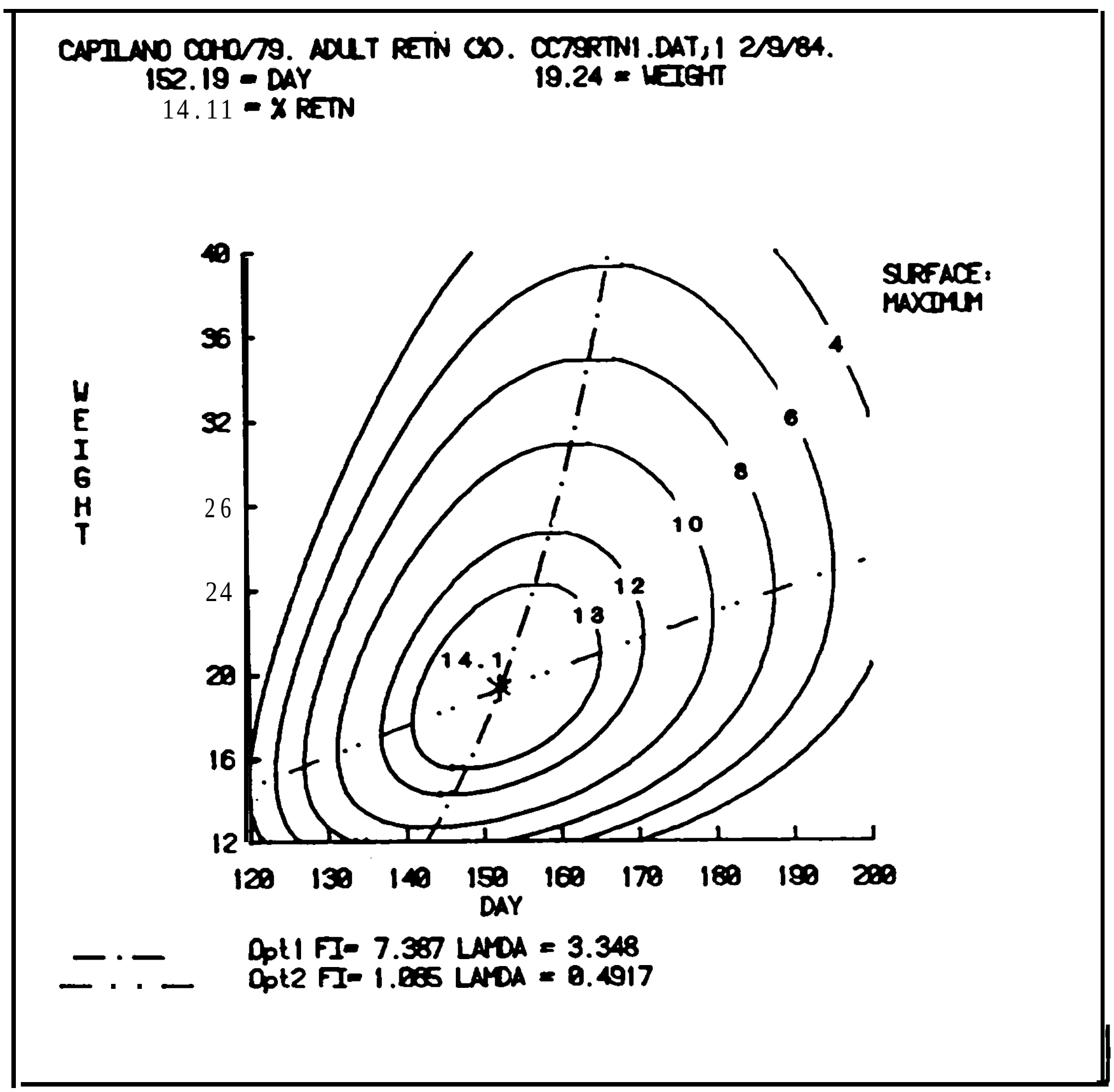


Figure **5.** Response surface for percentage of adults returning of coho salmon of differing sizes and times of release, Capilano Hatchery, British Columbia, 1981.

What I wculd like to leave you with is a research technique that can be used if people want to calibrate a smolt indicator. My own view Is that an indicator has to be evaluated in the contest where it is going to be used--that it is not possible to merely apply something that has been validated in one place in a new situation.

Questions From the Fioor

Q: Is it pcssible that equilibration takes less time in the larger fish because cf a greater volume to body surface ratio?

A: Well, the range of sizes is not that great in this, relative to some species we work with--much smaller fish, such as chinook, or chum, which can equilibrate within the same pericd, although they are a fraction of the size of these fish. These are all rather large; the bulk of them are between 15 and 25 grams. I wouldn't expect that sort of body surface to volume ratio to have that much effect here. It might, if you were comparing fry to very large yearling smolts.

Q: Then as long as the fish are reasonably vel! smolted, can you rule out osmoregulation as being what might be a really major factcr in surviva:?

A: In this particular case, it is not a major impediment to survival; I would think there is a rather broad period over which they were capabie of osmoregulating, so it is not a determinant of survival, but I think it's a correlate. The difference being that I believe that some of these physiological events are coupled internally in the anima!---that is why I call it an indicator. in other words, it's an indicator of the animal's physiolcgical timing rather than a determinant, although I think you might have a situation uhere, for example, the fish were incapable of osmdregulating for some environmental reason, and in that case, it would obviously be a direct determinant, not just an indicator. In this situation. It doesn't appear to be a limiting factor, but there is a correlation. Of course, one of the things I should mention is that we have done a similar type of match-up with Bilton's releases in three other experiments with coho. We want to see how reasonably this correlation holds up to repeated testing. Is it a one-shot coincidence, or are we, in fact, dealing with a reasonably consistent relationship?

Q: Do you have any indication of what variability is from year to year or from site to site?

A: No, we haven't.

Q: I'm wondering just how broadly one can really use this kind of predictor, if, as we heard earlier today, various environmental factors will tend to favor different genotypes from year to year? Just how good is this as a predictor? Will you have to replicate it over a number of years?

A: Yes, that is our feeling. One thing that I was reasonably surprised at was the agreement that Bilton got between his optimum release dates and sizes. He has done them now in two production facilities. My impression is that there is pretty good agreement between the optimum size and optimum time, at both Quinsam and Capilano facilities, which are about 90 miles apart.

Q: What is the basis for saying the saltwater challenge test relates to smoltification, and instead, just doesn't show that larger fish stand the stress better?

A: You see that the performance decayed after the middle of May, and, in fact, the fish keep getting larger beyond that. If it was strictly a matter of body size, it would have continued to improve as the fish grew (off to the right-hand side). This was not the case, so we conclude it was not simply a function of size. In fact, the effect of size is less than the effect of season in coho. My interpretation of that is that most of the fish, the coho in our hatcheries, are well above the threshold size for smolting, and the physiological developments are not highly correlated with size.

SMOLT INDICES AND MIGRATION

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To begin with, I would like to mention three conclusions reached in our research on various measurements of smolt development. Then, with these conclusions in mind, you may be able to see what I am attempting to point out as I go through the presentation.

First of all, I think our research has indicated that for both wild and hatchery fish, the migratory period is used as a time for smolt development. Along with this is the second conclusion: that very rarely, if ever, is a complete smolt developed in the hatchery situation. Our third conclusion is that the degree of smolt development influences the rate of migration. It also influences the horizontal positioning in the river, and there have been some thoughts recently about their vertical distribution. With these points in mind, let me proceed with the material I have prepared.

Gill sodium-potassium ATPase activities in yearling spring chinook salmon from the Leavenworth Hatchery are shown in Figure 1. The lower curve represents activities observed in fish at the hatchery. Some fish were held beyond the release time (arrow) to permit continued monitoring of enzyme activity; we also looked at enzyme activities in migrants captured at Jones Beach located downstream a distance of some 450 miles. Other fish from the same group placed in seawater experienced rapid development of ATPase activity as expected. We did not take samples from Day 7 of seawater exposure to Day 208, but we would have expected enzyme activity to continue to rise beyond that of Day 7 to some higher, stable level. It is interesting that after 8 months, ATPase activity of the fish in seawater was less than that developed during the migratory period prior to seawater entry. These results suggest that as

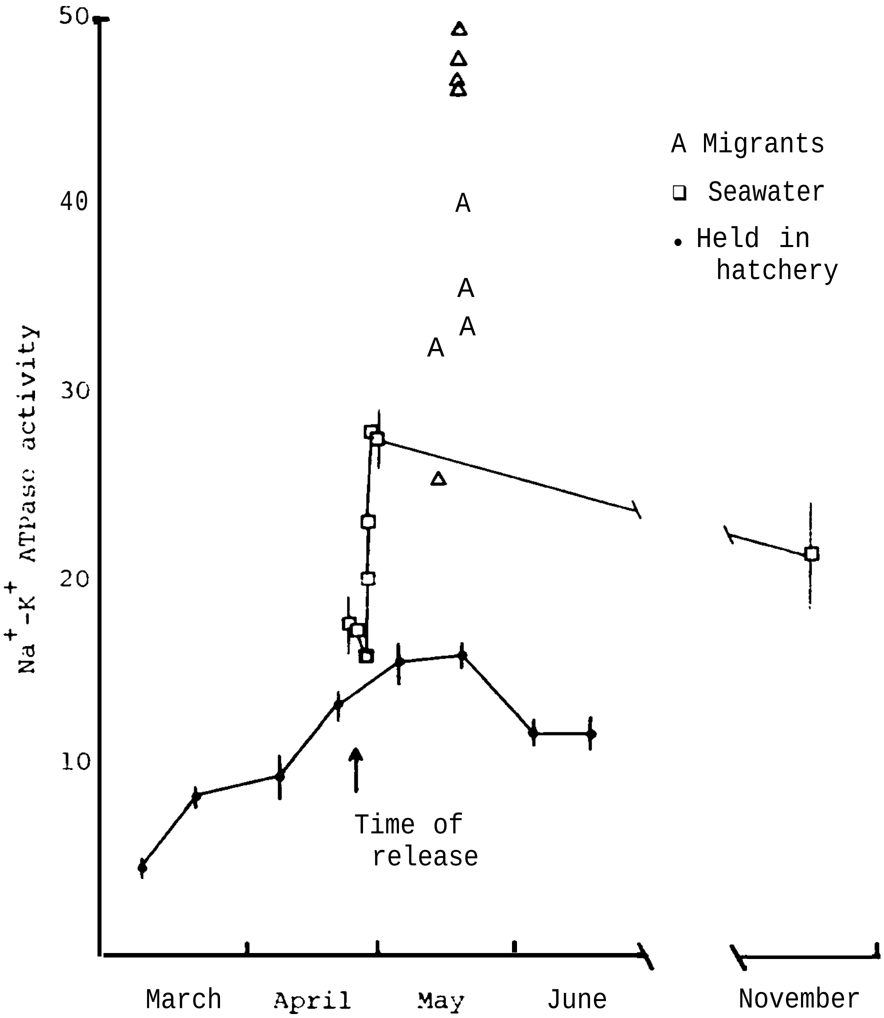

Figure 1. Gill **ATPase** activities in migrating and retained spring chinook salmon from Leavenworth National Fish Hatchery, 1979.

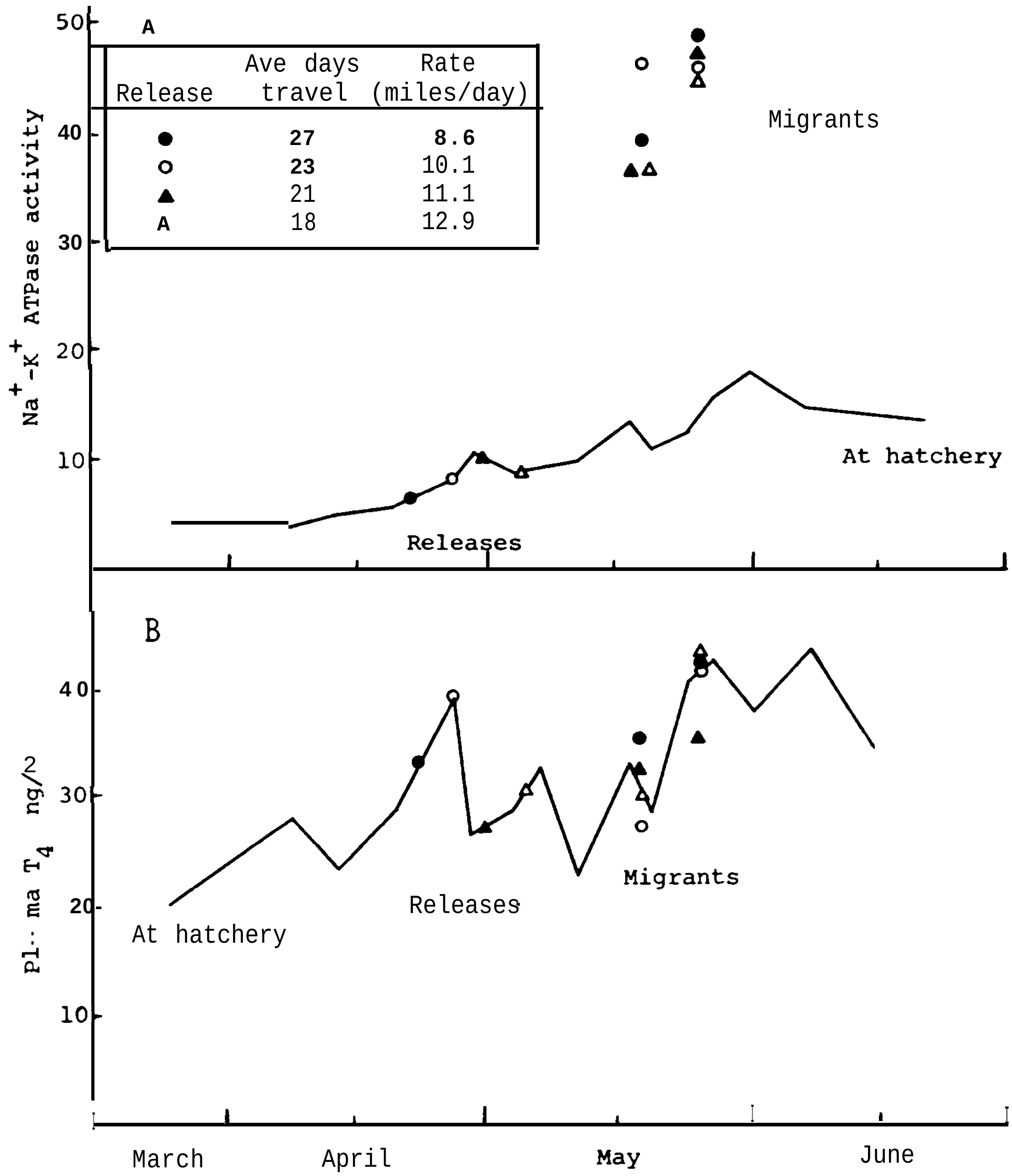

Figure 2. Gill **ATPase** activity and thyroxine **(T_4) levels in** migrating (from the **Methow** River to McNary Dam, 233 miles) and hatchery retained yearling spring chinook salmon, Leavenworth Hatchery, 1983.

long as the fish remain in the hatchery, full development of gill sodiun-potassium ATPase activity does not occur, and that during migration, further develcpment is reqr;ired to prepare these fish for seawater adaptation.

ATPase and migration. characteristics were studied in i983 by Parametrix, Inc., in a project funded by Public Utility Districts of Chelan, Douglas, and Grant counties and printed in a draft report by Drs. Don Weithkap and Ronald Loeppke. Yearling spring chinoook salmon from the Leavenworth hatchery were branded and released at the mouth of the Methow River, and then captured at McNary Lam after migrating 133 miies. The ATPase carve (Figure 2a) shows activities determined on fish at the hatchery. Symbols on the curve show the times (22, 26, 30 April and 4 May) and enzyme activities cf released fish. These same symbols above the curve show ATPase activities of the same groups of fish captured at ?!cVary Dam on 18 and 25 ?lay. AtPase activities in the migrants were much higher than in fish remaining at the hatchery. The box at the top of Figure 2 shows the average days of travel based on the median capture date (date at which one half of the total number of captured migrants had been caught) and the rete of migra:ion. Fish released later migrated more rapidly.

Similiar releases of franded fish were conducted at Priest Rapids Dam on 3, 5,m 7, 9, 11, and 15 of May and Captured at MCNary Dam after a migration of 105 miles. The same genera: results vere obtained: (1) migrants developed much higher gill AtPase activities than hatchery-held fish, and (2) migrants released later also migrated faster. Fish released on i5 May migrated at 15 miles/day, whereas those released 12 days earlier 32 3 May migrated at 6.8 miles/day. Thus, it is conceivable that one group of fish released later than anctier grcup might actually catch up to the earlier group by migrating more rapicily.

Plasma thyroxine (T_4) concentrations were also determined in the study of Leaven&orth spring chinook salmon conducted by Parametrix, Inc. Figure 2b shows levels found in ftsh held at the hatchery and in migrants released at

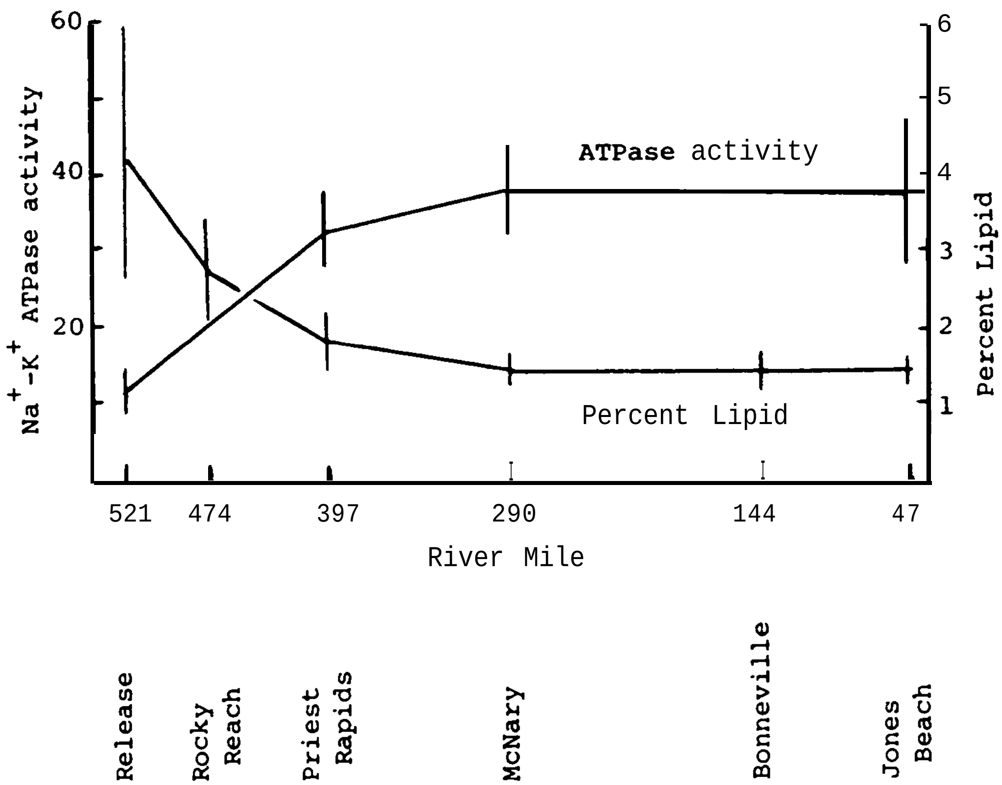

Figure 3. Gill ATPase activities and percent body lipid in Leavenworth spring chinook salmon on release at the mouth of the Methow River and at points downstream during seaward migration.

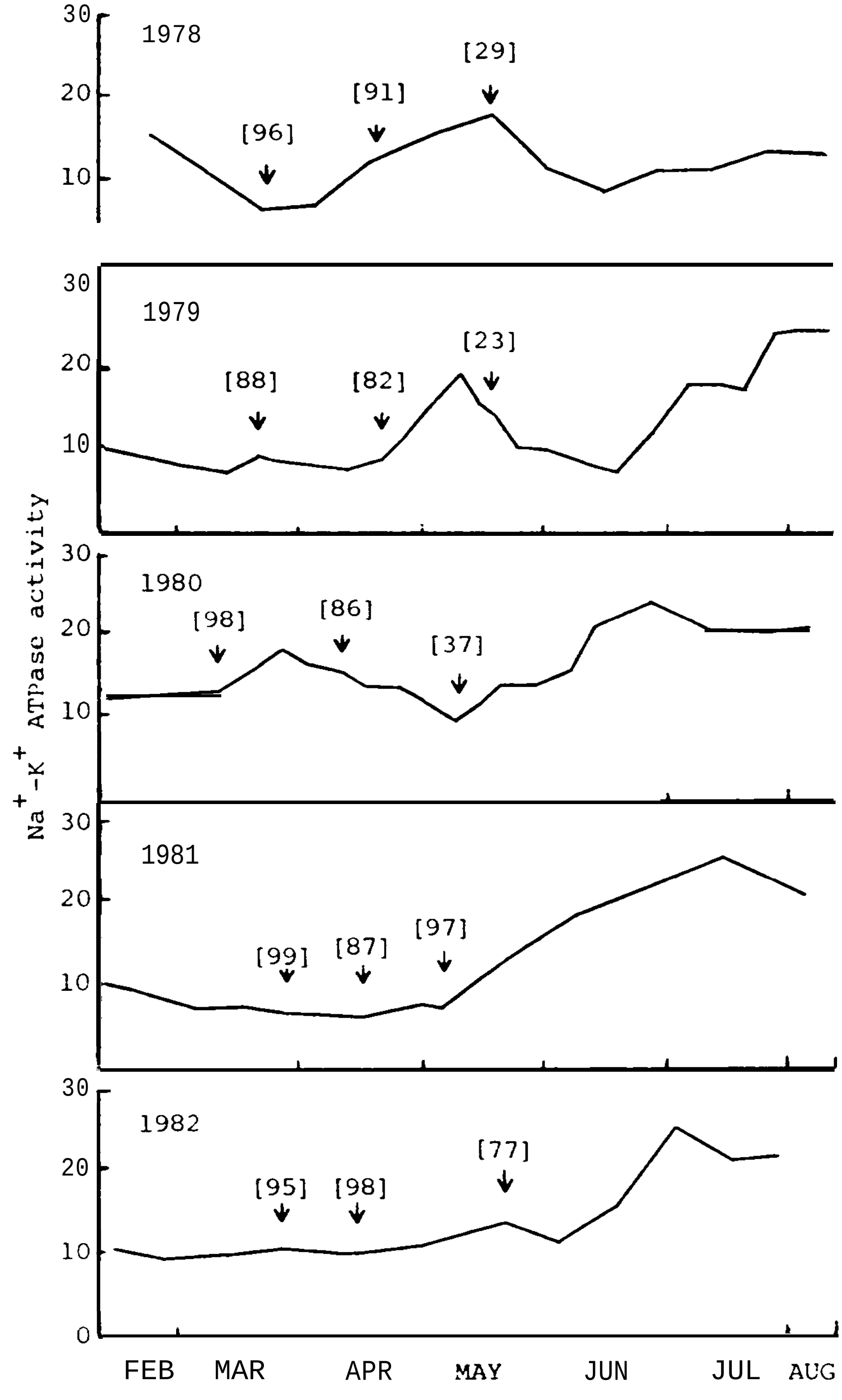

Figure 4. Gill **ATPase** activities in age-0 fall chinook salmon at Spring Creek NFH. Shown are release dates (↓) and percentages of captured migrants at Jones Beach caught in near-shore beach seines [ ].

the mouth of the Methow River and captured at McNary Dam. Symbols are positioned on the baseline curve at the times of release and for time of capture at McNary Dam after a migration of 233 miles. It is apparent that plasma T_4 levels changed very little during migration and in this respect differ from gill sodium-potassium ATPase activity which increased dramatically. It appears that major changes in blood levels of T_4 can take place in the hatchery and that the migratory experience may not influence these greatly.

Lipid depletion and gill ATPase development were studied by Dennis Rondorf and Mike Dutchuk from the Willard Substation of the National Fisheries Research Center (USFWS), on yearling spring chinook migrants from the Leavenworth hatchery (Figure 3). After release at River Mile 521, gill ATPase activity developed in the migrants until a maximum was reached at about McNary Dam (River Mile 290). Thereafter, ATPase activity appears to have remained constant, since levels had not changed at Jones Beach (River Mile 47). Total body lipids depleted rapidly after release and reached minimal levels at about McNary Dam to Jones Beach. The simultaneous development of gill ATPase activity and depletion of body lipids strongly suggest that river migration is important to the completion of smolt development. In experiments conducted with yearling spring chinook salmon at the laboratory, Rondorf and Dutchuk also demonstrated that starvation and exercise do not cause the same rapid and extensive lipid depletion which was observed in migrants: the lower level of lipid reached by the starved and exercised laboratory fish was about 3 percent compared to about 1.5 percent in migrants.

Profiles of gill ATPase activities for five successive years are shown in Figure 4 for zero age fall chinook salmon from Spring Creek National Fish Hatchery release times are indicated by arrows. Migrants from these groups were caught near shore at Jones Beach in beach seines and mid-river in purse seines. The numbers above the arrows show the percentages of the total number of migrants captured that were caught in the beach seine (i.e., near shore).

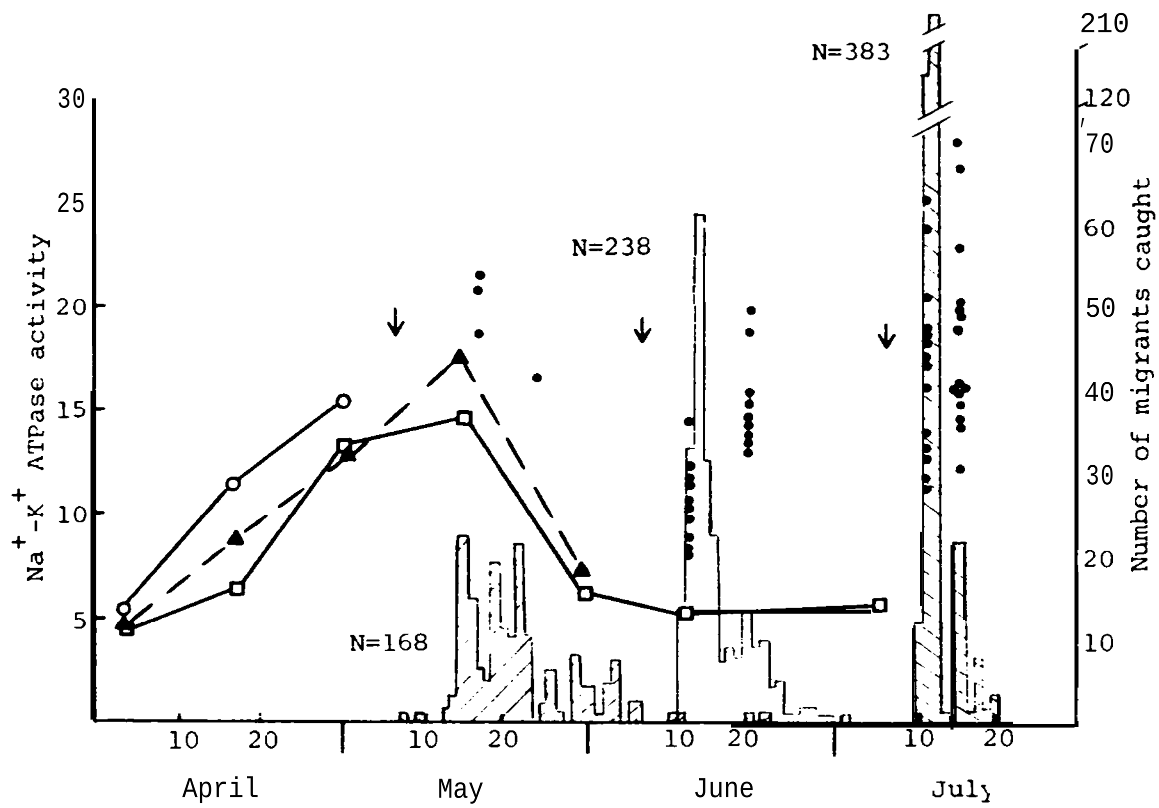

Figure 5. Gill **ATPase** activities in coho salmon at the **Washougal** Hatchery released (↓) in May (○), June (▲), and July (□). Numbers of migrants captured **at Jones Beach** for each **release** are indicated **(N=) with** histograms showing migratory patterns **of daily catches. Activities are shown for** individual migrants (●).

Note that the ATPase profiles are not the same from year to year. In 1978, 1979, and 1980, ATPase activities developed during the period when releases were being made. In 1981 and 1982, however, little or no development of gill ATPase activity occurred prior to releases in any of the groups. A much greater percentage of migrants from the May releases were captured in the beach seines in these two years than in the previous three. These observations suggest that as smolt development proceeds in fall chinook salmon (indicated by changes in gill sodium-potassium ATPase activity), the migrants tend to move to mid-river as they migrate seaward.

Figure 5 shows gill ATPase activity profiles in coho salmon from the Washougal Hatchery and in migrants captured at Jones Beach. Releases were made at times indicated by the arrows, and captures at Jones Beach are shown by the histograms. ATPase activities in individual migrants are shown by dots. Fish released in May as gill ATPase activities were developing in the hatchery migrated more slowly than fish released in June or July after ATPase activities had peaked and then declined. Although enzyme activities had returned to low levels in fish released in June and July, they were rapidly regenerated in migrating fish. If the June or July fish had been transferred directly to seawater at release time, they might have experienced stress because of impaired osmoregulatory ability. Migration, however, provided an opportunity to again develop the elevated gill ATPase activity that seems to be necessary for seawater adaptation.

Recently, we have given considerable thought to how we might compare measurements of smolt development to determine the importance of the degree of smoltification at release to their survival into adults stages. We have considered an experimental design that would use photoperiod to accelerate smolt development in yearling coho or chinook salmon. Figure 6 shows how an advanced photoperiod schedule would cause early development of the gill ATPase cycle in an experimental group (AP) compared to normal development in controls (NP). From two such groups, fish could be released at the same time and size but in different stages of smoltification. By selecting a series of release

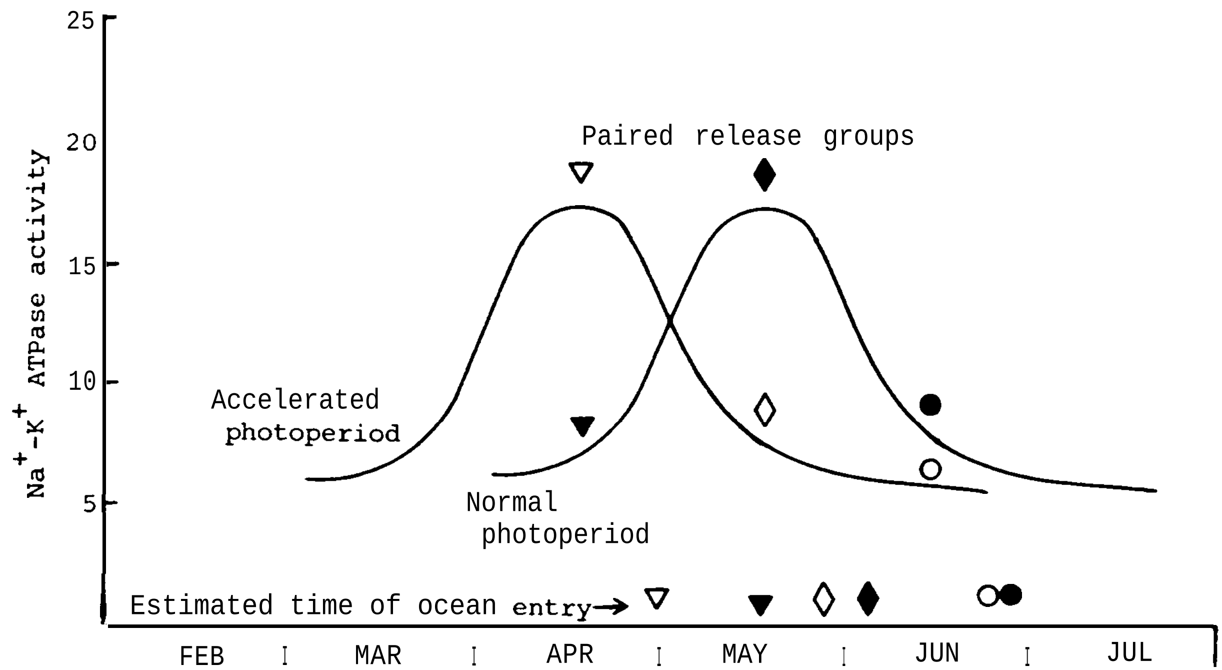

Figure 6. General outline of the effect of **photoperiod-accelerated** smoltification on gill **ATPase** activities and suggested experimental design to examine the effect of degree of smoltification on ocean entry times and smolt success of paired release groups.

times along these developmental curves, such as those indicated by the symbols in Figure 6, information could be obtained on relationships between smoltification state at release, migration rates, times of ocean entry, and adult survival.

Q: Did you take into account the effect of flow rates on migratory times?

A: With the yearling spring chinook salmon, releases were made over a 12-day interval, so flow rates had little effect. There were flow differences with the coho salmon where releases were made in May, June, and July. However, the flow rate in July was about one half of the rate in May, yet migration was faster, and there were greater numbers of migrants caught at Jones Beach. Fishing efficiency could have affected the numbers caught, but the differences in flow rate do not account for the differences in migration rates.

Q: Have you looked at the effect of transporting migrants on ATPase activity?

A: Several years ago, we examined the effect of transportation and found no influence on ATPase activity.

Q: Do you know if swimming increases ATPase?

A: I have conducted some experiments with coho salmon. After they had experienced a cycle of increasing then decreasing A.TPase activity, much like the Washougal coho, I increased their swimming activity by increasing the flows in circular tanks. However, I've never seen a regeneration of elevated ATPase activity. It would be interesting to discover what causes increased enzyme activity during migration.

SMOLT INDICES AND ADULT SURVIVAL

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Parr-smolt transfonmtion is a complex series of events that occur as juvenile anadrorous salmonids change from a fresh-water environment to a seawater environment. These events include morphological, physiological, and behavioral changes. If the young salmon are permitted to migrate during a certain period determined by light, temperature, and environmental factors, they will swim seaward to reach the ocean. If they are kept in the hatchery, and prevented from migrating they will lose the urge to migrate and settle down to a life in the hatchery.

A major question for fish culturists: Is the period of smolting the best tire to release salnonids for maximun survival to adulthood? Is salting actually involved in the survival process? Intuitively, it would seem so. Wby should the fish go through such complicated changes unless there is some survival advantage? But many recent studies have cast doubt on this relationship. Evidence in recent years suggests that smolting is not the entire story. Upwelling, densities of fish in the ocean food supply, ocean temperature, all can influence survival, and these have little to do with the smolting process. It seems more logical that populations of anadromous fish should have developed an asynchronous timing mechanism that causes fish to reach the ocean over a range of tires that bracket the times of optimum ocean conditions.

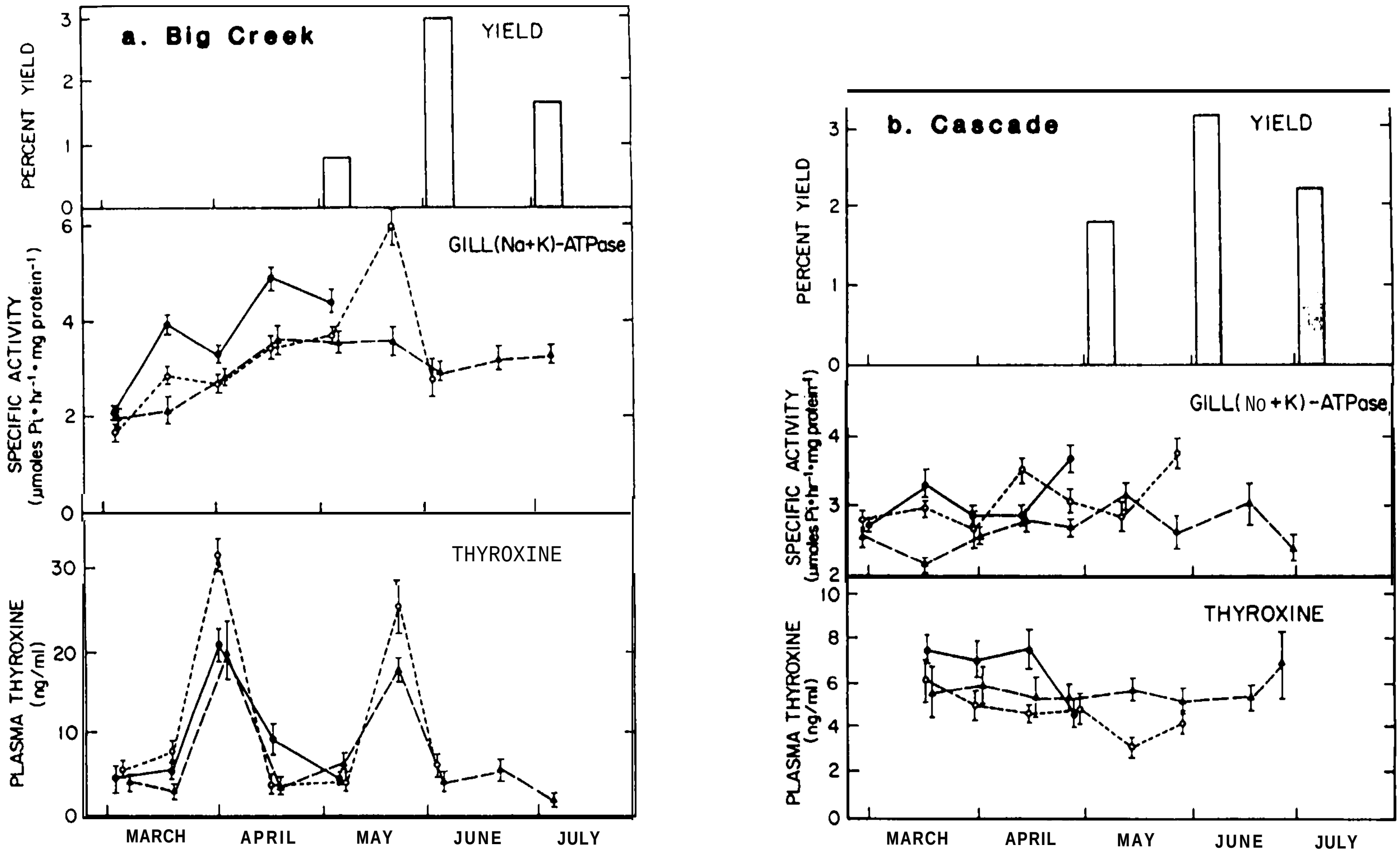

Figure 1. Relationship between yield of coho salmon released at three times from Big Creek Hatchery and from Cascade Hatchery with gill (Na+K)-ATPase specific activity and plasma thyroxine levels in the same fish. (Yield is defined as the sum of catch and escapement.)

All of this is an introduction to some results from experiments that began as early as 1976, attempting to relate smolt indices to release times that promote survival to adulthood.

Our best results have come from experiments on the release of coho salmon at three different times from two Columbia River hatcheries. Figure la compares yields for three times of release of coho from Big Creek Hatchery to the indices, gill sodium-potassium ATPase activity (ATPase activity) and plasma T_4 concentrations. The top line shows the survival of coho released in May, June, and July, the middle line shows the ATPase activity of the three groups, and the bottom line shows the plasma thyroxine (T_4) levels in the three groups. ATPase activity shows considerable variability. We don't know why this should be so, but suspect that it may change with growth rate. Chinook salmon in the laboratory on different growth regimes show a wide variation in the timing of peaks of ATPase activity. From changes in plasma T_4 levels, I would have guessed that April would be the best month for release. As you can see, none of the indices relate well to the timing of release that showed highest survival.

Figure lb examines the same relationship for coho salmon reared at Cascade Hatchery. The fish in these ponds were reared at twice the density development of peaks in ATPase activity and plasma T_4 of those in Big Creek Hatchery. At the higher densities development of peaks in ATPase activity and plasma T_4 may have been suppressed. In this case also, neither appears useful in determining best time of release.

Figure 2a compares return rates with physiological indices in Big Creek coho reared in a laboratory. A progression of events seem to take place in which plasma T_4 peaks around the first of April, ATPase activity peaks about the first of May, and seawater tolerance reaches a maximum around the first of June. Only the timing of seawater tolerance seems related to the time of release (June) that resulted in maximum survival to adulthood.

Let us move on to some less direct experiments on timing the release of spring chinook salmon. These experiments were not set up to check on the relation between smolt indices and time of release that results in maximum survival, but some information can be obtained from them. Previous experiments on Rogue River spring chinook suggested that the best survival occurred in fish released in December. However, the number of variables operating simultaneously was large, so the results were not particularly reliable. We began experiments on timing the release of spring chinook salmon from the Cole Rivers Hatchery in 1976, and we are just now getting the final returns. Figure 2b shows the ATPase activity and plasma T_4 levels of spring chinook salmon reared in the laboratory with the returns to the hatchery of groups released at various times. Only those with error bars included replicates; the others are the results of single releases, adjusted so that they are relative to either October or December releases. As you can see, maximum survival occurs a month before the peak in ATPase activity and two months before the peak in plasma T_4 concentration. Only the condition factor seems to relate closely to the best time to release spring chinook salmon.

At Round Butte Hatchery on the Deschutes River, release timing for best survival was examined briefly, but again, the experiments were not designed to test the efficacy of smolt indices in predicting survival. Fish released from Round Butte Hatchery in 1977 showed a nice peak in ATPase activity around the first of June (Figure 3a). These fish were tagged and released in June and followed in their migration downstream. They were captured in Maupin, at the Dalles Dam, and at Jones Beach, showing that they migrated directly to the ocean. Oniy 8 fish from 122,000 released returned to the hatchery. The percent return is shown as a tiny bar in the graph. The best returns were

obtained from fish released in October when they did not migrate to the sea and were captured by beach seines all winter long. These results were certainly not what was expected, even from the behavioral data.

During the next year, fish were released in June and April from Round Butte Hatchery (Figure 3b). It is difficult to tell if April is an optimum time to

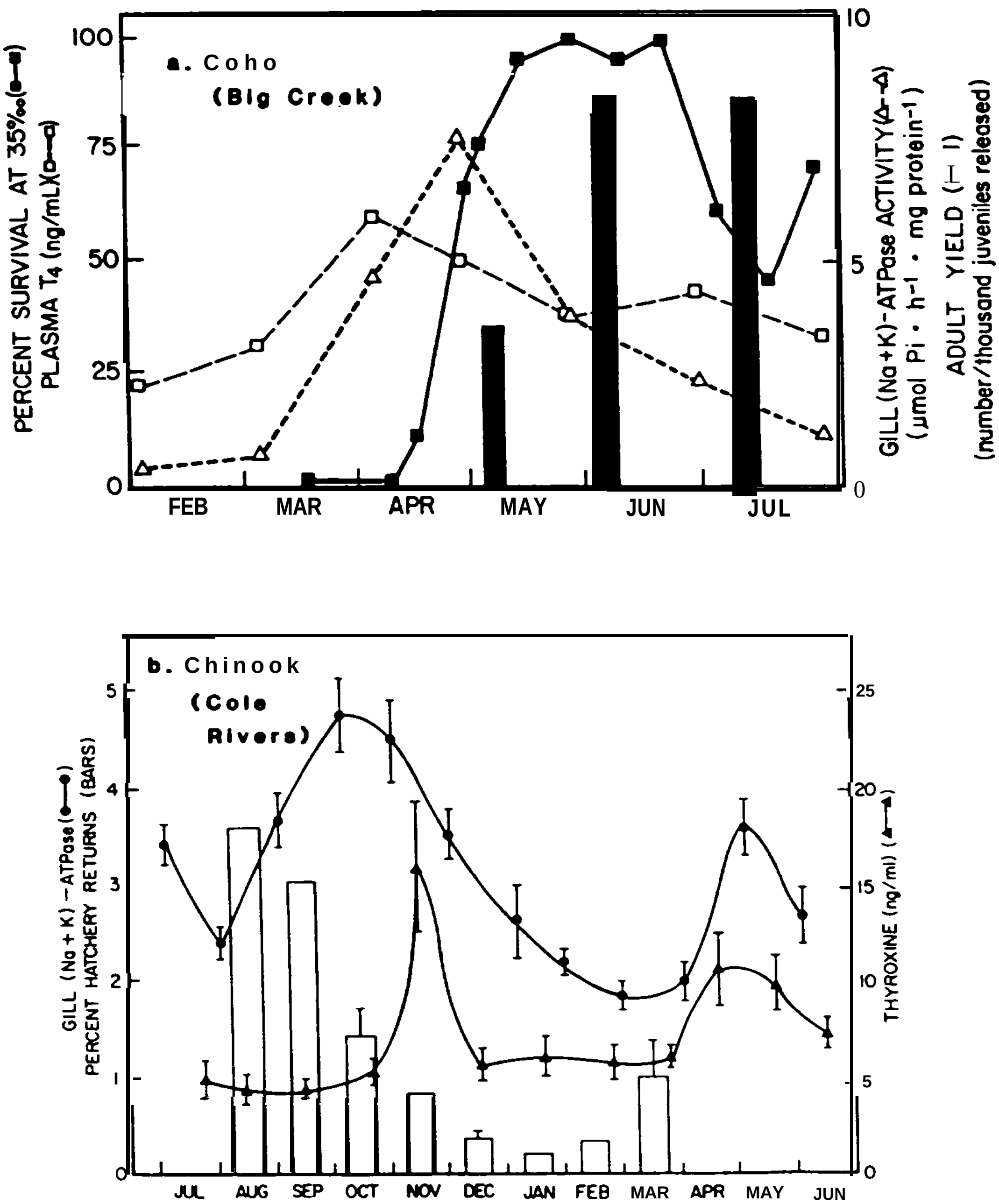

Figure 2. Relationship between return of coho or spring chinook salmon released at monthly intervals and gill (NatKLATPase specific activity and plasma thyroxine levels of the same stock of fish reared from eggs at the Corvallis Fish Research Laboratory. (Error bars on return data are standard errors for four brood years of releases.)

release spring chinook from Round Butte Hatchery because there are no other data points for comparison, but April is certainly better than June as a release date.

As an exercise, let us pretend that we did not know what time of year it was, but were locked in a room with only these data to predict the best time to release fish. Could we do it? I guess if there were nothing else, these data could be used. The prediction would be better than random guessing, but it would certainly be far from accurate. However, it takes only a single positive result to wipe out negative results like these I have presented. If the ocean is important in survival of the juvenile fish, we may never get a good index for release timing until we realize what the conditions of the ocean are that influence their survival and incorporate those factors into our predictor.

In spite of present shortcomings, a number of benefits have accrued from the examination of smolt indices:

1. If we consider only the release of spring chinook salmon from Cole Rivers Hatchery alone, a study of the ATPase activity in chinooks has resulted in a four-fold increase in the return of adults. The monetary benefits to the fishery would probably pay for all the research done on ATPase activity to the present.

2. ATPase has become a tool for distinguishing migrant from non-migrant fish. One can now go out into the wild, sample fish, and say with reasonable accuracy that one fish is a migrant while another is not.

3. ATPase activity can be used to titrate density levels in hatcheries. It can probably be used as a fairly sensitive index of hatchery conditions that are deleterious to the fish. In many of our hatcheries, something takes place during rearing that prevents development of ATPase activity until they are released.

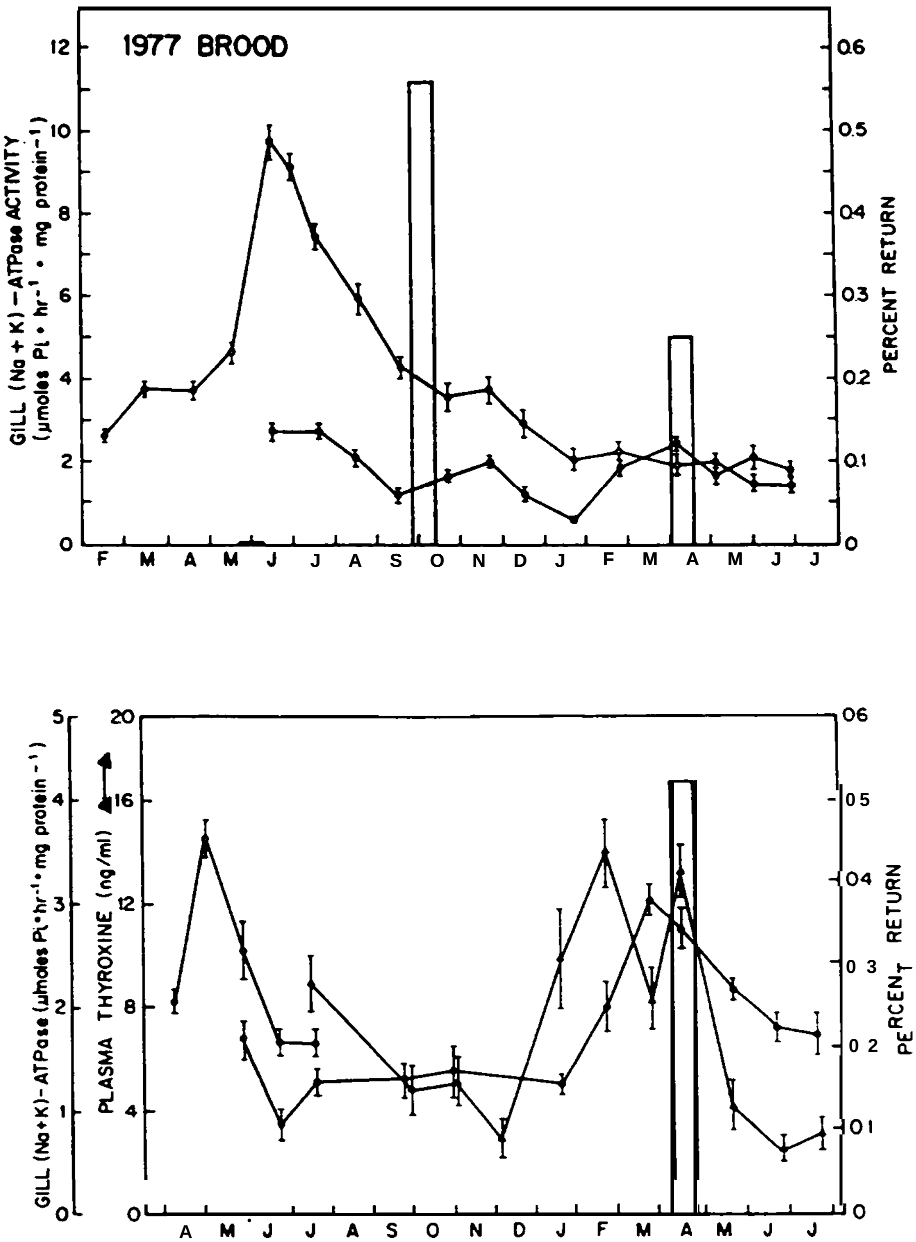

Figure 3. Relationship between **AtPase** activity and survival of spring chinook salmon released from Round Butte Hatchery in June and October of the following year (fast-reared **[O]**) or April of the year after **(slow-reared [●])**.

4. The results from W. Dickhoff's analyses on plasma T_4 levels and W. C. Clarke's analysis of plasma sodium ion levels have given us a means of determining the best timing for net pen rearing of salmonids.

5. Recently, we used thyroxine as an additive in feed for trout to block migration of the trout out of reservoirs. This apparently works quite well to inhibit the migratory process.

In summary, our goal of developing the perfect index for predicting the size and time for release of salmonids to obtain maximum survival to adulthood may be a long way off--it may, in fact, be unobtainable. But I have no doubt that the search for such an index will result in an exciting array of better management techniques for fisheries.

ENDOCRINE TESTING

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I wish to cover three basic areas and just make some general comments about endocrinology in fish and endocrinology in smoltification, and then more specifically cover some of the work that we have done with thyroid hormones and smoltification of coho salmon. Finally I will make some comments about application of these endocrine indexing or endocrine measurement methods and some suggestions of future applications of endocrinology in smoltification.

Human beings have all of the same major endocrine organs that fish do, although fish have a few that we don't have, like the caudal neurosecrotory system. A number of common peripheral organs, such as the adrenals, the thyroid, and the gonads, are dependent on functions of other parts of the endocrine system, particularly the hypothalamo- hypophysial system of the hypothalamus at the base of the brain, which controls the pituitary.

The pituitary is a very powerful organ. It can control functions of the thyroid, and adrenals, and the gonads. Environmental information such as photoperiod, temperature, lunar phase, and other factors, including social factors, can be perceived by the brain, and then this information is processed to end up in the hypothalamus. Ultimately, this information is used to control the release of pituitary hormones that will then affect the other parts of the endocrine system. So there is a hierarchy here of environmental information going down through the endocrine system. The hormones that are released into the blood will affect peripheral actions such as gill ATPase, ion transport across the skin, morphological changes in the body, changes in hemoglobins --a number of physiological processes.

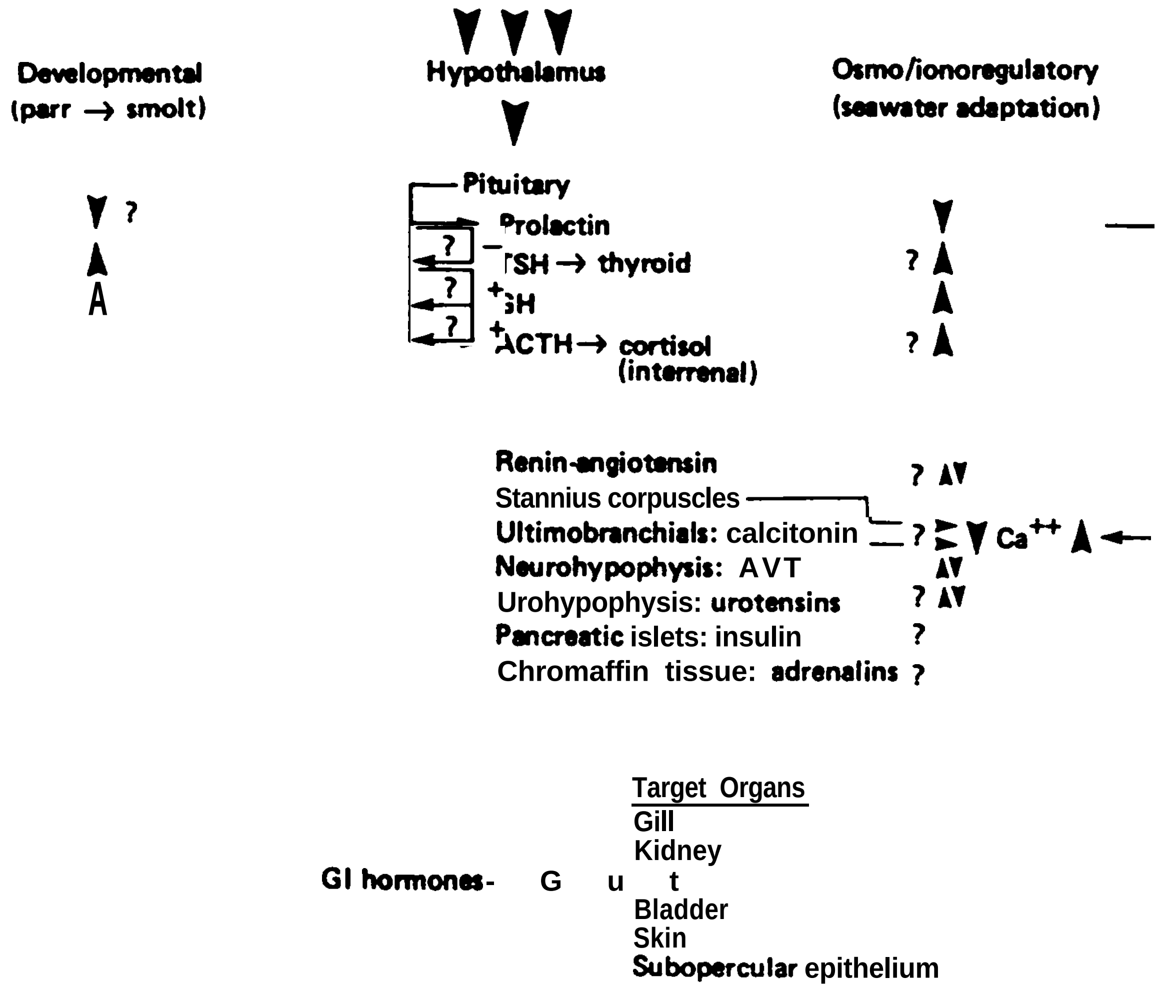


Figure 1. **Schematic** representation of endocrine systems involved in smoltification. (From Bern 1977.)

The hormones are one step up in this biological hierarchy. We have identified over a hundred hormones and neurohormones, including the brain hormones and those for the peripheral organs. In humans, we have assays for a lot of these, whereas for fish, there are only 20 or 30 hormones that have been isolated, and there are assays only for a handful of them. Some of the hormones, the steriod hormones and thyroid hormones, are identical in humans and fish, so we can essentially use assays developed in clinical medical laboratories to find blood hormones in fish. The majority of the hormones are sufficiently different in fish that we cannot measure their blood levels using assays developed for humans.

Figure 1 is a proposed summary of the endocrine systems involved in smoltification. It was prepared by Bern (1977), at the time when several groups of endocrinologists started working on salmon smoltification. The process of smoltification is divided here into parr to smolt development vs. seawater adaptation, and osmoregulatory processes. On top, there are several arrows indicating environmental information processed through the hypothalamus and then either through the pituitary or directly on these pituitary hormones, prolactin, thyroid stimulating hormone, growth hormone, and ACTH (gonadotropin may be included in this), and these regulate the thyroid, internal activity, and cortisol. There are additional endocrine systems here, including endocrine systems of the gut, that may be involved in smoltification.

In the seven or eight years since Bern's summary was put together, many of his question marks have been replaced by positive data that suggest that most of these hormones are involved in some aspect of smoltification. Indeed, for the assays that we have available for changes in blood level of hormones in fish, we see changes in thyroid hormones (Shreck's lab at OSU has shown the changes for cortisol). There are changes in reproductive hormones in some cases, and we have recently found that there is a cycle of insulin during smoltification. For many of these hormones (in fact most of them), the data suggest that they are involved in smoltification at some point. So, I would like you to keep in mind that although I will be talking specifically about thyroid hormones, there are a lot of other hormones operating, and a lot of physiological changes that must be kept in mind in that context.

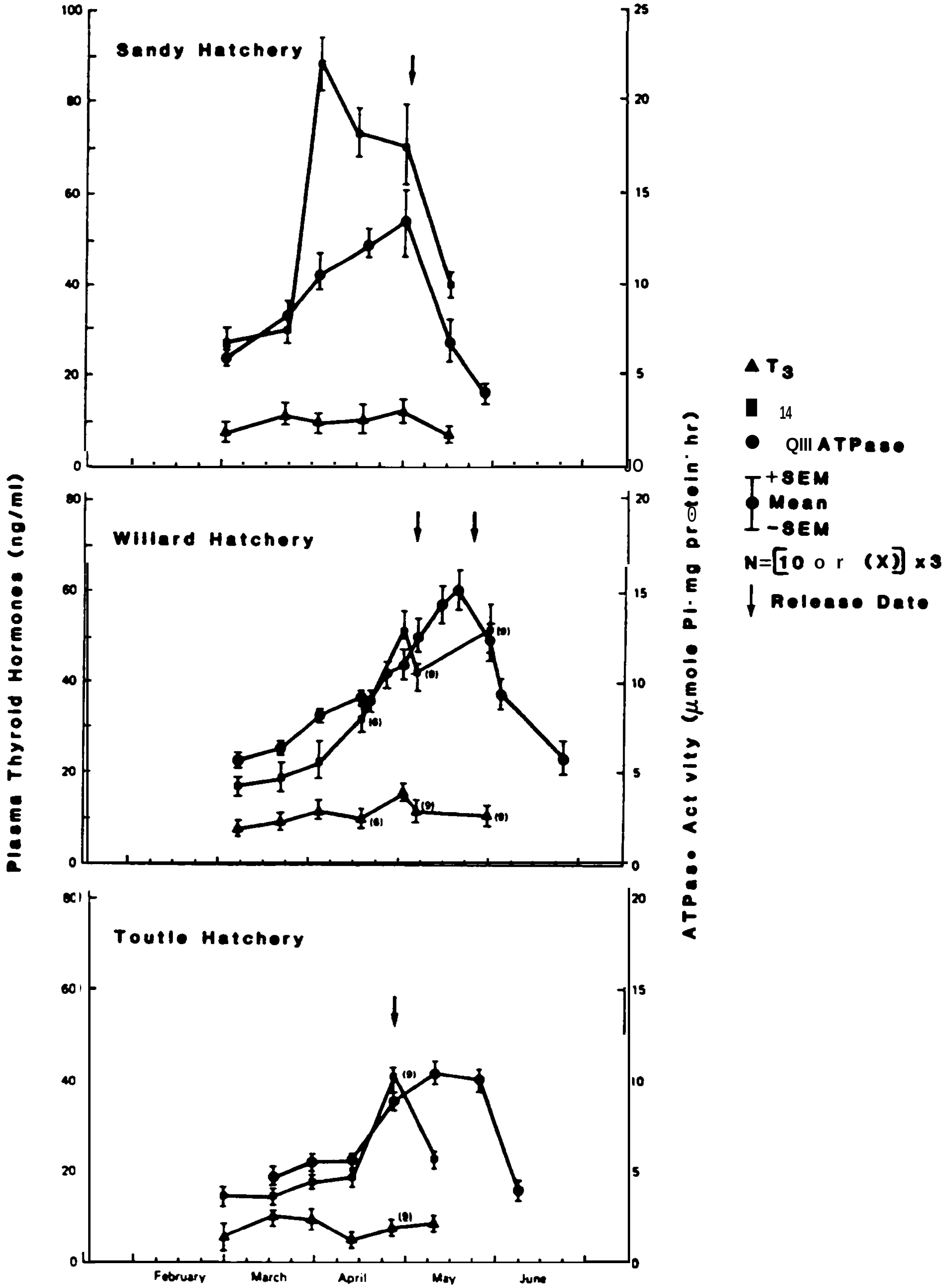


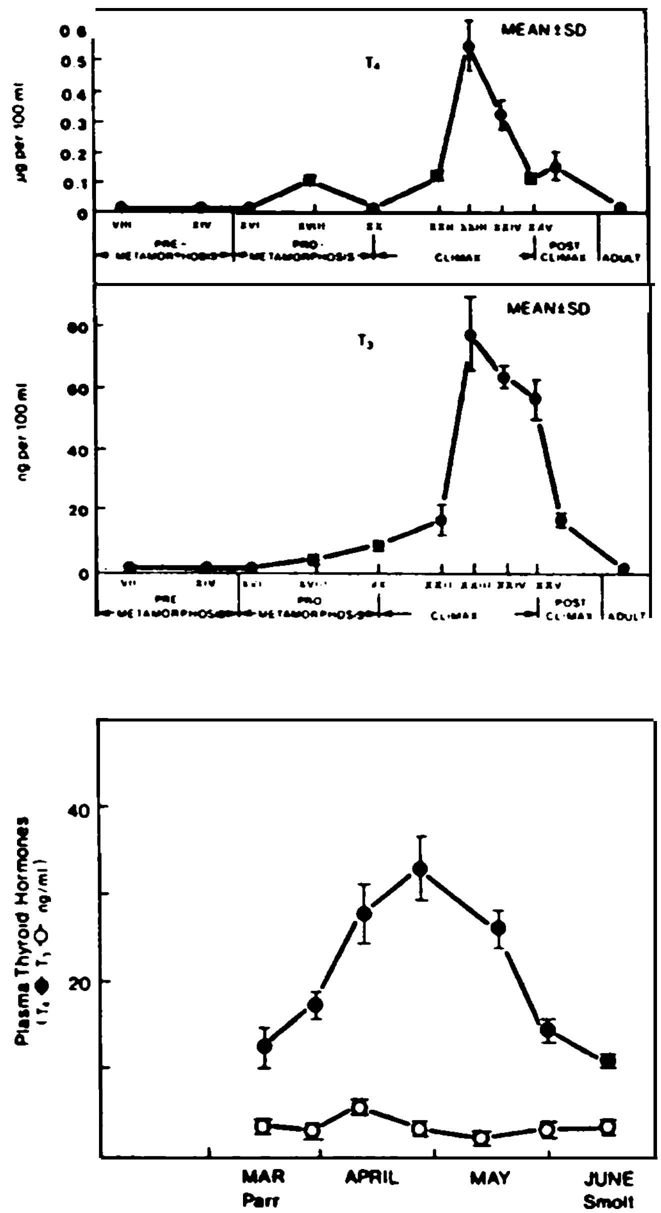
Figure 2. Changes in blood concentrations of thyroid hormones during the metamorphosis of the bullfrog **(a)** and during the **parr-smolt** transformation of yearling coho salmon **(b)**. (From Regard et al. 1978 [a]; **Dickhoff** unpublished **[b])**.

It has long been known that the thyroid system is activated during smoltification, and it has long been known that thyroid hormones can affect some of the developmental changes in fish. In a study done about 20 years ago by Dodd and Matty, where Atlantic salmon fry that were immersed in either 2-4 thyroxin or its more active product triiodothyronine, or T-3, the hormones generally increased yolk absorption and produced some silvering, and had the general effect of enhancing development. To show that these are evidence of exogenous hormones having this effect, I will adduce evidence that endogenous hormones can also cause these changes. Various environmental parameters (temperature, light, etc.) mediated by the nervous system, cause pituitary releases of TSH, stimulating the thyroid to release its hormones, and these can then affect peripheral targets. One of the pieces of evidence to suggest that this pituitary-thyroid-endocrine brain relationship is involved in smoltification comes from studies of amphibian metamorphosis, where a similar phenomenon occurs.

When the tadpole stage of a frog is changing to the adult stage, the tadpole goes through premetamorphosis and then a metamorphic climax; it then emerges as an adult frog. These changes are accompanied by changes in levels of the hormones T-4 and T-3 (Figure 2). At the point of elevated hormone levels, the tadpole essentially becomes a tadpole with legs, and then the tail resorbs, the hormone levels come back down, and it is now an adult.

Also in Figure 2, we see stages of smoltification, going from parr to smolt. These data show changes in T-4 and T-3 for coho salmon (reared at Rocky Reach in 1978). Again, there is an increase in T-4, and then it comes down--a surge in thyroid hormone similar to the one seen in amphibian metamorphosis. So there is a biological parallel here in the development of organisms.

Data from several hatcheries in 1978 show similar surges in T-4 during the smoltification period (the arrow indicates the time at which a group of fish were transferred to seawater net pens where their survival and growth was followed for six months): Willard Hatchery (where two groups of fish were



a. Frog **tadpole**

b. Salmon **smoltification**

Figure **3.** **Mean** gill **ATPase** activities and plasma T_4 and T_3 concentrations from fish in fresh rater at three hatcheries.

transferred to seawater net pens), Sandy Hatchery, and the Toutle Hatchery (Figure 31. These data indicate that there is also a considerable difference in the patterns of T-4 at the different hatcheries, suggesting that the pattern of T-4 observed is influenced by other factors, such as conditions of rearing (e.g., temperature). We have found since then that there is also a genetic component. We see different basal levels of thyroid hormones in different stocks of fish and in hybrids of those stocks. And we see effects of different diets. So the levels of these hormones, or rather the patterns of change in them, are responsive to a number of factors.

In all of these groups, we have groups that were transferred to seawater net pens at different times during the seasonal change in thyroid hormones. If we compare the distance that the fish have moved through the T-4 surges with their survival and growth over five or six months in seawater net pens, we get significant correlations.

The percentage survival of smolts in one experiment showed a high, positive correlation with the percentage of the thyroxin surge for nine different groups of fish ($R=0.92$); we repeated this experiment a number of times with a number of groups of fish. The correlation between survival in seawater and the integrated area under the T-4 peak through which another group of fish in another experiment had gone was also high and positive ($r=0.89$; $p < 0.01$).

The fish that survived--what we were counting as successful smolts in this case--are fish that continued to grow and to retain smolt-like characteristics in seawater. Regarding the fish that died, among coho at least, most did not die immediately after seawater entry--the mortality was not caused by a sudden challenge of osmoregulatory performance--but rather they tended to die off in greater numbers several months later during the declining photoperiod. The fish would not grow; they "desmolted" in seawater. The parr marks would reappear, and the fish would become darkly pigmented. Studies on the endocrine status and other biochemical status of these fish indicated that they were hypothyroid and had reduced numbers of growth hormone receptors and suppressed levels of circulating insulin. Histological examination of other

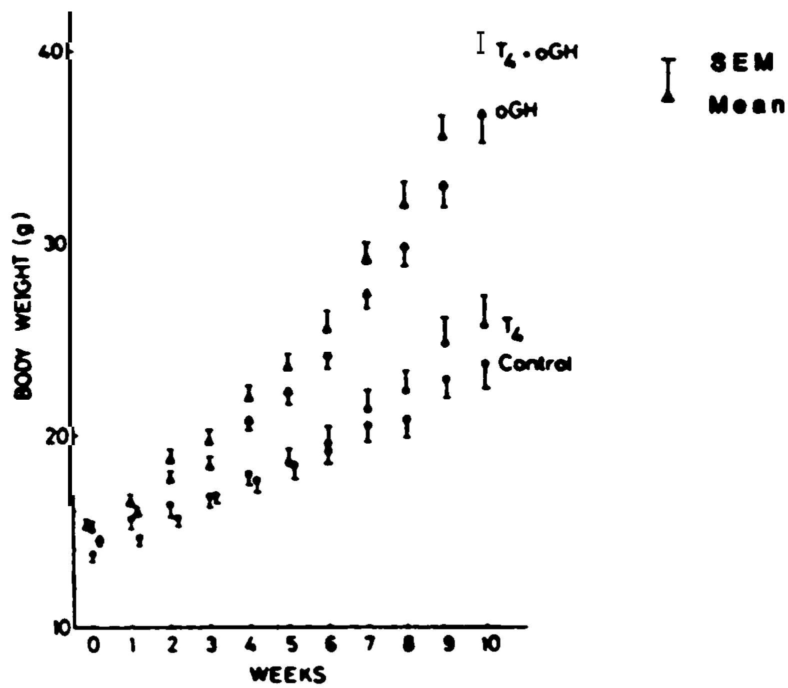


Figure 4. Changes in body weight of underyearling amago salmon administered either L-thyroxine (T_4), ovine growth hormone (oGE), a combination of these hormones, or no hormone (control). (From Miwa and Inui 1985.)

endocrine organs showed aberrations indicating that the fish were suffering from some metabolic disorder. These laboratory experiments, then, indicate that thyroid hormones could in principle be used to predict the best time for transfer of fish into seawater.

The question that remains is whether the correlations would hold up in hatchery studies. As Richard Ewing has shown, in many cases they do not. We suspect that this is because of the uncontrolled variables that are involved when you try to correlate the state of smoltification at release with catch or escapement data where the fish have been subjected to differential rates of downstream migration, different efficiencies of bypass systems at dams, different river flow rates, different predation pressures, different effects of nearshore survival--variations in upwelling, among other factors.

Perhaps what is needed is some other index of success of smoltification, such as efficiency at getting to Jones Beach. If these indices prove to be useful in that case, we can at least address the question of whether the murres' stomachs are full of high-quality smolts or poor-quality smolts!

In terms of future applications, I think, as Ewing has mentioned, that there are a lot of spinoffs from this research, suggesting, for example, that densities are important and can affect development of smoltification.

With regard to hormones, not only can you look at their levels in blood and judge development of the fish, but you can also use them to control development, growth, and smoltification. The use of hormones as growth promoters has received quite a bit of attention in Ed Donaldson's laboratory and others'; I think that hormones will prove useful, at the very least, in reducing the cost of feed, but perhaps also in controlling the rate of smoltification. This must be used to put out smolts early, or at more nearly ideal conditions in the ocean, or at higher flows in the river. Some recent data suggest that growth hormone might be used with other hormones to control growth and smoltification. Figure 4 shows the growth of amago salmon (?liwa and Inui) at Mie in Japan, the growth rate over 10 weeks of control fish, and fish treated with a combination of ovine growth hormone and thyroxin, or with ovine growth hormone alone. There is at least a doubling of the growth rate, and the fish go from 5 to 40 grams in 10 weeks. More recent, unpublished data suggest that even greater growth rates can be obtained with salmon growth hormone.

One of the problems with the use of growth hormone is that in all tests, it was injected into fish, as here, but there is a recent publication by Deigani and Gallagher indicating that growth hormone may be effective when incorporated into the diet. This is rather surprising. If it can he verified, it may prove to be a powerful tool for control of smoltification. An additional factor is that growth hormone has been shown to facilitate seawater survival. It may also become cheap to use, because adequate supplies may be available next year through genetic engineering from cloned salmon growth hormone.

To summarize, I think that the endocrine indices can be developed to predict seawater survival and could then be used as predictive indices of smoltification, but perhaps a more valuable use of hormones in the future may be to control smoltification.

2.3 MEASUREMENT OF SMOLT HEALTH AND QUALITY

Diseases of Migrating Smolts (J.S. Rohovec)

Stress Measurement (C.B. Schreck)

Health Measurements (L. Smith)

DISEASES OF MIGRATlNG SMOLTS

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Very few studies have been conducted concerning diseases of smolts and the impact pathogens have on the survival of the fish as they migrate and enter salt water. Our laboratory has done some very limited work in this area which will be described here.

Bacterial kidney disease (BKD) is caused by Renibacterium salmoninarum, and is the disease with which we have the most experience. Bacterial kidney disease is probably the most troublesome bacterial disease in salmonids cultured in the Columbia River Basin. Unlike other bacterial and viral patbogens, R. salmoninarum usually does not cause acute epidemics in which mortality is high. The progress of BKD is most often chronic because the organism grows slowly and incubation times are long. Because of these characteristics, mortality caused by R. salmoninarum may not occur until fish have already left the hatchery, and thus, large losses may go undetected in the river or ocean.

We began studying what effect BKD has on fish entering salt water. Preliminary tests were done with chinook salmon from three different locations in the Willamette River system. The hatcheries included were the Oakridge, McKenzie and South Santiam hatcheries which are operated by the Oregon Department of Fish and Wildlife (ODFW). Fish were released from each of these installations at two times in the year. Fish which had attained a sufficient size were released in the fall, and the remainder of the populations were reared through the winter and released in the spring. In the fall and again in the spring, 300 fish from each of the three sites were collected. A sample of 100 fish from each group was examined for the incidence of BKD using a fluorescent antibody technique (FAT). The remaining 200 fish were separated into two equal lots and placed in tanks supplied with W-sterilized sea water. The fish which died in salt water and the survivors were all examined for BKD using FAT.

Results of this experiment are shown in Table 1. In the fall of the year, we did not detect any BKD in fish that were held in fresh water. If we had had a more sensitive detection method such as the ELIA test which has been described, the incidence might have been higher. After these groups of fish had been in salt water for 100 days, fish from each hatchery had experienced approximately 10 percent mortality as a result of BKD. When fish from the same population were tested in the spring, the incidence of BKD in fish in fresh water ranged from 1 to 13 percent. After being in salt water for 100 days, the mortality from BKD in the three groups was 17, 43, and 49 percent. This mortality continued to increase, and after 200 days was as high as 81 percent. These results indicate that this disease continues to progress in salt water and can be a major contribution to saltwater mortality.

In another study, we captured migrating smolts at Jones Beach in the lower Columbia River. The fish which were caught either by beach seining or purse seining were then transferred to a holding site where they were observed for 180 days. The results varied (Table 2). but mortality as a result of *R. salmoninarum* infection was higher than 50 percent in some groups of fish. This mortality indicates that these smolts were not of very high quality.

we were able to continue this study in a subsequent year, but in addition to holding the fish at the freshwater site, we also had the opportunity of holding duplicate groups in salt water. Chinook salmon captured at Jones Beach that were held in fresh water had an average of 5.8 percent mortality from BKD; whereas, fish maintained in salt water experienced an average of 45 percent mortality from the disease.

TABLE 1 MORTALITY OF CHINOOK SALMON AND INCIDENCE OF BACTERIAL KIDNEY DISEASE (BKD) AFTER TRANSFER FROM FRESH TO SALT WATER.

Hatchery Site	Time of Release	Incidence[a] Before Transfer (%)	Mortality Attributed to BKD After Holding in Salt Water 100 Days (%)	200 Days (%)	Survivors With BKD[b]
Oakridge	Fall	0	12	--	17
	Spring	1	43	56	0
South	Fall	0	10	--	9
Santiam	Spring	11	49	81	0
McKenzie	Fall	0	11	--	0
	Spring	13	17	45	5

(a) Detected by fluorescent antibody (FAT) analysis of kidney smears from a 100-fISH sample taken from the population of fish to be studied before transfer to salt water.

(b) R. Salmoninarum detected by FAT.

TABLE 2 MORTALITY (%) OF SALMONID SMOLTS EXAMINED FOR R. SALMONINARUM(a) DURING A 180-DAY HOLDING PERIOD FOLLOWING COLLECTION IN THE LOWER COLUMBIA RIVER

Date Collected	Coho	Chinook Purse Seine	Chinook Beach Seine	Steelhead
5-20	10	27	1	30
5-27	6	21	1	23
6-03	4		1	16
6-10	50	12		20
6-17	6	21	25	
6-24	8	9	6	
7-01	--	13	4	100
7-15	--	59	11	--
7-29	--	12	28	--
8-12		13	7	
8-26		30	18	--
9-08	--	27	14	--
Number Collected	193	542	1,169	74
Number Positive	16	98	111	15
Average % Mortality Overall	8.3	18.1	9.5	20.3

(a) As determined by the fluorescent antibody technique.
Note: -- indicates that no sample was taken.

These data show that BKD infections continue in salt water, and that the death of fish from this disease is probably accelerated in the marine environment.

During the last four years, we have had the unique opportunity of examining juvenile salmonids caught in the open ocean. Using FAT, we have assessed the incidence of bacterial kidney diseases in these fish. The results are shown in Table 3. Although not all the fish that were caught in 1984 have been examined, the relative numbers infected do not significantly change the percentages presented. Approximately 11 percent of all chinook captured harbored R. salmoninarum, and more than 2 percent of them had overt infections as determined from the presence of gross kidney lesions. These lesions are indicative of advanced cases of the disease, and animals with them are near death. We were also able to detect kidney disease in all other species, but at somewhat lower incidences. Bacterial kidney disease seems to be a contributor to ocean mortality; if healthy fish can be released from hatcheries and enter salt water uninfected with R. salmoninarum, survival is certain to be higher. In fact, experiments conducted by personnel of the ODFW at Cole Rivers Hatchery have shown this to be true. (See paper by H. Lorz.)

In addition to experimentation on the effects of R. salmoninarum on saltwater survival, studies have been done on a myxosporidan parasite, Ceratomyxa Shasta. The infectious stage of this protozoan has a limited geographic range but includes much of the Columbia River Basin. Fish migrating through the Columbia River are exposed and can be lethally infected. The disease has an extended incubation period, and the time from initial infection until the host dies can be long. Using experimental designs similar to those employed in the study of BKD, we examined the effect of C. Shasta on migrating fish and those which enter sea water. We collected fish at Jones Beach and held them for 180 days, during which time they were examined for mortality caused by the parasite. In some groups of fish, there was significant mortality resulting from ceratomyxosis (Table 4) with averages of approximately 10 percent in some species of fish. The effect of C. Shasta on migrating smolts may be even greater than is reflected by these data, because the fish we examined were ones that successfully reached the lower part of the river; many others may have succumbed before reaching Jones Beach.

TABLE 3 PREVALENCE OF RENIBACTERIUH SALMONINARUM[a] IN JUVENILE SALMONIDS CAPTURED IN THE OCEAN OFF THE COASTS OF WASHINGTON AND OREGON, 1981-1983

Species	Number Examined	Infected with R. salmoninarum No.	Infected with R. salmoninarum percent	Showing BED Lesions No.	Showing BED Lesions percent
Chinook salmon	721	80	11.1	18	2.5
Chum salmon	197	6	3.0	0	0
Coho salmon	1,882	56	3.0	6	0.3
Pink salmon	15	2	13.3	0	0
Sockeye salmon	24	1	4.2	0	0
Cutthroat trout	95	1	1.0	0	0
Steelhead trout	91	3	3.3	0	0

(a) All fish were examined for R. salmoninarum by FAT.

Experiments have also been done under controlled conditions in which fish that are highly susceptible to C. Shasta (Alsea steelhead trout) and a stock which is resistant to infection (Big Creek coho salmon) were exposed and then held in fresh and salt water. In these tests when fish were held in fresh water, 100 percent mortality occurred; when held in salt water, a significant but lower (50-80 percent) mortality was experienced by susceptible fish (Table 5). Resistant coho were not infected by C. Shasta. Other investigators have reported that fish held in salt water experience the same high mortality as those held in fresh water. From the data presented here, it is obvious that C. Shasta contributes to the success or failure of salmonid smolts in the Columbia River.

Very little work has been done on the effect of infectious diseases on migrating smolts. Although two diseases have been discussed here, there are many viral, bacterial, and parasitic diseases that occur in the Columbia River Basin. The impact of these diseases on the survival of smolts is not known. Until recently, there was an attitude that if fish survived until released from the hatchery, the program was successful. It is time to consider what happens to smolts as they migrate. I think that one major question that should be answered is what impact the trucking and barging programs have on smolt survival. In these operations, fish are crowded together and stressed, creating perfect conditions for the transmission of disease. In collection facilities, there is little concern about the mixing of stocks of different origins. Healthy, high quality smolts may be mixed with those carrying different pathogens, and all of the fish may become infected.

The hatcheries need to rear healthy smolts, but it is equally important to keep them healthy on their seaward migration.

TABLE 4 MORTALITY (%) OF SALMONID SMOLTS EXAMINED FOR <u>CERATOMYXA SHASTA</u>[a] DURING A 180-DAY HOLDING PERIOD FOLLOWING COLLECTION IN THE LOWER COLUMBIA RIVER.

Date Collected	Coho	Chinook Purse Seine	Chinook Beach Seine	Steelhead
20 MAY	4	27	3	20
27 May	6	8	1	--
03 Jun		X	3	14
10 JUN	25		2	
17 JUN	6	8	3	X
24 JUN	15	9	2	100
01 JUL	--	16	13	
15 JUL		13	13	X
29 JUL	X	22	4	X
12 AUG	X	11	13	X
26 AUG		5	24	X
08 SEP	X	18	20	X
Number Collected	193	542	1,169	74
Number Positive	10	63	97	9
Average percent Mortality	5.2	11.6	8.3	12.2

(a> Determined by wet mount examination of intestinal scrapings.
Note: (--> indicates that no sample was taken.

TABLE 5 EFFECTS OF SALT WATER ON STEELHEAD TROUT AND COHO SALMON EXPOSED TO THE INFECTIOZiS STAGE OF CERATOMYXA SHASTA

Salmonid	Exposure Period (days)(b)	Fresh Water: Number Recovered(a)	Fresh Water: of Fish Infected	Fresh Water: Percent Infected	Salt Water: Number of Fish Recovered(a)	Salt Water: Infected	Salt Water: Percent Infected
				1983			
Steelhead trout (Alsea)	3	21	21	100	6	3	50
	5	23	23	100	13	7	54
	Control	19	0	0	11	0	0
				1984			
Steelhead Trout (Alsea)	5	18	18	100	9	8	89
	Control	25	0	0	16	0	0
Coho salmon (Big Creek)	5	25	1	4	25	0	0
	Control	25	0	0	25	0	0

(a) Number of fish exposed minus number of fish that died before spores were detected.

(b) 25 fish in each exposure group; control fish were not exposed to the infectious stage of & Shasta

STRESS MEASUREMENT

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I am pleased to be able to talk today about smolt quality. I would like to do this primarily from the perspective of stress. One problem that I am having, however, is that I really can't define "smolt", and I can't really define "quality". I solicited comments earlier on what a smolt is, and nobody has an acceptable definition. One other problem that we have is that it is very difficult to separate estimators of stress and quality from those involved in estimating smoltification. As Dr. Dickhoff showed you, just about all of the physiological processes are linked to each other. When I talk about estimators of stress, they are quite often the same types of estimators people use to estimate smoltification, and vice versa. The two are interrelated. So even if my discussion today relates to stress and that aspect of quality, it is not separate from smoltification.

I plan to review what we know and try to leave you with a feeling for the state of the art of stress physiology in fish. Then I will give you an example of how this knowledge of basic physiology can have management implications. lastly, I would like to conclude with consideration of what I think we need to know--broad aspects of the problems to which we do not know the solutions yet.

I should give you my main conclusion first, and that is that there really is no quick fix. I don't think we know enough yet to come up with a rapid solution to the definition of smolt quality.

Let me start off with what we do know. Smolt quality is basically dependent on three factors. Genotype determines what a fish can do, and rearing history and the environment will determine what a fish will do. I have separated infectious disease from non-infectious diseases because I believe non-infectious diseases are an area to which we have not paid much attention. The area of non-infectious diseases, I believe, is vitally important to the well-being of our fishes. I believe also that infectious diseases can quite often be attributable to prior exposure to non-infectious diseases.

Basically, I think non-infectious diseases and stress can be defined more or less as one and the same thing. With regard to the type of things I think we need to worry about, (1) density-flow types of relationships in hatcheries are obviously important in determining fish quality. These relate very closely also to (2) the effect of water quality on the development of fish. (3) Nutrition is an aspect that we cannot leave out, and prior nutritional history i important in determining how a fish will respond to subsequent stresses.

There are also (4) possible effects of variability in size. What does it mean if a population is very synchronous in size versus very diverse in size? Is it good or is it bad? Other stresses (5) such as transportation, tagging, and so forth can have residual effects. I would consider these as non-infectious types of diseases. Then, (6) there is improper timing of hatchery management practices. If you release your fish too early and they are incapable of doing what they need to do out there in the wild, this could be likened to a non-infectious disease. So I think all these aspects are extremely important in our consideration of smolt quality.

There are really two definitions of stress. First, there is the medical definition which is basically that stress is the nonspecific response to any demand placed on the body--the physiological response. I tend to prefer the common usage, that stress is really the perturbing situation, like temperature is a stress. So let's stick to the more common usage. Just be aware that when you read literature, people quite often do use "stress" as the physiological response.

Most stresses produce what is called the general adaptation syndrome. That is, there is a suite of physiological responses that happen more or less independently of the source of the stress. Thus, most stresses will cause energy mobilization and hydromineral imbalance in fish. They will suppress the immune system response, and they can modify behavior and learning. These things are typically independent of what the stress is. There are stresses that don't elicit these responses, but most of the kinds of stresses that we are concerned with cause such reactions.

Stresses, however, also cause specific responses which depend on the nature of the stress. For example, certain stresses cause hemorrhage; if you are wounded, you bleed. Certain stresses cause disorientation. I think this is perhaps important when we think in terms of imprinting, and perhaps of subsequent homing and so forth. Lastly, certain stresses can hinder smoltification, and this is an area that we're concerned with today. so, you have generalized responses to stress, and you have specific responses to stress.

There are numerous clinical things we can measure to indicate that the fish is stressed: plasma cortisol, plasma glucose, plasma lactate, hepatic glycogen, hematocrit, leucocriti, white blood cells, and internal cell nuclei--this is a sample of about 20 or so physiological determinations that can be made.

To indicate that a change in these clinical parameters really means something, we run a battery of what I call "performance tests." These consist basically of asking the fish to do a variety of things that they must normally do to survive: seawater challenge, resist secondary stresses, disease challenge, seawater growth, and swimming performance. You can think of these as bioassays of fitness. By and large, results of the clinical tests correspond with those for performance tests. These can be looked at as a short range tag and release type of study. Performance tests require the fish to do something in response to a management situation, and using that response as an index to verify that the physiology really does indicate what you think it is indicating.

I think it is extremely important to recognize there are lots of things that change during smoltification. Walt Dickhoff, Dick Ewing, and Craig Clarke and the others cn that panel showed you examples of the sort of things that changed during smolting. What we know about stress is that the kinds of stressful situations that cause fright, discomfort, or pain cause a generalized stress response. You need one of those three elements to get the generalized clinical response to distress. The elements of fright, dLscomfort, and pain are important. The psychogenic aspect of stress is equally important. The other thing that we know now is that we can say when fish are stressed. We cannot say when fish are not stressed, and that is an important distinction. I feel comfortable in saying, "This fish is stressed." I do not feel comfortable in saying, "That fish is unstressed."

Stress is modulated through psychological interpretations by fish. Four factors affect its response: (1) The fish's genotype determines how it can respond. (2) Its particuiar state of development will determine how it will respond; in other words, the state of smolting is important in the stress response. (3) -he prior history of the fish will determine how it will respond. And, (4) the present environment the fish is in will determine how it will respcnd. These together, then, can affect the response to stress, and thrcugh it both short-term and long-term survival.

Another thing that we have learned is that the effects of stress tend to be cumlative, in other words, if you stress a fish once, you get a particular kind of response. Then you would expect the response to decay back to normal. If you stress the fish a second time, you get a cumulative effect; if you stress it a third time, there's further cumulation of the response, and so forth. So, discrete stresses cause almost additive stress responses.

We also know that different stocks of fish respond differently tc the same stress. Coho salmon cf Cedar Creek and Trout Creek were given the exact same three stresses, and there was clearly a difference in the magnitude of responses in pissma cortisol levels. It is also interesting that diseased fish respond differently than healthy fish, as evidenced by salmon from Salmon

River Hatchery which were unable to respond to three stresses separately. A single, very brief handling stress caused the maximal response in these fish which were suffering from cold-water disease. They were no longer capable of responding to the additional two stresses. In fact, at the time of the third stress, these fish were starting to die from stress, whereas there was no mortality in healthy control groups. Nutritional background is important; fed fish can have different basal levels of stress factors than starved fish. Nutritional level is extremely important in determining what a fish can do and what it can't do.

Temperature is an important variable that affects fish. Fall chinook given a very brief stress at temperatures that are representative of the Columbia River in early to middle runs, say, June and July temperatures, respond differently to handling stress than those stressed at late-run temperatures like those in early August. So, clearly, present environment influences the response of fish to*stress.

State of development can effect how a fish responds to stress. Coho salmon, sampled through the spring, experience a typical smoltification-kind of change in plasma levels of cortisol. If these fish are given a single very brief stress at various points in this process, the response to the same stress is greater and greater as the fish progress through smoltification. Thus, state of development is important in modifying the response to stress.

With that, I would like to give you a few brief examples of how knowledge generated in a fairly cost-effective way in laboratory settings can be used for management interpretations, using the types of theories that I've been talking about here.

There have been loading studies conducted at several different national fish hatcheries recently. We were able to evaluate loading and density at the Willard and Eagle Creek hatcheries. What we were able to find--based on a number of different physiological indicators of stress and smoltification, such as thyroxine and cortisol, among others--is that density appeared to be the most important variable affecting smoltification. Flow is secondarily important. Tn other words, metabolic loading was not as important, although it was not unimportant. Density does appear to be the most important variable. And interestingly, tag returns at both Eagle Creek and at Willard show tnat these data had anticipated the return rate: fish reared at high densities did not come back as well.

Since the psychogenic aspects of stress are important, we conducted an experiment with anesthetics in the Laboratory to see if we could eliminate that aspect of the stress response. Fish put to sleep with an anesthetic before they were subjected to stresses did not experience physiological reactions to the stress. To prove that this really meant something to the fisn, we allowed the fish to wake up in the dip net in which they were being held in the anesthetic. They remained in that dip net the rest of the day. Another grcup of fish was anesthetized immediately after capture and otherwise treated similarly. Fish in both groups were fully awake, the only difference being that one group was asleep as they went into the net, the other group was awake. The group that was awake experienced 32 percent mortality. The groups that were anesthetized before capture experienced only l0-20 percent mcrtaliry. An unanesthetized control group experienced 85 percent mortality. So, it appeared to us that clearly, pre-anesthetization, which eliminated the psychogenic aspect of fright associated with being chased around and captured, helped diminish the stress response. This sort of reaction really ought to have application in various aspects of management.

We were able to evaluate this at McNary Dam. Basically, the test was to avoid the stress that is associated with holding the fish at high density following collection at the dam, crowding them up and letting them flop onto a pan before they are anesthetized in the tagging procedure. Even though the evaluation situation was less than optimal for the fish, the fish that were anesthetized showed a significantly more rapid recovery from the marking procedure than those fish that were awake and then were anesthetized after :hey had gone into the marking shed at McNary, as measured by plasma cortisol levels, In another attempt to eliminate the psychogenic aspect of stress, we used the principle of leading a horse out of a fire with blinders on. In a laboratory experiment in which we acclimated steelhead trout either to light or dark, we stressed them and then allowed them to recover in either light or dark. Based on plasma cortisol levels, it appears that, independent of acclimation conditions, fish recovered in the dark much more rapidly than in the light. Again, we think that this is something that might be applied in a real-world situation.

We also had the opportunity to test this at McNary Dam. The collection facility, from the upwelling box to and including a raceway, was covered with black plastic, and thus we had fish that went through the dam and didn't experience bright sunlight, unlike controls that were coming into the normal raceways. The fish that recovered in the dark from the bypass of the dam recovered, as judged by plasma cortisol levels, more rapidly than those that recovered in the light.

One last example concerns the upstream side of McNary Dam. In 1982, we had the opportunity of sampling fish from the gatewell and then on the downstream side of the dam and in the raceway. We found that in the early and middle run of fall chinook, the fish that were sampled out of the gatewells appeared to be relatively unstressed--not entirely unstressed, but their stress indicators were "low". We felt fairly confident that fish coming through late in the run were stressed. At this particular time in late July or August, the gatewell was full of shad with the smolts bottled up behind them. We hypothesized that getting rid of the shad would relieve stress on the smolts. This was an obvious management strategy with which the Corps was also concerned. The Corps increased the fiow through the system and flushed out the shad. We then reevaluated the system. Both in 1983 and again in 1984, late-run fish appeared to be comparable to early-run fish in 1982. So, a simple strategy of increasing water flow--flushing the shad out-- appeared to alleviate the stress related to crowding caused by the bypass of shad.

We know that genetics affects the performance capacity of fish, environment affects it, and stress further restricts the capacity of fish to do the things they cculd otherwise do. I believe that what we need to know is, if the fish has a particular kind of performance capacity, how do things such as disease, temperature tolerance, or management practices modify that capacity.

I think we need to know what is normal for hatchery juveniles. What do normal hatchery juveniles do? As Dr. Lynwood Smith pointed out earlier, we also need tc know, as a yardstick, a measure of what wild juveniles do. Second, because of our sampling problem, I think we need to know what is done by hatchery and wild juveniles that are "destined" to survive seawater entry and then perform afterwards. It is not good enough to know what the average fish is like; we need a characterization of those that are going to be survivors. From such information, we can perhaps come up with a determination of what hatchery practices cause the difference between survivors and nonsurvivors

I would like to conclude with a few brief examples of more specific kinds of things at which we would want to look. First of all, we would like to know what is the deviation from normal and whether it is good or bad. Conczrlling the variance of the population, is it desirable to have a large variance or a small variance? Are survivors represented in one tail or the other of the populational variance? Second, how important is the synchrony of members of a population? Third, we need to know if stress indicators mask smoltification indicators Can stress mask those indicators or cause false indicators? Lastly, we need to know if "good" returning stocks have the same chsracteristics as "poor" returning stocks, for I believe we spend too much effort studying situations with problems and not enough effort learning how healthy, high-quality stocks function.

HEALTH MEASUREMENTS

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I have been studying the exercising of smolts for several years now. I got started in the late 1970's on exercising smolts as part of a major project on smolt indexing which was funded by the Tri-State Commission, and supported by Washington, Oregon, and Idaho. The project leader was C. Mahnken, who allowed me to attempt to influence smolting with exercise, something quite different from the general objective of developing a smolt index.

I started from the point of view that there were thousands of things happening to smolts. Virtually every function in their body is changing, and on that basis, I wanted to look at some general features of smolting. How could we stimulate the fish as a whole? Were there general things one could do so that the fish would then carry out the process of adjusting all those other little nitty-gritty things that the rest of the project members were looking at as specific indicators of smolting status?

On that basis, a student, Michel Besner, did nearly four years work on exercising coho smolts, the last two years of which were funded by the Tri-State Commission. The work was continued in a project that was funded by Sea Grant with the cooperation of Anadromous, Incorporated. Terry Greenke of Anadromous, persuaded us to change from continuous (Besner's strategy) to intermittent exercise. A number of additional people also contributed.

We have identified a number of effects of exercise. Stress resistance appears to be enhanced by exercise. Another student of mine, John Woodward, showed that exercise lowered the threshold for adrenalin production during stress.

Adrenalin increased more quickly and decreased faster in exercised than in non-exercised fish. We decided that an exercised fish is more like a wild fish than the typical hatchery product. Exercise may also enhance disease resistance. We had some cases of a lower mortality rate, in this case from bacterial kidney disease, in exercised fish than in controls. Most people would expect to see exercised fish as having increased vigor. This is an intuitive or very subjective criterion which is very hard to define, but we described vigorcus fish as being more alert and more active, as well as having increased swimming stamina. The one thing that peopie do agree on in exercise studies is that conversion efficiency increases, although sometimes at the cost of slightly increased food consumption. We also interpreted that in some cases exercised fish appear to be less concerned about their neighbors, perhaps because they were too busy swimming to be aggressive with the other fish around them. We have often wondered whether, in fact, hatcheries are producing fish which school when released rather than individual fish such as might occur in a stream. That is a question we would like to investigate.

Anotner benefit that we believed that we should see in exercised fish, altnough the estuarine research has not been done, is that exercised hatchery fish would know how to feed in the estuary. We have seen hatchery smolts coming down the river into the estuary and eating fir needles, sawdust chips, and all sorts of things that looked like hatchery pellets. They appear to swim around randomly at the surface. We would like to use exercise to train smolts in some way in the hatchery so that they wiil swim and feed at depth, and have a more effective predator avoidance system than we see at present. smolts need to make a relatively rapid adjustment to seawater. One of the great advantages that we had working with Anadromous, Inc. was that they held their fish in seawater ponds for three weeks before releasing them which allowed us to see changes in their behavior and physiology in sea water.

there 'have beer. a number of genetic studies which have consjstently shown that hatchery fish have become genetically different from wild fish. In Table l, I have tried to specifically consider smolts and to list the differences that we

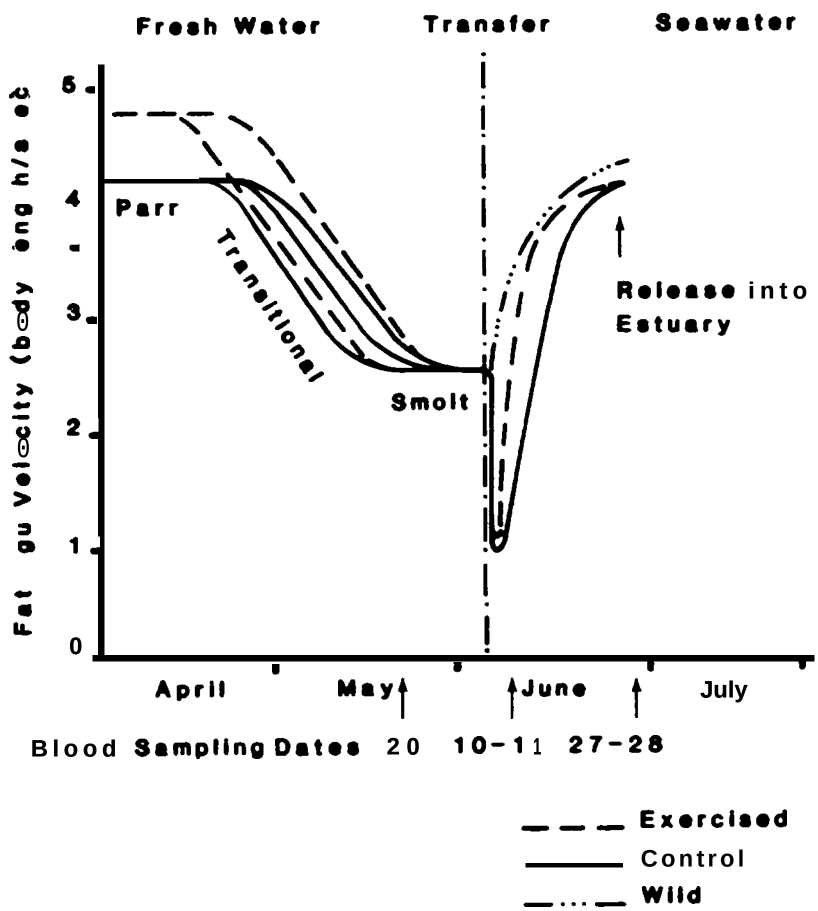


Figure 1. Change in swimming performance ability of young salmon around the period of smoltification, in fresh water and seawater.

have seen between ordinary smolts reared in hatcheries and exercised, or wild fish. Most of the comments concern coho smolts, but are not strictly limited to that species. I should note that the comments are as much personal Jbscrvations as they are the results of experiments.

During smolt transformation, there is a decrease in swimming stamina (defined as the maximum velocity which they can sustain for a period of time). Figure 1 summarizing about eight years of research shows that ordinary hatchery parr can maintain just a little bit over 4 body lengths per second; exercised fish acn maintain slightly more than 4 l/2 body lengths per second. But regardless of whether the fish are exercised or not, they suffer a decrease in swimming stamina 3t smcltification, to about half the parr level, and you cannot tell the exercised fish from the controls. At the point where the fish enter seawater--indicated by the dot-dash line--hatchery fish show a tremendous further decrease in swimming stamina and much lethargy. In the estuary, they vould be prime targets for predators. How much predation actually happens, I don't really know yet. A dash-dot curve (Figure 1) shows some data that we obtained a year ago on wild coho coming down Big Beef Creek on Hood Canal. These fish showed no decrease in swimming stamina whatsoever. They swam stronger and stronger minute by minute as we replaced the fresh water in the swim chamber with seawater. We believe that this is further evidence that hatchery smolts no longer perform like their wild counterparts.

Turning downstream migration, I think there is a real question as to whether smolts are feeding or not. During the entry into seawater that I just deserined, the smolts, whether exercised or not, eventually got all of their bodily functions properly adjusted. This is suggested by the fact that their swimming stamina finally increased to presmolting levels.

A thing that we saw at Anadromous Inc., that may have been one of the most significant things thus far, was the behavior of hungry, exercised fish. immediately after entering seawater, when they were being exercised in round ponds in the seawater, they turned and swam downstream with the current instead of holding their position against the current. And in the 3-foot-deep

TABLE 1 PHYSIOLOGY AND BEHAVIOR OF MIGRATING YOUNG SALMON, WILD AND HATCHERY-REARED

Physiology and Behavior	Juvenile Salmon	
	Wild	Hatchery-Reared
Swimming upstream	Hold position near bottom, obstructions, dart out from cover to feed.	Random swimming, feed at surface, schooling
Smolt transformation	Silver color, decreased condition factor	Same
Thyroxin surge	Decreased swimming stamina, lipid reserve	Same
Downstream migration (tailfirst?)	Off bottom, quick downstream migration, feeding stops(?)	Released on schedule, slow migration with delays
Entry into seawater	Immediate increase in swimming stamina	Further decrease, then increase in stamina
Downstream orientation	Immediate change to downstream swimming at sea water entry	Delayed change to downstream swimming

TABLE I PHYSIOLOGY AND BEHAVIOR OF MIGRATING YOUNG SALMON, WILD AND HATCHERY-REARED CON'T

?hysiology and Behavior	Juvenile Salmon	
	Wild	Hatchery-Reared
Feeding	Normal foraging (?)	Increased vigor when hungry
pass through estuary, nearshore waters	Avoid predators (?>	Predation by birds, sculpin, rockfish (?)
High seas navigatron	Electromagnetic cues?	Tow fish to sea in cages

ponds, they were in the bottom foot of depth. They also ate vigorously only twelve hours after entry into sea water. My interpretation of that behavior is that they probably would have oriented downstream in the salt wedge and gone out to sea. I recognize, of course, that the salt wedge oscillates back and forth and doesn't always flow downstream. But it took three, four, or five days for normal hatchery fish to start feeding and to orient downstream.

That response was the strongest in fish that were hungry going into seawater. They were supposedly being fed a maintenance ration in fresh water, and actually were gaining wet weight by adding water, but were losing dry tissue weight. Those exercised fish fed very vigorously in salt water, whereas the controls were quite lethargic. This would suggest that the exercised fish may have been more like wild fish than the controls, but I have no data for making comparisons, only observations.

I’m trying to think of simple ways to apply energy considerations and exercise to a hatchery situation. One of the questions is whether we should try to induce our smolts to imitate wild fish. I think that the answer is yes, mostly for lack of any other choices. One must recognize, of course, that wild fish are probably adapted to the Columbia River as it used to be, not as it is now. Related questions would be how to produce fish that are ready to go to sea, that is, how to stimulate fish to smolt at a specific time, instead of just identifying when the majority of the fish are ready to go as we do at present.

A third question concerns how to speed up the very slow migration rates in the Columbia River. One possible reason for slow migration is that fish may be coming down the river tail first. As the water velocity has slowed down with all of the added dams, the fish's upstream swimming speed nearly equals the water velocity. There should be something that we could do to move fish down the river more quickly. Perhaps we can get them to swim downstream head first? If so, they ought to come downstream in a few days. Since exposure to seawater seems to produce a downstream orientation, perhaps we should expose them to salt water at the hatchery by some means as simple as putting salt blocks in the raceway. Even if the fish oriented downstream, one would still have to determine how long the stimulus lasted out in the river where there was no salt to stimulate downstream orientation.

What should the bioenergetic status of smolting fish be? I think that we haven't looked enough at wild fish. My guess is that wild smolts are pretty hungry as they go downstream, because the exercised fish we saw at Anadromous, Inc., which were very hungry at sea water entry, survided best and behaved the most vigorously in the salt water--more like what I assume wild smolts must do. We need to put some radio tags on some releases and see how some fish behave in the estuary and the near-shore waters when they are really hungry. It appears that along with the reduced swimming stamina which I have already described, it may be normal for smolts to have very low lipid reserves during sownstream migration. And yet the average hatchery manager would say, "Oh Boy I really had good smolts this year. They were fat and healthy. None of those fish are going to starve to death." Maybe ihey should be hungrier rather than fatter at the beginning of their downstream migration.

A proposal that I have a graduate student working on now is to try to build an artificial stream in a normal hatchery raceway with high density rearing and see if we can come up with an exercise program to get hatchery fish tc orient to underwater turbulence like wild fish do in streams. That is going to cost the hatchery something in terms of the energy needed to increase the water velocities. However, it might also create some of the wild characteriz;ics that we need, such as foraging behavior, predator avoidance,m increased vigor, stamina, and conversion factor that seems to be characrrristlc cf wild fish.

I also want to show some specific stress data (Figure 2). We are using blood glucose as a stress indicator. These were coho smolts, exercised in fresh water at hnadromous, Inc., at three levels, for two hours in the mmorning and two hours in the afternoon. I want you to look at :he single point sample whitch was taken 24 hours after transferring the fish into seawatyr. The control fish (which had been swimming in less than half a body-length per

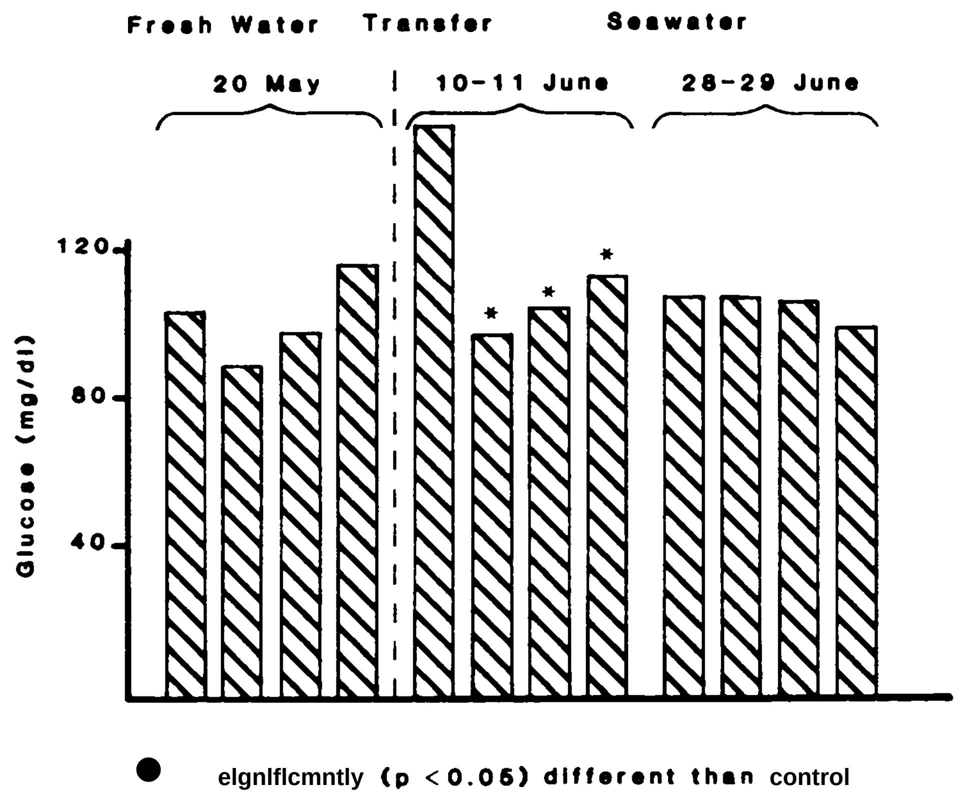
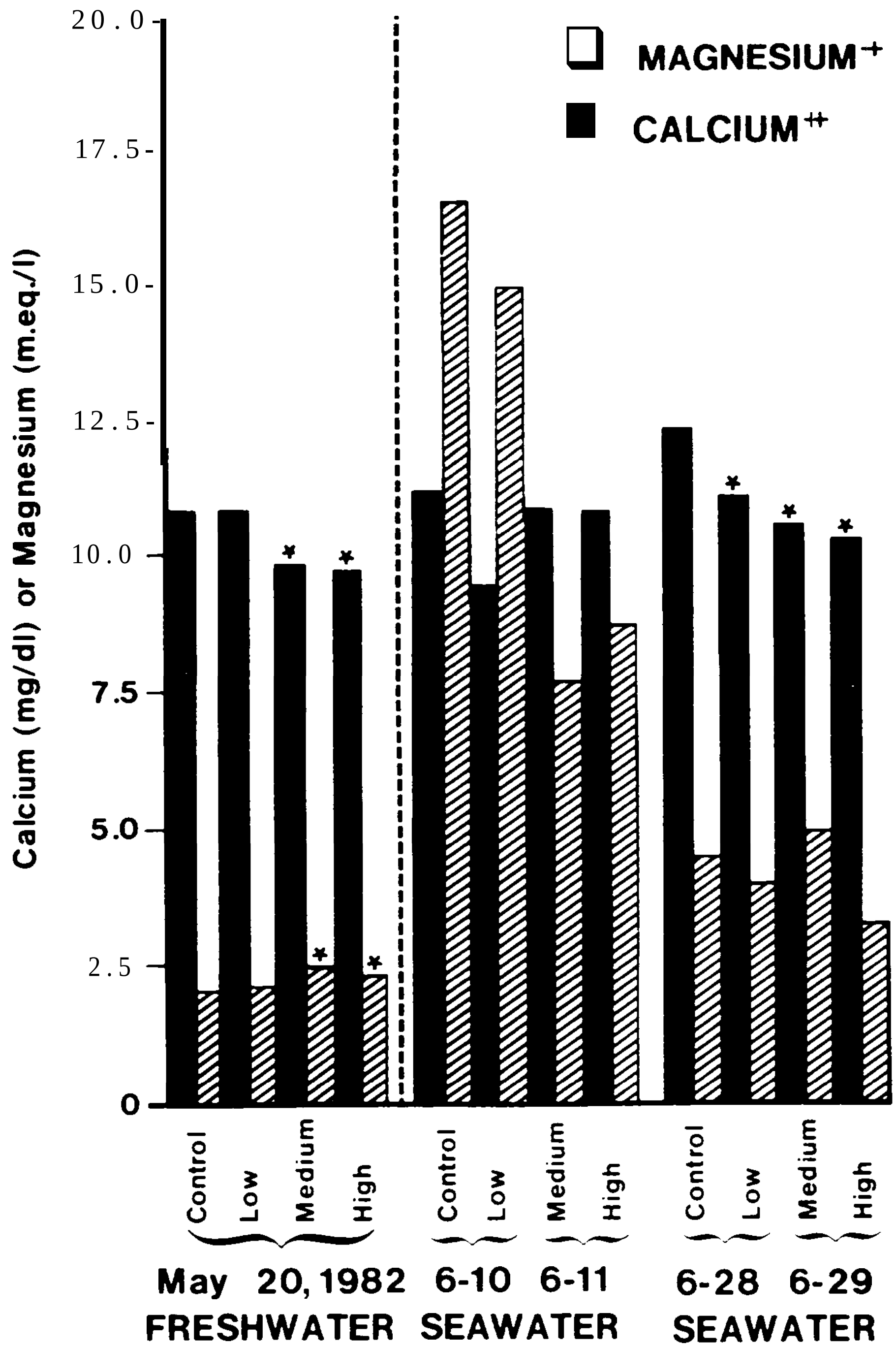


Figure 2. Indications of stress in exercised and non-exercised coho salmon smolts around the time of a transfer from fresh rater to seawater.

second water velocity) showed approximately 120 mg of glucose per LOO ml of blood. This indicates that the controls were not seriously stressed, as far as typical glucose stress data goes, but certainly that they were more stressed than the exercised fish. You can also see that the higher exercise levels were mildly stressful (in fresh water) as well. However, after nearly three weeks in sea water, when they were ready to be released, all four groups had managed to reduce their stress levels.

I also wanted to point out that there are some crucial things that we don't know about osmoregulation in smolts, especially regarding divalent ions in general and magnesium ion in particular. Data on plasma magnesium levels were taken at the same times as the blood glucose data shown in Figure 2. Both the control fish and the 2-length/set groups had high enough blood magnesium levels immediately after sea water entry that they should have died. There was considerable mortality from bacterial kidney disease in all groups at sea water entry, but control fish with the highest magnesium levels had the highest mortality (37 percent), whereas the 2-length/set exercised group which had the seccnd-highest magnesium leveis had the least mortality (l1 percent). We do not understand how smolts deal with the potential toxicity problems of magnesium ion when they enter seawater.

Finally, I would like to emphasize that the estuarine and near-shore coastal waters are probably the places where there is considerable smolt mortality. There have been a few observations of increased numbers of well-fed birds and rockfish around the Coos Bay and Newport release sites, although there seems to be no increase in birds around the mouth of the Columbia River. The offshore release experiments conducted by Oregon Aqua Foods (reported by McNeil in this workshop) have given anywhere from moderate to spectacular increases in adult returns. I believe that the exercise program that we carried out with Anadromous, Inc. showed promising results in fresh water. There also might have been long-term benefits (i.e., increased adult returns) that were masked by the El Nino oceanic conditions during the first year of the exercise program and by heavy predation in the estuary and near-shore waters during the second year. One possible way to test this hypothesis would be to exercise smolts again and release them offshore.



MAGNESIUM+
CALCIUM++
Calcium (mg/dl) or Magnesium (m.eq./l)
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
Control
Low
Medium
High
May 20, 1982
FRESHWATER
6-10
6-11
SEAWATER
6-28
6-29
SEAWATER

2.4 REARIYG AND RELEASE STRATEGIES TO PROMOTE SMOLT SUCCESS

Sex Control Strategies (E.M. Donaldson)

Lower River Release Strategies (R. Gowan)

Ocean Release Strategies (W. McNeil)

Upriver Release Strategies (T.C. Bjornn)

SEX CONTROL STRATEGIES

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INTRODUCTION

Salmon lend themselves to a wide range of culture strategies. As in some other vertebrates, one can induce ovulation and spermiation and regulate the time of spawning. When gametes are produced, the option is available of storing the sperm or eggs for a short period, or the sperm for an indefinite period. In addition, owing to the inherent flexibility of teleost reproductive mechanisms and the external fertilization process, there is the opportunity during early development to produce, not just regular fry (i.e., mixed males and females), but all-female fry or totally sterile fry by a variety of techniques. I will discuss first the production of sterile salmonids and the reasons for producing them in certain situations, and then the production, by various techniques, of female fry only. For the Columbia River, the production of all females is probably of particular interest.

PRODUCTION OF STERILE SALMON STOCKS

The objectives for producing sterile salmon for release into the natural environment are the following: (1) The harvest can be redistributed from the hatchery to the fishery by preventing anadromous migration. This is particularly applicable where large numbers of fish, as with coho, return to a successful hatchery. (2) The production of precocious males that have not achieved their full growth potential--"jacks''--can be eliminated. (3) Larger fish can be produced through extending the life span, in both ocean-release and landlocked freshwater strains. (4) Silver-bright quality can be maintained year-round in the fishery. (5) The value of the wide-ranging species such as chum, which deteriorate in quality as they approach subterminal and terminal fisheries, may be susceptible to improvement through delay of sexual maturation based on partial sterilization. (8) A large buffer of sterile fish could be deployed to reduce exploitation of wild stocks (provided that a ceiling were kept on the permitted harvests of the sport and commercial fisheries). Such fish would have no impact due to interbreeding.

Sterilization has strong potential for aquaculture and mariculture. In particular: (1) there is no problem of sexual maturation of either males or females; (2) it permits harvest of larger fish; (3) silver-bright quality is maintained; and (4) losses associated with males maturing in sea water are eliminated.

There are several current or potential techniques of sterilization. The first is androgen treatment during the alevin and early feeding stages. Androgen treatment has a high success rate, and there is no treatment-induced mortality if it is conducted properly. There is no problem of scale-up for production. The technique does involve the use of an androgen, and this can be of potential concern with regulatory authorities, although it appears that with appropriate safeguards, the authorities are going to approve the technique in Canada, and probably in the United States as well. While certain small amounts of androgen are used at the alevin and early fry stages, the levels of androgen in sterile fish of market size are much lower than in normal fish. One result of these lower androgen levels is a somewhat lower adult growth rate, although their ultimate size is greater because they live longer.

The androgen is administered during the alevin stage by recirculating water containing a low concentration of the appropriate steroid through the incubation system at intervals. In the early feeding stage, the treatment is continued for two to three months by feeding a diet that has had the androgen sprayed on it.

Sterilized fish can be distinguished from normal males or females at 3-5 months by histological examination of the gonads, and in older salmon by dissection and direct visual examination. Rainbow trout are more difficult to sterilize than coho salmon, and further research is underway on this species.

At the age of maturation, the difference between the silver-bright quality of the steriles and the dark color of the mature females is very evident. It is at this time that the dressed weight of the sterile fish overtakes that of the normal fish.

Our first experiment on sterilization of coho salmon for ocean release was begun at Capilano Hatchery with the cooperation of the Salmonid Enhancement Program in 1978. Fertilization took place in the fall, and the sterilization treatment was conducted in the winter of 1978-1979. Coded-wire tags (CWT) were inserted, and the smolts released in the spring of 1980 after 15 months of rearing. No jacks came back that fall. Both steriles and controls were caught in the fishery in the next summer, and then many femaie controls and a few fish marked as steriles returned to the hatchery as 3-year-olds in fall 1981. The few "steriles" that came back proved not to have been sterilized completely. In the fourth year, 1982, additional steriles were harvested in the fishery, but only one or two control fish, and in the fifth year, 1983, a handful of steriles were harvested.

CWT data from the fishery indicated that the fish appeared to remain in coastal waters. Most of them were caught in the Strait of Georgia and off the west coast of Vancouver Island; others were caught in Puget Sound or off the west coast of Washington. Comparison of the harvest of 3-year-old steriles with a set of all-female controls indicates that more females were caught than steriles, particularly near the hatchery where the females that homed to the river mouth were caught in the terminal sports fishery. On the other hand, the harvest of b-year-olds consisted almost entirely of steriles. In this first release, a little more than 70 percent of the steriles were caught as 3-year-olds, less than 30 percent as 4-year-olds, and a few as 5-year-olds.

A graduate student in this laboratory, Tillmann Benfey, is investigating the production of steriles by the induction of triploidy. Unlike the first technique, it does not involve the use of a steroid. Testicular development is not fully inhibited in triploid salmonids, so the procedure is preferably used on all-female stocks. There is some treatment mortality, but it is at the egg stage, so the loss is not great in economic terms. Scale-up requires rigid control of treatment parameters. Early data indicated a possible lower growth rate in triploid fish, but the data on growth has been variable, and some more recent data indicate that they can grow just as well as controls, although they do not grow any better than controls.

To induce triploidy, the eggs are subjected to heat or hydrostatic pressure shock after fertilization with normal sperm. This prevents the separation of the second polar body, and thus, instead of a diploid zygote with two sets of chromosomes, a triploid zygote having three sets of chromosomes is obtained. Triploids can be identified by using a flow cytometer to measure the amount of DNA in erythrocytes (unlike those of mammals, the red blood cells of fish contain a nucleus).

The development of techniques for sterilization of Pacific salmon has provided a powerful new tool for fisheries managers and mariculturists. It will take a number of years to fully explore and evaluate the use of this technique for both ocean-release fish and those raised in captivity. We have conducted a number of further releases since our original one, and the CWT data will be coming in from those in subsequent years.

PRODUCTION OF MONOSEX FEMALE STOCKS

Increasing the numbers of female salmon probably has greater application than sterilization in the situation we are discussing this week: the enhancement of the Columbia River hatchery stocks. In British Columbia, we have been applying the techniques of producing female smolts to our chinook salmon in order to increase the egg takes at our hatcheries. The objectives for production of all-female cohorts of salmonids for release into the natural environment are the following: (1) We can enhance suboptimal or endangered stocks by increasing the proportion of females in a given escapement. Typically, fewer than half of the fish returning to the hatchery are females, and there is no reason why the proportion of females could not be increased at the expense of the number of males. (2) In the case of a healthy stock, it is possible that one could maintain egg take with the return of fewer fish to the hatchery (a lower total escapement) by having a larger proportion of females in the escapement. (3) The technique reduces the number of jacks and, particularly in the case of chinook, changes the structure of the population towards older fish, because the females tend to mature at an older age. (4) The technique also increases the value of the commercial catch by producing a higher proportion of roe-bearing fish.

For commercial aquaculture, the advantages of rearing all-female stocks are three: (1) The technique eliminates the problem of precocious males, and thus permits harvest of larger fish over a longer period. (2) It eliminates mortality of precocious males in seawater. (3) It reduces the cost of keeping a captive brood stock, because if the farmer raises mainly females, he can save the cost of the food that the males would have eaten and the pen space they would have occupied.

The first feminization technique that we developed and used was direct production of phenotypic females by estrogen treatment in the alevin and early feeding stages. The term phenotypic refers to the appearance of the fish: externally and internally it is a female, although it may not be genetically. The treatment with estradiol is fully effective. The fish are indistinguishable from normal females, and there is no treatment mortality at the optimum dose. It does involve the use of an estrogen, but it is the normal salmon estrogen (which is the same as the one that occurs normally in human beings). The problem is that half the fish are genotypic males and not suitable for broodstock, although they are suitable for rearing for harvest. Examination of ovaries after about five months of rearing indicates that those taken from the genetic males have the same appearance as those from genetic females.

Ohe second technique that we have developed for Pacific salmon is the indirect production of all-female cohorts using milt from genotypically female fish that had been converted to phenotypic males by androgen treatment in the alevin and early feeding stages. Such fish develop as normal males and produce sperm, but all of the sperm contain X (female) chromosomes rather than half containing Y chromosomes. The procedure is fully effective: 100 percent females are produced, and the fish are normal genotypic females that can be used as broodstock. Steroid treatment is only used in the initial stage--in the previous generation. Since it is a two-stage process, considerable lead time is required to implement the technique.

In our initial and continuing work on the production of female chinook milt for the hatchery program and for commercial mariculturists, we have reared the males producing the female milt in captivity at the West Vancouver Laboratory. In recent years, however, we have also embarked experimentally on a different strategy. This second technique uses the natural ocean environment to produce the female sperm. Normal production alevins of mixed genotype (XX and XY) are treated with androgen. The fish which are now all phenotypic males, are then reared to smolt size, marked with coded wire tags (CWT) and fin clips and released into the ocean. Lhen these fish mature, they return to the hatchery as XY and XX males; if there are equal numbers, 75 percent of the sperm will be female and only 25 percent male. Mlilt from these fish can be used to produce 75 percent female offspring with normal eggs. There is also an option to keep the families separate, masculinize a portion of each family, conduct progeny testing to determine which of these are the XX families, and then re-treat with androgen in the next generation, thus obtaining sperm that produces 100 percent females. This is what we have done to date in our laboratory and hatchery studies. In the past three years (1983-19851, we have been providing increaing amounts of chinook sperm that produce only female offspring, for hatchery studies and for commercial mariculture.

The status of hatchery production of all-female chinook salmon to increase egg takes is as follows: In June 1983 at Capilano Hatchery, we released 175,000 marked, phenotypic males. When the fish return, these males will be separated, and their sperm will be used to fertilize production eggs. This process should produce 75 percent females. A group of 100,000 all-female chinook were released in June 1984 from the Capilano Hatchery. These were all-female, CWT-marked smolts from X milt that we had produced at the West Vancouver Laboratory. In fall 1985 and spring 1986, we are going to release two groups of 50,000 females produced with X milt. They will have been held in the hatchery longer than the normal 90-day smolts and will thus be released at a larger size. Another group consists of all-male fish having a loo-percent-female genotype which were treated with androgen to convert them to phenotypic males; 100,000 of these have been produced and externally marked. Half will be released in fall 1985 and half in spring 1986. When they return as adults, they will produce 100 percent female milt for the fertilization of production eggs at that time. Those eggs will then develop as a production batch of all-female smolts for ocean release. As the chinook males return as 2-, 3-, and 4-year-olds, from one release we expect to obtain males for three years that can be used in this way. Lastly, at Big Qualicum Hatchery in fall 1984, we used our "female" milt to treat 420,000 chinook eggs for commercial mariculture in British Columbia, and this program will be expanded in fall 1985.

There is a third technique that can be used to produce all-female groups of salmon. This technique, induced gynogenesis, is another chromosome-set manipulation technique which is being investigated in our laboratory by Tillman Benfey. Gynogenetic salmon are all females, but there is a significant mortality associated with the technique at present, and the production characteristics of gynogenetic fish have not been evaluated fully. The technique is a research tool, and it will probably not be used directly in hatchery or aquaculture production. It involves the irradiation of the sperm with ultraviolet light to destroy the genetic material. Consequently, when the irradiated sperm activates the egg, it does not contribute any genetic material. If allowed to develop, the cells of the embryo would have only one set of chromosomes--the embryo would be haploid. Haploid embryos develop "haploid syndrome" and die before they hatch. If the newly fertilized egg is subjected to heat or hydrostatic pressure shock, however, the separation of the second polar body is prevented and the embryo is converted to a diploid. Offspring produced by inhibiting the separation of the second polar body are partly inbred. If, on the other hand, diploidy is restored by preventing the first cell division, the offspring are homozygous, or, in other words, completely inbred. The latter process is quite difficult to accomplish, and requires further research and development.

In conclusion, the development and implementation of sex control techniques for Pacific salmon have opened up a whole new range of options for the enhancement and management of hatchery stocks, and also for the optimization of commercial aquaculture systems.

Q: How long do the sterile fish live?

A: In the ocean environment, they are subject to natural mortality, and the oldest coho captured in the fishery from our original release were a relatively small number of 5-year-olds. On the other hand, quite a few 4-year-olds were harvested. They have lived in captivity as long as seven years, but by the sixth or seventh year, they are not feeding as well; they have probably passed through a normal aging process. The life of the Pacific salmon is cut off in its prime by sexual development. Ghen salmon are sterilized, they realize their full potential life span.

REFERENCES AND FURTHER READING

Benfey, T.J. and A.M. Sutterlin. 1984. Growth and gonadal development in triploid landlocked Atlantic salmon (Salmon salar). Can J. Fish. Aquat Sci. 41:1387-1392.

Chourrout, D. 1984. Pressure-induced retention of second polar body and suppression of first cleavage in rainbow trout: production of all-triploids, all-tetraploids, and heterozygous and homozygous diploid gynogenetics. Aquaculture. 38:111-126.

Donaldson, E.M. and G.A. Hunter. 1982. The ocean release and contribution to the fishery of all-female and sterile groups of coho salmon (Oncorhynchus kisutch), in proceedings of the International Symposium of Reproductive Physiology of Fish, Wageningen, Netherlands, 2-6 August 1982 (H.J.Th. Goos and C.J.J. Richter, eds.), p. 78. Pudoc, Wageningen.

Donaldson, E.M. and G.A. Hunter. 1982. Sex control in fish with particular reference to salmonids, in W.S. Hoar Symposium, Fish Reproduction: Behavior and Endocrinology. Can. J. Fish. Aquat. Sci. 39:99-110.

Donaldson, E.M. and G.A. Hunter. 1985. Sex control in Pacific salmon: implications for aquaculture and resource enhancement, in Proc. Salmonid Reproduction, an Int. Symp., Review papers (R.N. Iwamoto and S. Sower, eds.), pp. 28-32. Washington Seagrant Program, Bellevue.

Donaldson, E.M. 1986. The integrated development and application of controlled reproduction techniques in Pacific salmonid aquaculture. Fish Physiology and Biocheministry 2:9-26.

Goetz, F.W., E.M. Donaldson, G.A. Hunter, and H.M. Dye. 1979. Effects of estradiol-17beta and 17alpha-methyltestosterone on gonadal differentiation in the coho salmon, Oncorhynchus kisutch. Aquaculture 17:287-278.

Hunter, G.A., E.M. Donaldson, F.W. Goetz, and P.R. Edgell. 1982. Production of all female and sterile groups of coho salmon (Oncorhynchus kisutch) and experimental evidence for male heterogamety. Trans. Am. Fish. Sot. 111:367-372.

Hunter, G.A., E.M. Donaldson, J. Stoss, and I. Baker. 1983. Production of monosex female groups of chinook salmon (Oncorhynchus tshawytscha) by the fertilization of normal ova with sperm from sex-reversed females. Aquaculture. 33:355-364.

Hunter, G.A. and E.M. Donaldson. 1983. Hormonal sex control and its application to fish culture in Fish Physiology, Vol. IX, part B, Behavior and Fertility Control, ch. 5 (W.S. Hoar, D.J. Randall and E.M. Donaldson, eds.), pp. 223-303. Academic, New York.

Lincoln, R.F. and A.P. Scott. 1983. Production of all-female triploid rainbow trout. Aquaculture 30:375-380.

Lincoln, R.F. and A.P. Scott. 1984. Sexual maturation in triploid rainbow trout, Salmon gairdneri Richardson. 3. Fish Biol. 25:385-392.

Onozato, H. 1984. Diploidization of gynogenetically activated salmonid eggs using hydrostatic pressure. Aquaculture 43:91-97.

Parsons, J.E. and G.H. Thorgaard. 1983. Production of androgenetic diploid rainbow trout. J. Hered. 76:177-181.

Refstie, T., J. Stoss, and E.!I. Donaldson. 1982. Production of all female coho salmon (Oncorhynchus kisutch › by diploid gynogenesis using irradiated sperm and cold shock. Aquaculture 29:67-82.

Scheerer, P.D. and G.H. Thorgaard. 1983. Increased survival in salmonid hybrids by induced triploidy. Can. J. Fish. Aquat. Sci. 40:2040-2044.

Solar, I.I., E.M. Donaldson, and G.A. Hunter. 1984. Optimization of treatment regimes for controlled sex differentiation and sterilization in wild rainbow trout (Salmon gairdneri Richardson) by oral administration of 17alpha-methyltestosterone. Aquaculture 42:129-139.

Solar, I.I., E.M. Donaldson, and G.A. Hunter. 1984. Induction of triploidy in rainbow trout (Salmon gairdneri Richardson) by heat shock and investigation of early growth. Aquaculture 42:57-67.

Solar, 1.1. and E.M. Donaldson. 1985. Studies on genetic and hormonal sex control in domesticated rainbow trout. I. The effect of heat shock treatment for induction of triploidy in cultured rainbow trout. Can Tech. Rep Fish. Aquat. Sci. 1379.

Solar, 1.1. and E.M. Donaldson. 1985. Studies on genetic and hormonal sex control in domesticated rainbow trout. II. Use of methyltestosterone for masculinization and sterilization in cultured rainbow trout. Can. Tech. Rep. Fish. Aquat. Sci. 1380.

Solar, I.I., I. Baker, E.M. Donaldson, G.A. Hunter, and E.T. Stone 1986. Coded wire tag recoveries from the first release of all-female and sterile groups of coho salmon (O. kisutch) into the marine environmental Canadian Data Report of Fisheries and Aquatic Sciencies, No. 609.

Thorgaard, G.H. 1983. Chromosome set manipulation and sex control in fish, in Fish Physiology, Vol. IX, Part B, Behavior and Fertility Control (W.S. Hoar, D.J. Randall, and E.M. Donaldson, eds.), pp. 403-434. Academic, New York.

Ctter, F.M., 0.x. Johnson, G.H. Thorgaard, and P.S. Rabinovitch. 1983. Measurement and potential applications of induced triploidy in Pacific salmon. Aquaculture 35:125-135.

LOWER RIVER RELEASE STRATEGIES

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I was asked to talk about lower river release strategies. I define release strategies as a manipulation of the time of liberation designed to meet conditions extraneous to the hatchery. I also wanted to talk about a technique that increases survival, so I included smoltsize at release from the hatchery.

When I began getting material together for this report, I started calling all the people involved in Columbia River research on "smolt size and time of release" studies that have been done in the past, primarily W. Hopley from Washington and A. Hemmensen and R. Ewing from Oregon. I got the impression that time and size of release had been done at length--that everyone had done it, and that the issue was pretty well settled. But the more I got into it, the more confused I became. As far as smolt size at release experiments are concerned, there have been several done, but usually the experiments run two months or two groups in a month. There is no continuum, say, from April through July.

In an experiment at the Toutle River Hatchery, a repetition of an earlier experiment, they had small, medium, and large fish released in April and then again in !lay (Table 1). You can see in both months approximately a 40 percent increase in survival going from the small to large fish. That result is consistent with most other size at release experiments done on the lower Columbia and on the Oregon Coast which is: a larger size for a given time results in increased survival. But the increase is highly variable. My company runs serial time of release experiments from April through August. We

TABLE 1 ESTIMATED CONTRIBUTION TO FISHERY BY TIME - GROUP OF 1972 - BROOD TOUTLE RIVER COHO SALMON

Release Date, 1974	Size at Release (g)	HARVEST Oregon Sport, Troll	California Troll	Columbia River	Washington Sport, Troll	Hatchery Returns	Total	Percent of Total
1 Mar	20.1	744	385	60	362	356	1,907	3.65
1 APR	14.2	734	322	12	220	296	1,584	5.00
1 APR	20.5	704	482	0	320	387	1,873	4.48
1 APR	30.5	687	357	73	293	420	1,830	3.73
1 May	14.2	867	83	73	299	444	1,766	5.71
1 MAY	21.5	573	333	60	429	359	1,754	4.10
1 MAY	29.6	641	224	126	252	451	1,694	4.05
1 Jun	20.0	1,355	590	240	639	563	3,387	8.19
1 Jul	11.7	2,044	727	287	1,127	910	5,095	16.40
1 May	18.0	417	138	165	242	305	1,267	3.97
1 Msy	18.0	671	233	85	241	389	1,619	3.92

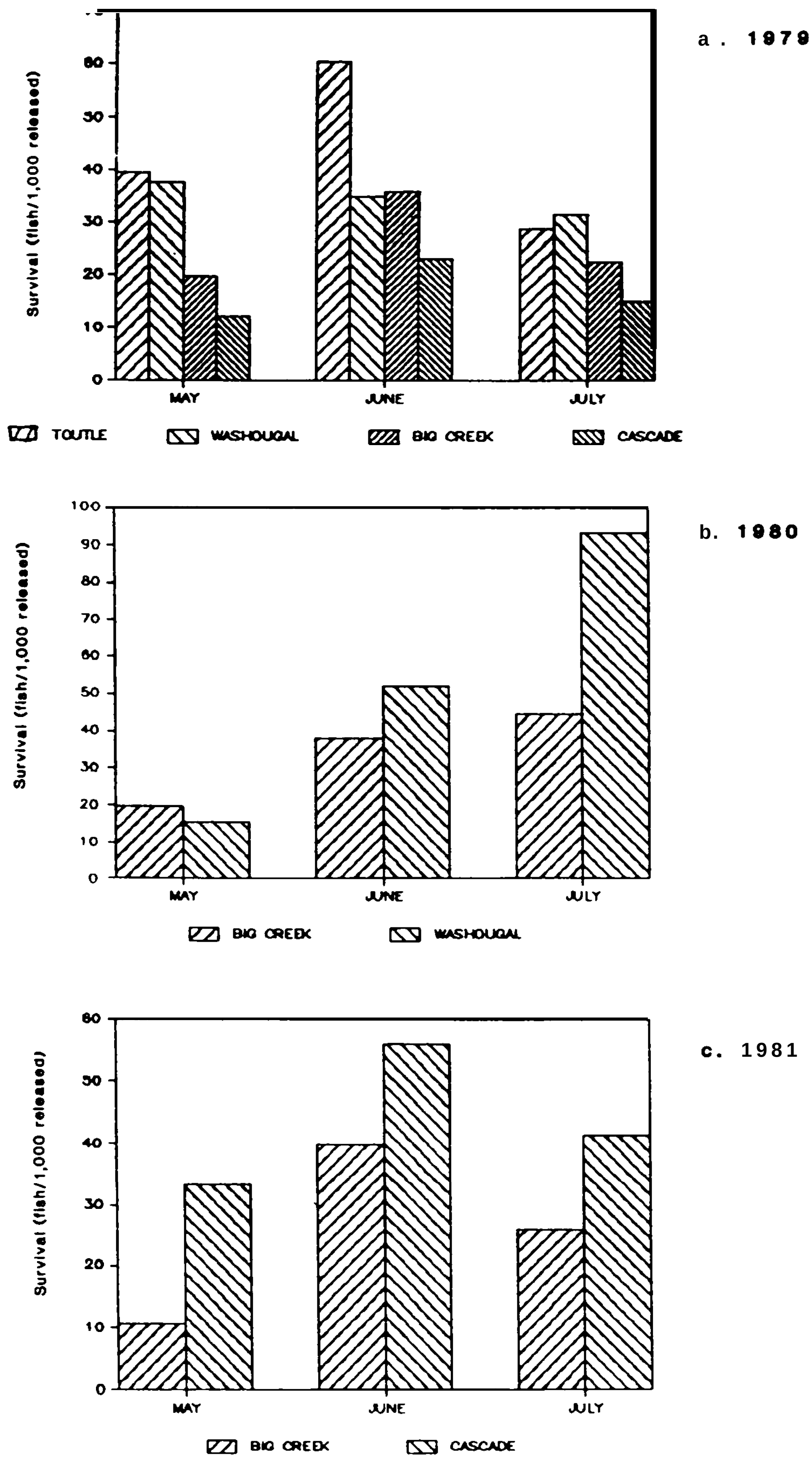

Figure 1. Survival rate to adulthood of coho salmon released at Columbia River Hatcheries in **May,** June, and July, 1979-1981.

find that for some periods, you can double size and get about a 10 percent increase in survival; in other periods, you get a 200 percent increase in survival. So the increase that you get is highly variable.

When I started looking at time of smolt release for the Columbia River, the most comprehensive time of release study of which I was aware was the joint experiment done by the Washington Department of Fisheries and the Oregon Department of Fisheries starting with the 1979 release cycle. In 1979, experiments were done at four hatcheries (Figure la): the Toutle and Washougal hatcheries in Washington and the Big Creek and Cascade hatcheries in Oregon. There were a few trends that were readily apparent from the first releases. By the way, these numbers represent survival per thousand fish released, and the fish were generally the same size at release. The Washougal showed a slight decline in June survival as compared to ?lay, but all the other hatcheries showed the best return from a June release, and there was a substantial increase in survival with a June release compared to a May release. In 1980, Big Creek and Washougal continued the serial releases (Figure lb). In that year, survival increased into June, but also increased again into July. So the best period to release changed from one year to the next.

After 1980, Washington dropped out for budgetary reasons, but Oregon continued to conduct serial releases. In 1981, the Big Creek and Cascade hatcheries released groups in May, June, and July (Figure lc). In terms of survival, June was the best month, followed by July and then May. To those 1981 data, I have added our May, June, and July releases from Coos Bay (Figure 2a). I was looking to see if there was a common thread among all these release experiments. In other words, if June is optimum to the Columbia, is it optimum also on the Oregon coast? That was not the case for the Coos Bay forced releases in which survival increased steadily and appreciably over time.

Big Creek continued serial releases in 1982 (Figure 2b), when May and June produced almost equal survival, but the situation changed with 1983 data from

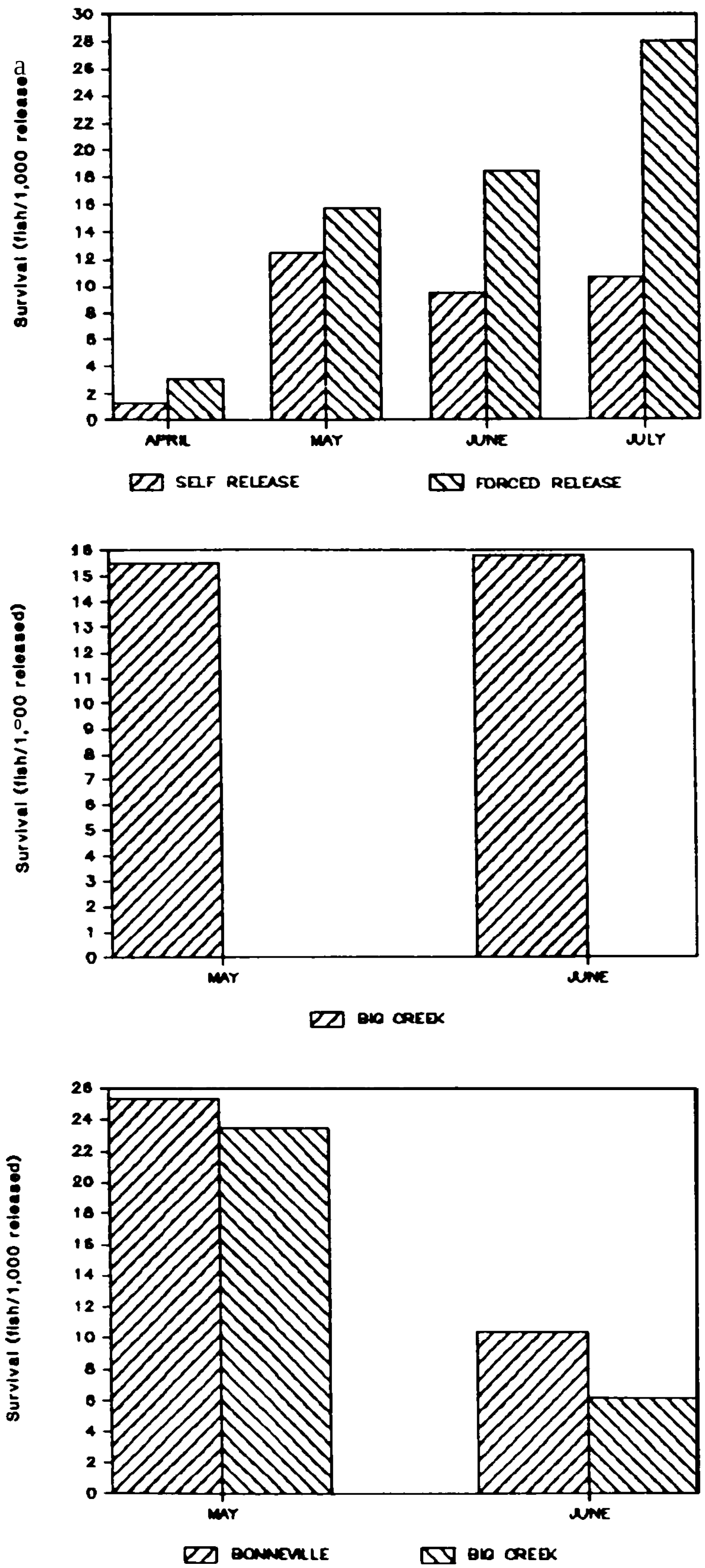

Figure 2. Survival rate to adulthood of coho salmon released at Coos Bay, Oregon at two Columbia River **Hatcheries,** in various months, 1981-1983.

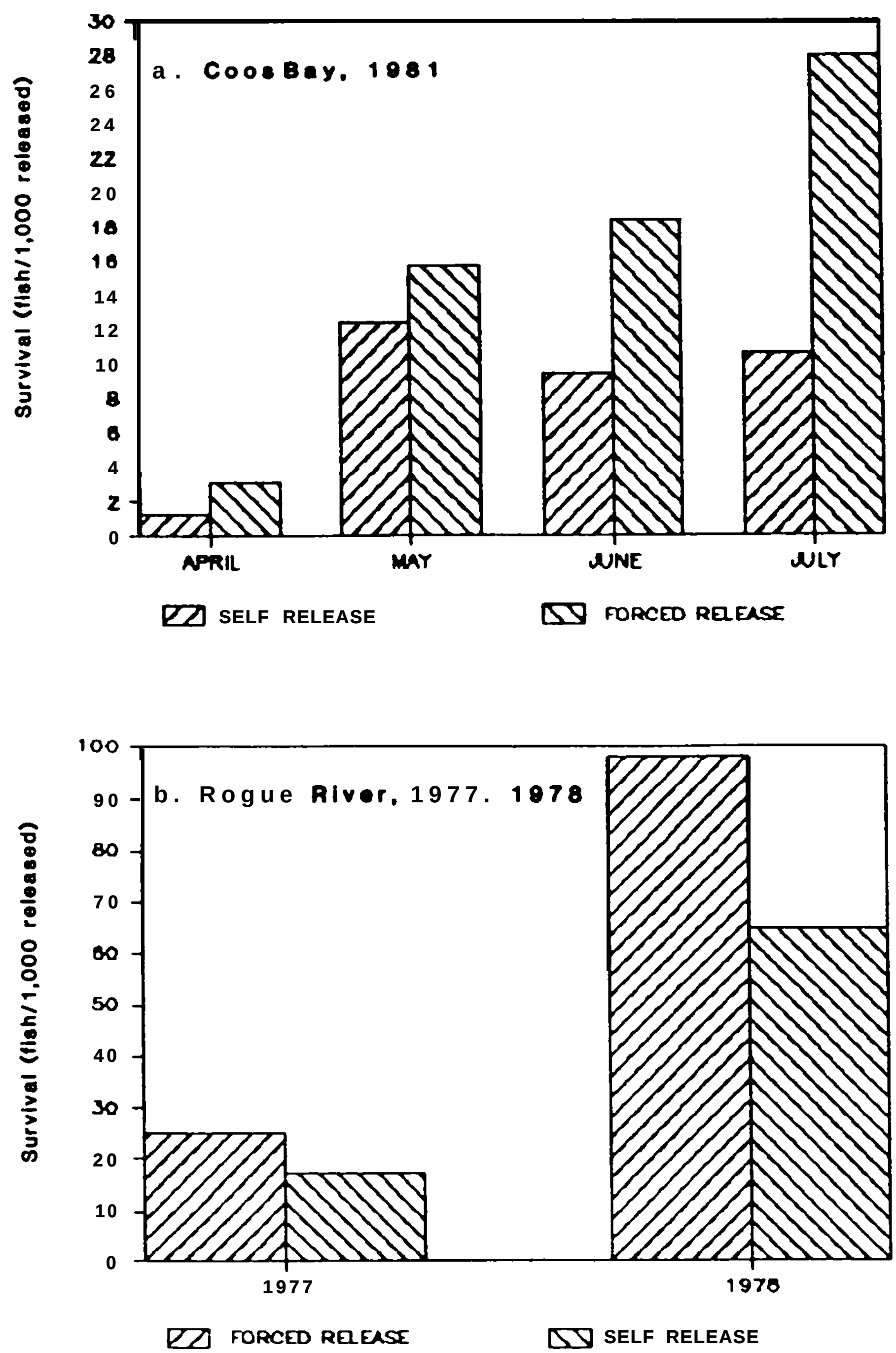

Figure 3. Survival rate to adulthood of coho salmon self-released or force-release at Coos Bay and steelhead self-released and forced-released at Cole Rivers Hatchery.

Bonneville and Big Creek hatcheries (Figure 2c), which continued to conduct serial production and evaluation releases. In 1983, May releases in these experiments produced double the survival of June releases. But also in 1983, our May releases at Coos Bay survived at a low rate while June produced the best survival, and for July releases, survival was intermediate. Time of release is important--but which time is optimal?

As far as release strategies go, there has been a lot of interest in volitional or self-released fish versus forced-release fish. By volitional, I mean that the screen is pulled on fish that are in a raceway or rearing pond, and they are given a certain period of time to outmigrate on their own. It has been thought that this technique must be better than pulling the screen on the raceway and crowding the fish out. I'm not so sure about that after a release experiment we conducted in 1981 comparing forced with volitional release.

We compared a volitional release with forced-releases in an experiment over a four month period. In the raceways containing the volitional-release groups, we pulled the screen and gave them two weeks to outmigrate. During the middle of the outmigration period for the volitional groups, the forced-release groups were released by pulling the screens and crowding the fish out. For all four months, the forced-release groups survived at a better rate (Figure 3a). We don't know why forced-release groups survived better than volitionally released fish, but we think it might have been related to swamping the local predators.

I thought these results were unique, but Dick Ewing has given me some data from the Rogue River Hatchery. The Rogue has been conducting volitional versus forced release for the last four years with steelhead. The returns are complete for the first two years of the release (Figure 3b). It is the same general design that we used, except that fish not outmigrating at the end of the two-week period were removed from the raceway and used as catchable-fish planters, so actually these numbers in the table are a little deceptive. If you start with 1,000 fish in a raceway, let 700 self-release, and count that as your release number in computing your survival portion, you get one amount. But if you count the total number of fish in the raceway prior to release, you get an even greater difference between forced and volitional releases.

These results are consistent with Harry Wagner's study on the Alsea River in the mid-1960s when he conducted volitional versus forced release with steelhead. I am not saying volitional release is not good; I am only saying that if it is done, it should be evaluated to see if it does, in fact, confer a survival advantage.

I have heard a lot of discussion about adapting to the local situation, "adaptive fisheries management", at this workshop. In looking for an example of it, I had to go to British Columbia to The Big Qualicum Hatchery (Perry, 1983). At that hatchery, they had a problem with bird predation. The hatchery was very close to the ocean, sitting almost on the estuary, and marine birds preyed heavily on outmigrating smolts. They estimated the extent of the predation by sitting up on a jetty with binoculars, counting strikes of the gulls, and recording successful strikes. They came up with a numerical estimate of bird-caused mortality:

	1979	1980	1981	1982
Number Released (in millions)	2.55M	2.90M	4.34?l	3.47?l
Predation Est.	220,000	300,000	860,000	50,000
Percentage	8.7	10.4	19.8	1.3

Thus, the predation rate in 1980 was 10 percent, and in 1981, they lost 20 percent. At that time, they changed their release strategy, primarily by three methods. They released late in the day in a period when the tide would be high the following morning to give the fish more water depth to escape predators. They moved the release from an earlier period to mid-June to coincide with expected low abundance of birds, and they force-released the fish instead of using volitional release. In 1982, the estimated mortality from bird predation dropped to 1.3 percent

This has been a quick trip through release strategies, but let us see where we are now. Time of release is important, but in any given year you don't know which time. And if you aren't going to look into the ocean conditions just in order to correlate survival with environmental factors, concentrating on June in one year may be a disaster. I think that in the Columbia this year, the jack returns from June releases was one of the lowest on record.

Larger smolt size at release is generally a survival advantage, but I would also consider that if you double the size of the smolts to maintain your production, you could have to double your survival to get the same number of fish back, so there is a problem of decreasing returns there. In the past, my company has released fish large enough to harvest and I sometimes wonder why we bothered putting them in the ocean.

I believe that it's important for someone or some agency, if not BPA, to relate time of release and other factors to oceanic or near-shore conditions. We know that conditions external to the facility determine adult survival. The purpose of this meeting is to find strategies which increase survival. Time of release has demonstrated a two- to three-fold increase in survival, but it is clearly a shotgun approach. We need to know why time of release and other releases strategies are important, as they relate to oceanic conditions.

REFERENCES

Perry, T., 1983. Bird predation of hatchery reared salmon. Proc. N.S. Fish Cult. Conf., pp 76-77.

OCEAN RELEASE STRATEGIES

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I would like to re-emphasize that the ocean is an integral part of the ecosystem of salmon, and it plays as significant a role in survival and production as fresh water does. We face many frustrations in attempting to define variables that we might control in the hatchery production process to improve marine survival. Our coho salmon program focuses on zero age smolts. These are reared in a freshwater hatchery and trucked as smolts to the coast and held in saltwater ponds (usually for a period of 10 days to two weeks) and are then released into Coos Bay or Yaquina Bay. The numbers, in millions, of juvenile salmon released from 1978 to 1985 are as follows:

1976	1977	1978	1979	1980	1981	1982	1983	1984	(Proj.) 1985
2.5	2.5	11.0	8.2	16.7	26.0	24.0	19.4	12.2	8.7

These numbers give some idea of how our production has trended over the years; they show that in 1981 and 1982, we reached rather high release numbers. Coincident observations on feeding behavior of common murres (a common fish eating seabird) in Coos Bay and Yaquina Bay, particularly the former, go some way in explaining why we implemented an off-shore release program.

Observations conducted by the University of Oregon, Institute of Marine Biology, indicated that the feeding behavior of murres changes in response to the availability of prey. Murres do not ordinarily feed on juvenile

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salmonids; but in 1981, institute biologists found a very high incidence of juvenile salmon in the stomach contents of birds, presumably from releases by private hatcheries. There were some preliminary estimates that murres consumed upwards of 50,000 smolts per day. These estimates, of course, are provisional. Based on estimated population size on the Oregon coast and the murre's requirement for fish or seafoods to maintain bodily function, this bird predator is more than capable of consuming all of the smolts released from all of the hatcheries up and down the coast, including the Columbia River, perhaps 3 or 4 times over. And the murre is but one of many fish predators. I am not going to blame the murre for our lack of success in getting fish back from the ocean, but it may be an important contributor.

In an attempt to reduce near-shore predation, two companies, Oregon Aqua-Foods and Anadromous, Inc., are cooperating to develop and construct an offshore-transport vehicle. The prototype vehicle has been launched. It moved its first experimental groups of fish offshore yesterday. All field trials have been encouraging in terms of the mechanics of moving fish offshore.

We base this program on four postulates: (1) Ocean mortality is highest and most variable during and shortly after smolts enter the sea; (2) Ocean mortality is due largely to predation, but the capacity of smolts to osmoregulate, grow, and resist disease can affect their vulnerability to predation; (3) Ocean mortality from predation is density-dependent, but functional responses between mortality and smolt abundance are not well understood; and (4) Ocean mortality from predation can be reduced by modifying release strategy and procedures.

Field observations indicate that murres have switched from marine forage fish and invertebrates to salmon smolts when smolts have become available in coastal estuaries and near-shore waters. Observations also indicate a decided increase in the density of murres in near-shore areas, where smolts are most concentrated.

The estuary and its entrance to the ocean between jetties may act as a funnel. Smolts are concentrated as they pass through the funnel, a narrow and shallow body of water where predators can have easy access to prey. Unfortunately, functional responses between mortality from predation and smolt abundance are not well understood.

Experiments with offshore release of Atlantic salmon in Europe provide some encouraging background information. A summary of the results of 18 observational studies conducted over a decade has been compiled (Larsson 1982: Hansen 1982). Tagged smolts were released onshore and offshore; the results are expressed as the ratio of offshore-release fish to onshore-release in tagged fish, both in the fisheries and at the release locations. Fifteen of the 18 observations showed a ratio greater than one for recovery from offshore release, ranging from 1.2 to 13. Two observations were indifferent (1.0) and one observation favored the onshore release group (0.6). The average offshore/onshore release recovery ratio for the 18 observations was 2.8. Several workers in Europe have expressed the opinion that predation is one of the biggest problems related to survival of Atlantic salmon.

Largely on the basis of observational data on murres and information on offshore release of Atlantic salmon in Europe, we released groups of tagged coho smolts offshore from Yaquina Bay in 1982 and 1983. We started very simply in 1982 by putting a deck tank (into which seawater was pumped) aboard a fishing vessel and transporting the tagged fish offshore for release. In 1983, we constructed a floating cage that could be towed offshore. Tagged groups were released by the two methods at distances of about 5 and 15 statute miles offshore. Table 1 compares relative survival of tagged groups released offshore and onshore.

Results were inconsistent for tagged groups released from a deck tank. In some instances, fish released offshore showed greater survival than fish released onshore; in other instances, fish released onshore survived better than fish released offshore.

TABLE 1 COMPARISON OF RELATIVE SURVIVAL OF COHO SALMON SMOLTS RELEASED ONSHORE AND FIVE AND FIFTEEN MILES OFFSHORE, YAQUINA BAY, OREGON

Date of Release	Ratio of Tags Recovered: Onshore	5 Miles	15 Miles	Transport Method
6/25/82	1.0	1.8	1.9	Deck Tank
8/24/82	1.0	0.6	0.5	Deck Tank
6/29/83	1.0	1.4	2.3	Deck Tank
8/25/83	1.0	0.3	0.2	Deck Tank
9/17/83	1.0	0.4	0.2	Deck Tank
7/18/83(a)	1.0		4.1	Net Pen
7/28/83(b)	1.0	0.9		Net Pen
8/8/83(c)	1.0	1.4		Net Pen
Average	1.0	1.0	1.5	

(a) The onshore group was released 7/16/83.
(b) The onshore group was released 7/27/83.
(c) The onshore group was released 8/6/83.

Results from offshore release with the net pen were more encouraging than with deck tanks. This contraption consisted of a rigid metal frame with floats to keep it from sinking. A net was tied to the frame. The idea was to drift and tow the pen across the bar on an outgoing tide and continue to tow offshore as far as we could when the ocean was calm. El Nino was at its zenith, and the water was clear and warm. We made a nice 15 mile tour offshore. I am not going to dignify this effort by calling it an experiment--I will call it an observation. We asked ourselves why we were putting these poor fish miles offshore in a subtropical environment. We released nearly 50,000 tagged coho on 18 July 1983. In summer 1984, we began to receive reports of tagged fish recovered in ocean fisheries, and it soon became evident that this particular group had survived very well and dominated the tag recoveries. We began to wonder whether we would also see good returns to our recapture facility at Yaquina Bay. These fish returned at a rate about four times higher than fish released into Yaquina Bay from the recapture site.

Two other groups released from the net pen subsequent to the July 18th release were towed five miles offshore. On 28 July 1983, we towed the net pen in rough seas. We observed extreme billowing of the net and considerable scale loss from the 50,000 smolts in the net. We also observed dead and moribund fish when we released them. Even though the fish experienced severe stress, survival of smolts released offshore was similar to those released onshore. On 8 August, we released another 50,000 coho smolts about 5 miles offshore. These fish survived at a rate 1.4 times as high as fish released onshore (Table 1).

Ocean survival is only one of two important questions related to offshore release. The other question is straying. Straying is perceived to be one of the major issues related to offshore release, and we are attempting to gather some background on whether or not fish released offshore tend to stray more than fish released onshore. There are two ways that offshore release can contribute to an increased proportion of hatchery fish on natural spawning grounds. If offshore release contributes to higher ocean survival of hatchery fish, the number of hatchery fish returning to coastal waters, and thus the number straying, will increase even if the rate of straying is unchanged.

There is also the possibility that offshore release will contribute to an increase in the rate of straying. We do not have definitive information on straying at this time. Hatcheries represent the terminal recovery locations for tagged fish. We have some information which compares straying of coho released offshore and onshore expressed as the percentages of the total numbers of tagged fish recaptured at hatcheries in locations other than Yaquina Bay. Onshore releases suggest a possible declining trend in straying with time:

1979	1980	1981	1982	1983
1.5	0.5	0.7	0.2	0.3

Smolts released offshore seem to exhibit a greater propensity to stray when released from deck tanks than from the net pen:

Deck Tank		Net Pen
1982	1983	1983
2.5	1.5	0.3

Fish released offshore from the net pen in 1983 exhibited the same rate of straying as fish released onshore in that year.

Our data base is very limited, and it is premature to draw conclusions about the effect of offshore release on straying. We are encouraged, nevertheless, in our belief that use of a proper technique for transporting fish where a free exchange of water is provided while in transit will minimize any tendency for additional straying.

Our plan for 1985 is to release tagged groups of salmon smolts into Yaquina Bay and at four distances offshore (4, 8, 12, and 20 nautical miles). Smolts will be transported by truck from our Springfield hatchery and held in saltwater ponds at Yaquina Bay for about two weeks. Our usual procedure has been to drain the ponds and thus release the fish directly into the bay. We have modified the system so that ponds can now be drained into a barge instead of the bay. The barge is towed offshore. It has four chambers with individual remote-control release gates. Thus, we propose to release tagged groups at 4, 8, 12 and 20 nautical miles offshore on a single transect. Additional groups of tagged smolts will be released simultaneously into Yaquina Bay (onshore).

Our plan is to release tagged groups of coho in the months of May, June, July, and August. We will have three size groups of juveniles: small, medium, and large for release at each location on each date. We will also release tagged groups of chinook smolts in August and September at two distances offshore (4 and 12 nautical miles).

The first groups of tagged coho went out May 21, 1985, and everything went well. The small, medium, and large size categories were approximately 15, 20, and 25 grams. As the season progresses, smolt sizes will increase. In August, for example, small fish are scheduled to be 30 grams, medium fish 60 grams, and large fish 90 grams.

We hope to have three replications of tagged fish at each location on each date. I consider this project to be a preliminary survey to identify differences in survival that may relate to the three variables that we believe could be most important to success of offshore release: size, time, and distance. We do not have the resources at this time to replicate the independent variables adequately for a definitive evaluation of offshore release; our goal is to gain insight into the relative importance of the variables under consideration.

The cost of designing and building the barge for transporting smolts offshore has been shared equally by Anadromous, Inc., and Oregon Aqua-Foods, Inc. We initiated preliminary engineering design studies in November 1984, and by January 1985, we went ahead with formal design and started construction in

April. The barge was launched in early ?lay. We had two weeks to check towing characteristics, water circulation, and other operational criteria before releasing fish at sea.

The barge is 40 feet long, 14 feet tall, and 15 feet wide. The upper four feet of the hull on both sides consists of flotation chambers. About 10 feet of the barge is submerged and 4 feet remains above water to provide protection against wave action. The bow structure consists of a rigid, porous plate, and the stern structure is a porous gate that opens downward. The gate is hinged on the bottom and flops down when fish are released. The sides and bottom of the barge are solid metal. The top is open. It is constructed of ship grade aluminum.

The flow of water through the barge is determined by porosity of the bow plate and towing speed. It is designed so that when it is being towed at five knots the velocity inside the barge will not fatigue coho and chinook swimming steadily for several hours. As it turned out, some fish swam 20 nautical miles out to sea and then returned to Yaquina Bay (40 nautical miles in 10 hours) without apparent ill effects.

In operation, the barge is towed through the water at about five knots. About 200 cfs flows continuously through the barge; there is no problem with oxygen exchange when the barge is under tow.

We did have a concern about materials used in constructing the barge. We wanted to avoid the possibility of subjecting fish to an artificially induced magnetic field, since natural magnetic fields may play a role in homing. We used all non-magnetic material in the construction of the barge.

The side of the barge has ports for inserting a pipe to load smolts. The system is designed to drain the shoreside ponds where fish are acclimatized to seawater, directly into the barge.

The present configuration of the barge includes four cells so that we can take groups of tagged fish scheduled for release at four locations on one trip. Gates separating the cells are identical to the stern gate. Fish in the stern cell are released first and fish in the bow cell last.

Q: What sort of changes do you get in return rates, say May through August?

A: For fish released onshore, we often observe a 3 to 4-fold improved survival for coho released in August over those released in May. This pattern has been consistent since 1976. It took me some time to accept this, because it just didn't fit in with what I understood about the normal smolting behavior of the animal. We do see definite signs, I think, of smolt reversion even though the fish happen to be much larger in August. It costs more to produce large smolts for August release, and returning adults are small in comparison to adults from smaller smolts released in May and June. I suspect that small adult size is caused by a reduced period for ocean feeding, since time of return does not appear to be affected by time of release.

Q: Have you observed a higher stray rate by releasing fish directly into lower Yaquina Bay?

A: I do not believe that our stray rate is inordinately high. It appears that 2 to 3 percent of coho returning to Yaquina Bay overshoot our recapture site and enter tributary streams. I do not consider that to be unusual. The problem is that we get 100,000 to 130,000 fish back into the bay. Two or three percent straying into the Yaquina watershed puts far more hatchery fish in the streams than naturally-produced fish.

Q: Can you overwhelm predators through improved release strategies? When you released your fish in that subtropical water, it occurred to me that you may be doing the same thing there. In a condition like that, one might expect to find fewer predators year-round, and the fish would have a greater chance to disperse and get out there before they would be heavily preyed upon. This is reminiscent of some theoretical work done by Peterman years ago, where he satiated predators with large numbers of prey.

A: One of the problems when you are dealing with murres is that there is just no way that all of the hatcheries collectively could produce enough smolts to begin to satisfy their appetite. We apparently ran into a concentration of Shearwater birds yesterday when we released fish 20 miles offshore. At lesser distances, but beyond 4 miles, we have not observed concentrations of sea birds. At 20 miles we encountered shearwaters. Shearwaters are 10 times more abundant off Oregon in summer than murres. You are looking at a difference between a standing stock of 400,000 murres and maybe 4 to 5 million shearwaters at this time of year. So there is approximately an order of magnitude difference in the numbers of shearwaters versus murres, but they are more distant offshore. We observed a frenzy of feeding on our smolts released at 20 miles, which was not the case at 4, 8, and 12 miles.

Q: Would you like to just recap the concern about magnetism?

A: Evidence is building that magnetic fields play a significant role in the ability of a wide variety of animals, including fish, to recognize and imprint on magnetic fields. It certainly is true in birds, and similar behavior has been demonstrated with other animals including tuna and salmon. magnetite crystals similar to those found in birds that exhibit strong homing behavior have been found in chinook salmon. One of the reasons why we finally settled on release of smolts 4, 8, 12, and 20 nautical miles off-shore from Yaquina Bay is that we tried to pick locations for release that were magnetically very similar. magnetic anomalies typically occur in valleys and peaks, and the hypothesis is that salmon are very capable of sensing these valleys and peaks. So our concern right now is to at least minimize the potential role of magnetic force fields in the homing response of salmon. Someday we may try to structure some experiments to take a look at whether or not locations exhibiting a magnetic low or high offer an advantage for improved survival.

Q: There is no evidence that insertion of magnetized wire tags in the snout of fish affects their ability to home. Doesn't this suggest that the magnetic field hypothesis is not really that strong? Magnetic tags are implanted in the region where magnetite crystals have been found and could create a local magnetic field much stronger than anomalies normally encountered in the environment.

A: A scientist at California Institute of Technology is wrestling with this problem. He has taken magnetized tags into his laboratory to examine their properties. He is trying to better understand what effect artificially induced magnetism from the tag is likely to have on the fish. A number of variables could be involved, including distance of the tag from a magnetic sensory system and whether or not the tag interferes with the ability of the fish to detect and recognize natural anomalies in magnetic fields. There are a lot of unanswered questions.

UPRIVER RELEASE STRATEGIES

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Strategies for releasing hatchery salmon and steelhead are being developed because of some major changes that have taken place in the Snake and upper Columbia River basins. In the last 20-30 years, we have gone from salmon and steelhead runs that were mostly produced naturally, to the point where hatchery fish now outnumber wild fish in many drainages. This shift has occurred because of declining natural production and increased hatchery production. The number of chinook salmon redds counted in the Idaho index streams (Figure 1) has declined to about one-tenth of former levels. And although the production of hatchery smolts has increased, smolt-adult survival rates for hatchery spring chinook have also declined (Figure 2).

Dworshak National Fish Hatchery at the confluence of the North Fork Clearwater and the Clearwater rivers produces about 2.5 million steelhead smolts and 1 million chinook salmon smolts a year. These data are typical of hatchery operations in the Snake River basin in that large numbers of hatchery smolts are being produced to mitigate losses to the natural runs.

To give you an example of the role of the hatchery, 34,000 steelhead adults returned to the Clearwater River during the 1977-1978 fish year. About 27,000 fish could be accounted for as hatchery fish, either in the harvest or returning to the hatchery. The remaining 7,000 were assumed to be wild--in some cases because they could not be accounted for otherwise. In actuality, some of these fish probably died before they showed up anywhere. The wild fish estimate is really a maximum estimate; the real number is probably not

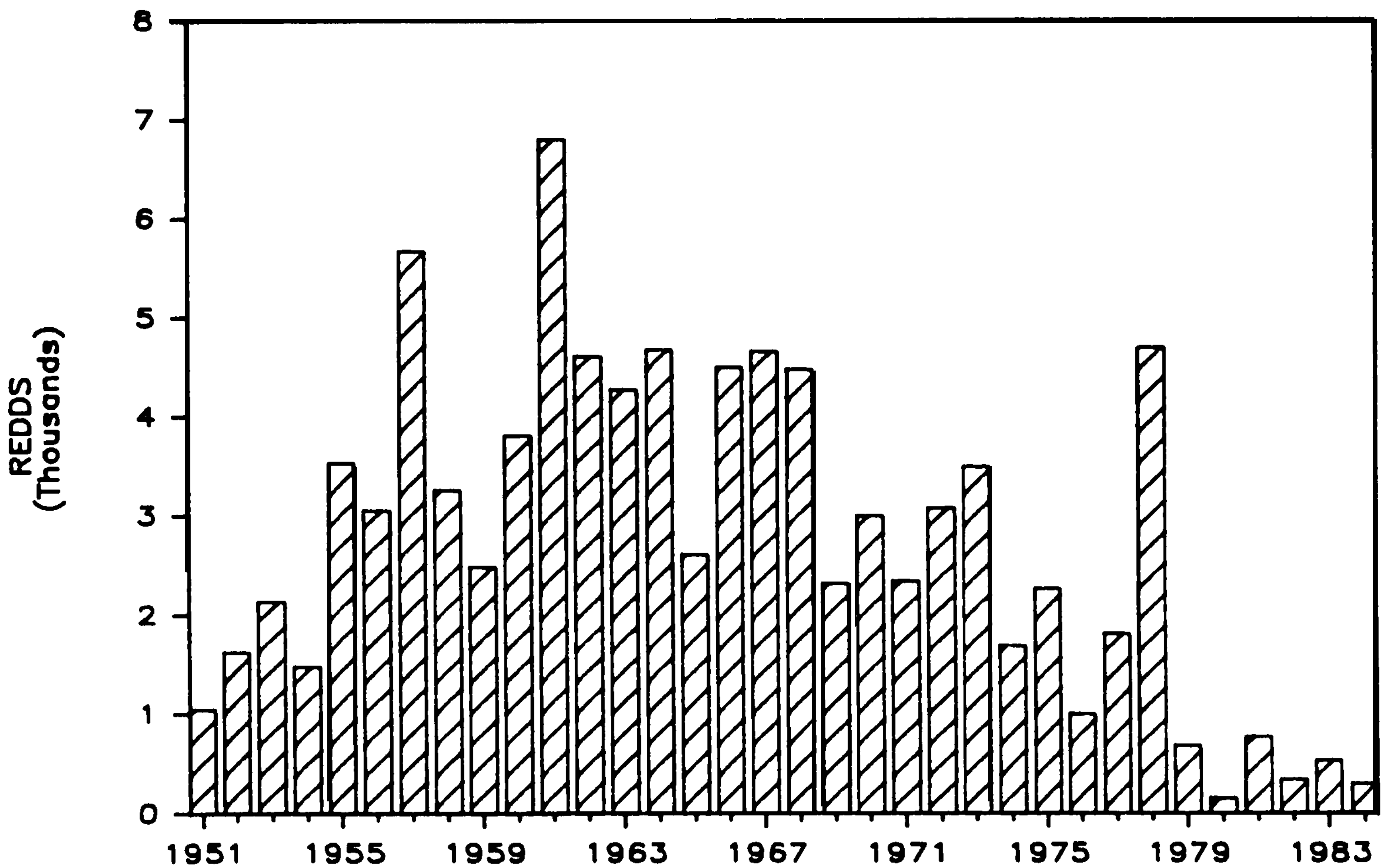

Figure 1. Counts of spring chinook salmon redds in Idaho index streams 1951-1984.

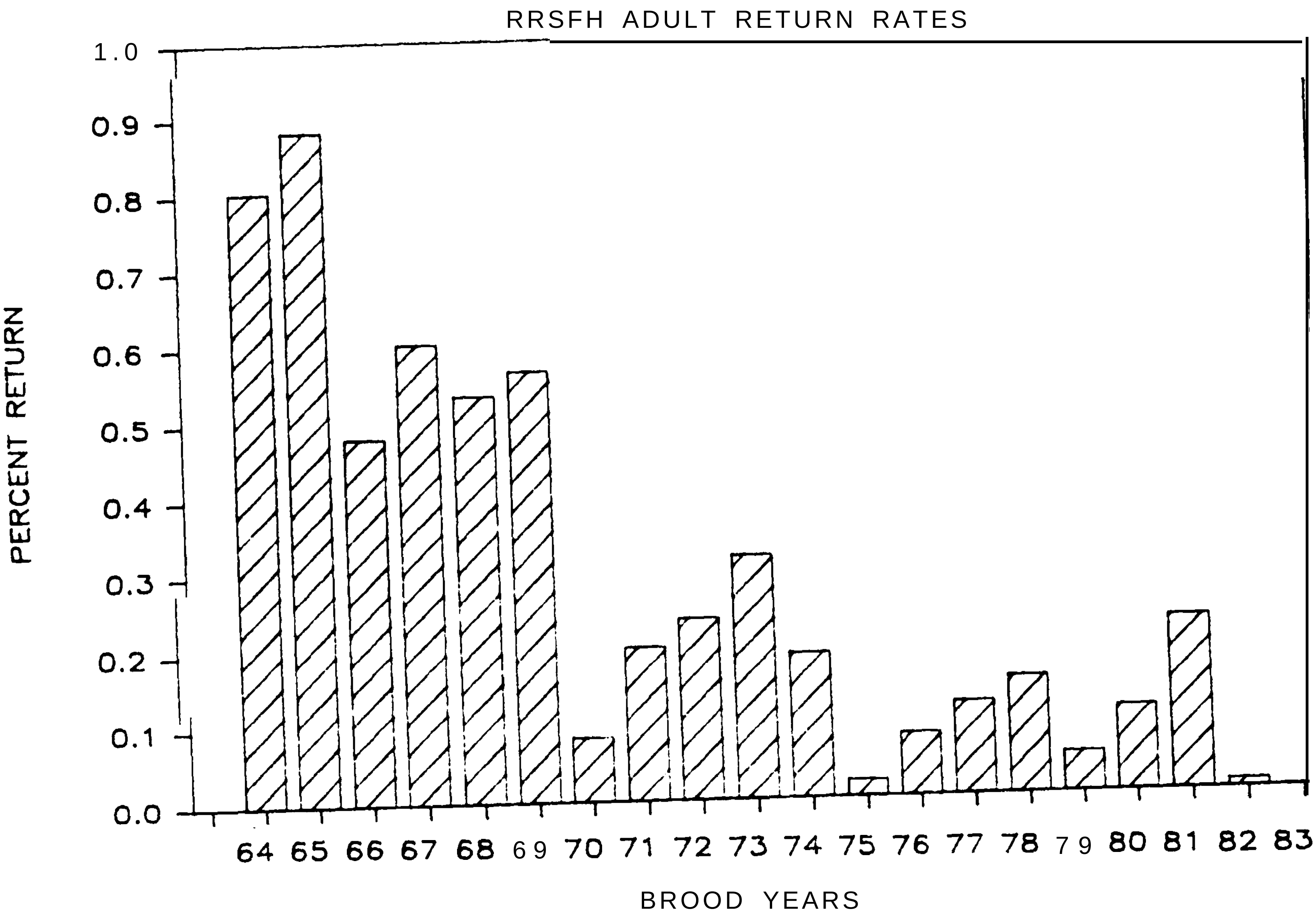

Figure 2. **Smolt-adult** survival rates for spring chinook **salmon** at Rapid River State Fish Hatchery, Idabo **1964-82.** Returns for 1982 **brood year incomplete**.

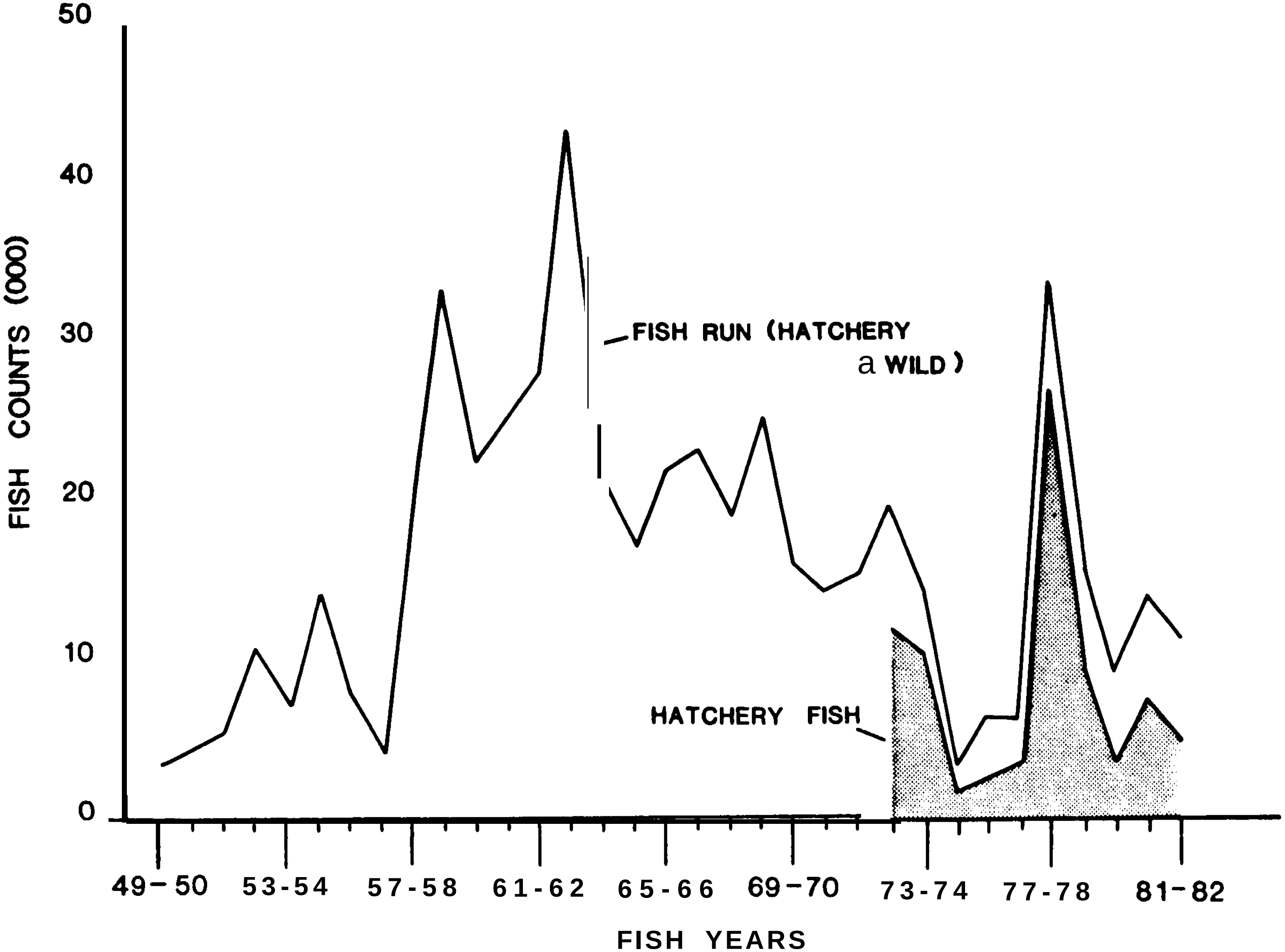

Figure 3. Counts (1949-72) and estimates (1973-82) of wild and hatchery steelhead trout adults entering Clearwater River, Idaho.

that large. The ratio of hatchery fish to wild fish was nearly 4 to 1. In other years, when the runs were not as large as in 1977-1978, the ratio was lower. Before 1971, the runs were natural, and some were as large as 40,000 fish (Figure 3).

Counts of steelhead entering the Clearwater River were relatively small before the Dalles Dam was finished in 1957 and inundated Celilo Falls. After 1957, there were years when virtually no fish were harvested in the net fishery upstream of Bonneville Dam, and large numbers of fish entered the Clearwater sys tern. Then, with the completion of more dams, there was a period (1974-1975) of generally declining abundance. Now hatchery fish make up a large part of the Clearwater steelhead runs, a picture that could be duplicated in other drainages.

In addition to increased hatchery production, collection and transportation or bypassing of downstream migrants past the dams is another factor that plays a role in upriver release strategies. The transportation program is designed to pick up fish at Lower Granite, Little Goose, and McNary dams and transport them to below Bonneville Dam. Fish that are not transported around the dams must be bypassed. A program to release stored water at critical times during the migration season has been established to aid the migrating fish in getting through the reservoirs. There is clear evidence that the transportation program benefits steelhead. The benefits for chinook salmon, although positive, are not as convincing. The chinook salmon runs have gone downhill for both hatchery and wild fish despite the transportation program.

To determine whether salmon might survive better if bypassed rather than collected and transported, chinook salmon smolts that arrived at Snake River dams in April 1982, 1983, and 1984 were bypassed rather than collected and transported. Chinook smolts typically migrate down the Snake River earlier than steelhead, so there was some natural separation of the two species, although it was not complete. Managers were trying to put most of the hatchery chinook salmon smolts down the river in April so they could be bypassed, and steelhead during May when they could be transported.

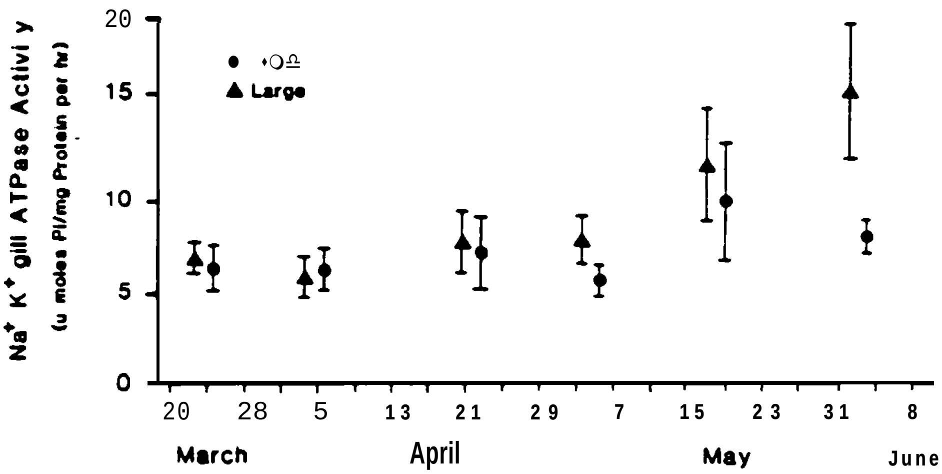

Figure 4. mean Atpase activity and 95% confidence interval for age- steelhead trout sampled in 1982.

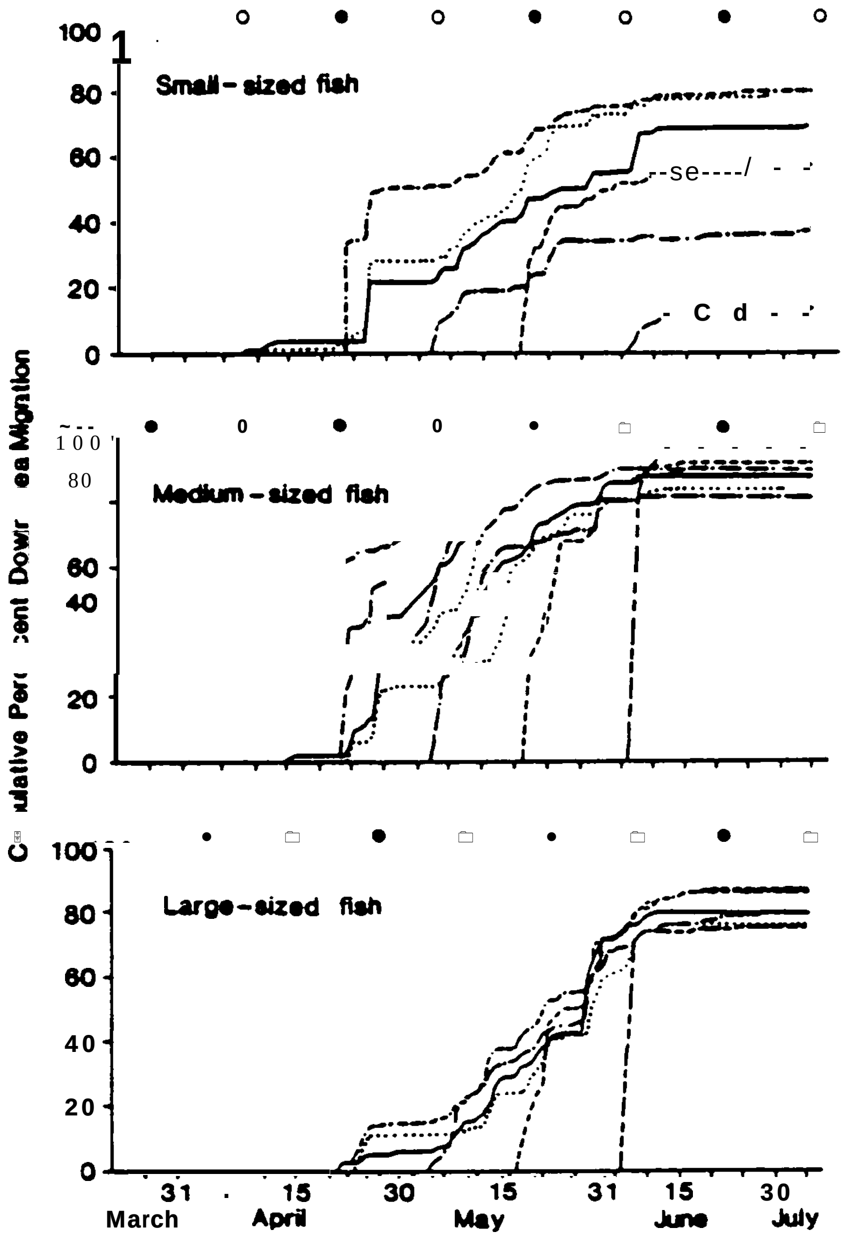

Figure 5. **Cumulative percentage of small, medium and large-** sized age-1 steelhead **trout** migrating **downstream** in the migration channel at Dworshak **NFH** from releases on 25 March **(.....)**, 8 April **(-----)**, 23 April **(- - .)**, 7 May **(- . -)**, 21 May **(- - -)**, and 6 June **(-- - -)** 1982. Lunar phases: ○ = full; ● = new.

Release strategies, then, are important because hatchery fish now make up a large part of the salmon and steelhead production in the upper Columbia River Basin, and management actions (timing of release, transport vs. bypass, harvest regulations) are affected by the presence of the hatchery fish.

The question of when to release smolts and at what size is still unresolved for some areas. The better studies were started after 1980; the return data are not yet complete. In 1982, we studied three size groups of steelhead with mean sizes that are released from the steelhead hatcheries. In some years, a majority of the fish may not exceed 170 mm.

One of the first things we investigated, with the help of Dr. Wally Zaugg (&XFS), was gill sodium-potassium ATPase activity for both large (200~mm) and small (160mm) steelhead (Figure 4). The large fish would normally be released in late April and early May. ATPase activity did not increase in those fish in the hatchery until after the normal release date. There was a peak in June for the smaller fish. The June sample came from the lower mode of a bimodal size distribution in that group. Even though ATPase activity had not increased by release time, those same fish, if sampled after they had migrated downstream a hundred miles, would have had ATPase levels in the range observed for fully developed smolts.

Next, we looked at migration behavior (Figure 5). We released large, medium, and small fish every two weeks, from late March through early June. Migration behavior was monitored at the hatchery in a sluiceway channel with drop structures. Fish released into the channel early did not move downstream. Even though we turned them out, they did not go; if they are not ready to migrate, they will not leave. Fish released later in the spring migrated rapidly from the channel. Large and medium-sized fish released between mid- and late April were ready to migrate, and did so. The later the fish were released, the quicker they migrated. In the groups of smaller fish, a high proportion had not smolted, and they did not migrate. The pattern of behavior that we saw in the migration channel was the same one observed when steelhead were hauled from Niagara Springs Hatchery up to the Pahsimeroi River for

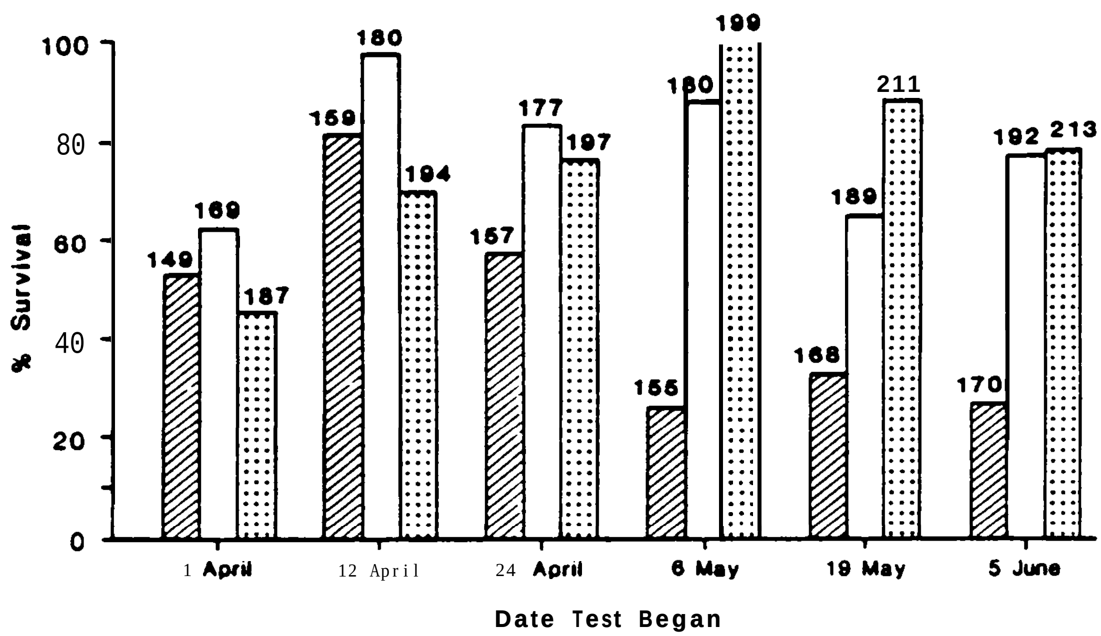

Figure 6. Percentage survival of small (striped bar), medium (open bar) and large-size (dotted bar) age-I steelhead trout in 9-10 days of seawater challenge, 1982. Mean total length (mm) of fish tested is indicated above each bar.

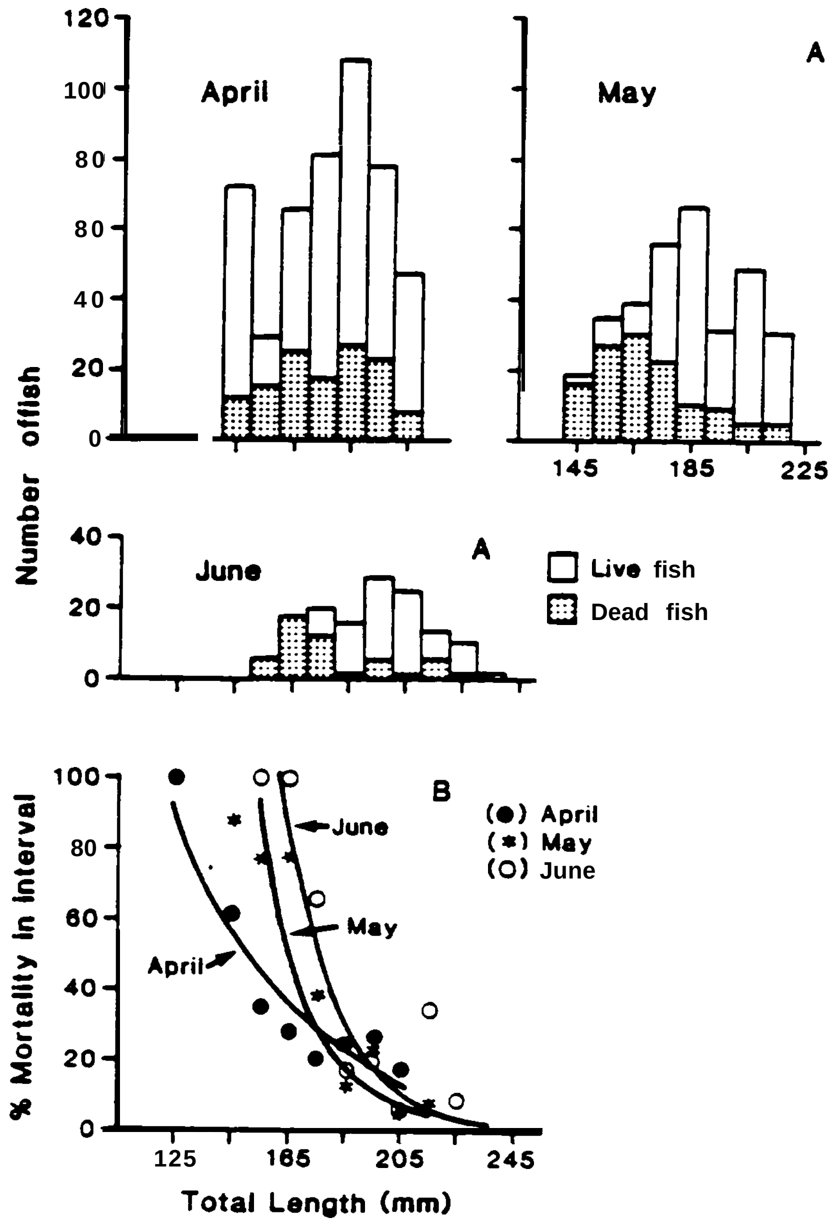

Figure 7. Length-frequency distribution of live and dead age-I steel **head** trout enumerated in seawater challenges, all size classes pooled, April-June 1982 **(a).** Percentage of fish within each 10 mm length interval that died **(b).**

release, i.e., fish placed in the river in March and early April did not show up at the Snake River dams until mid-May. The fish hold in the river until they are ready to migrate.

Starting in April, we challenged steelhead in seawater at 28 parts per thousand at the Marrowstone Field Station on Puget Sound (Figure 6). Survival rates in seawater of all steelhead at the beginning of April were low enough to show that they were having trouble osmoregulating. Survival of the medium sized and large sized fish improved later in spring and stayed relatively high. Survival of the small fish declined in late spring, but that was because we took the smaller fish (not yet smolts out of a bimodal size distribution. Survival in seawater was size-related (Figure 7). The smaller fish could not handle seawater, even at 28 ppt; if we had tested fish at 32 ppt salinity, the mortalities would have been even higher.

Taking large numbers of eggs, fry, or smolts produced in hatcheries and stocking them in areas away from the hatchery (outplanting) is becoming more common as a release strategy. As an indication of the extent of outplanting that is planned, a second large steelhead hatchery is on the drawing board for the Clearwater River drainage. Dworshak and the new hatchery will collectively produce about five million steelhead smolts. The fishable water downstream of the two hatcheries includes 40 miles of the Clearwater River and the Snake River reservoirs. Anglers are learning how to catch steelhead out of the reservoirs, but the preferred areas are the free-flowing streams. The plan is to outplant most, if not all, of the fish reared in the new hatchery (3 million) in the Clearwater and lower Salmon River drainages. At present, 20 to 25 percent (L/ million) of the steelhead reared at Dworshak are outplanted.

Managers must decide which fish to rear in the hatchery, which fish to release at the hatchery, and which fish to outplant; they must consider how outplanting will affect natural production. Fish populations are often changed when reared in a hatchery in ways that may lessen their ability to survive outside of it. Sometimes characteristics of the population are

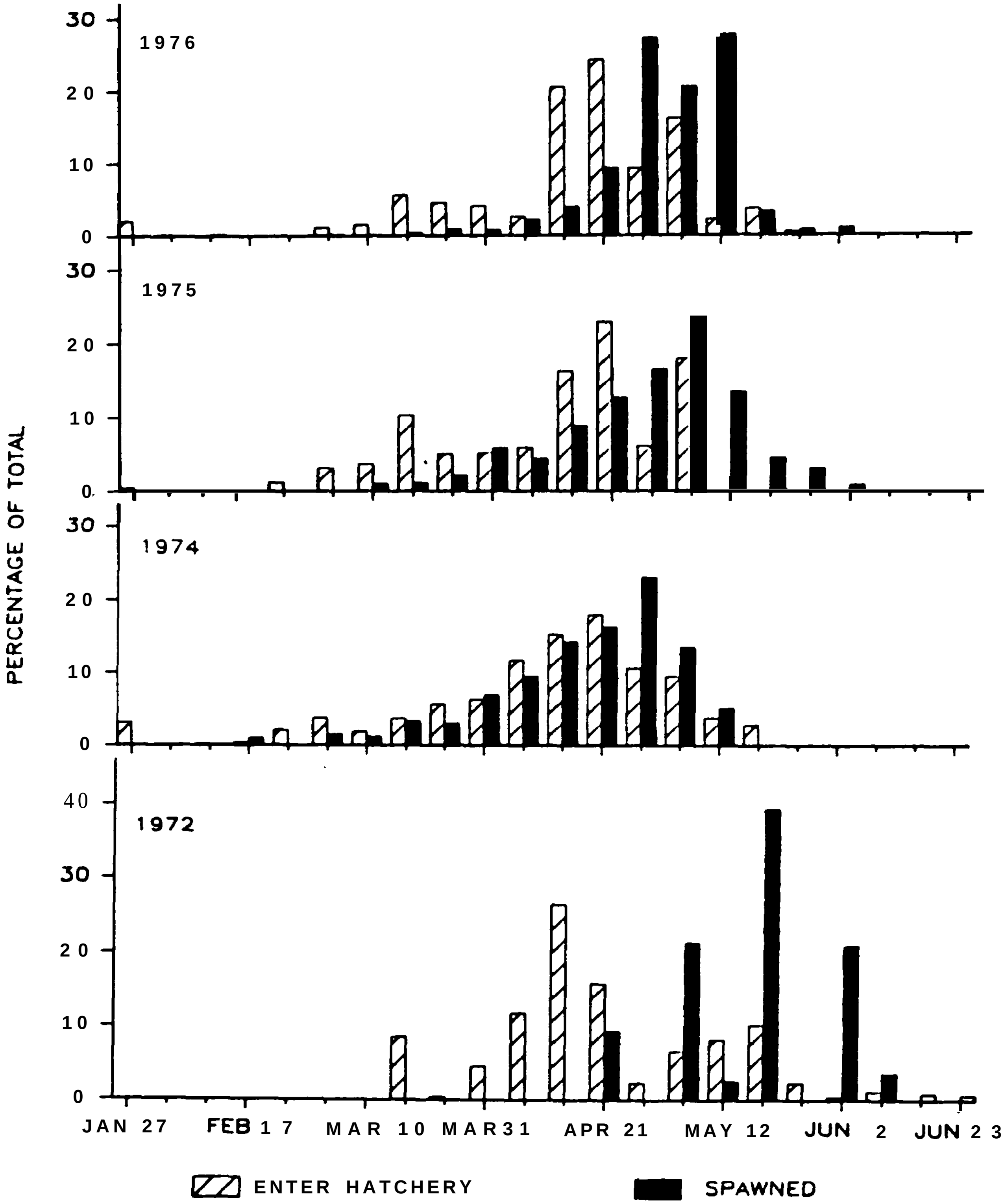

Figure 8. Timing of adult steelhead entry and spawning at Dworshak National Fish Hatchery in 1972, when only wild fish were returning, and 1974-1976, when reservoir releases warmed the river downstream during the overwinter holding period.

FIGURE 9

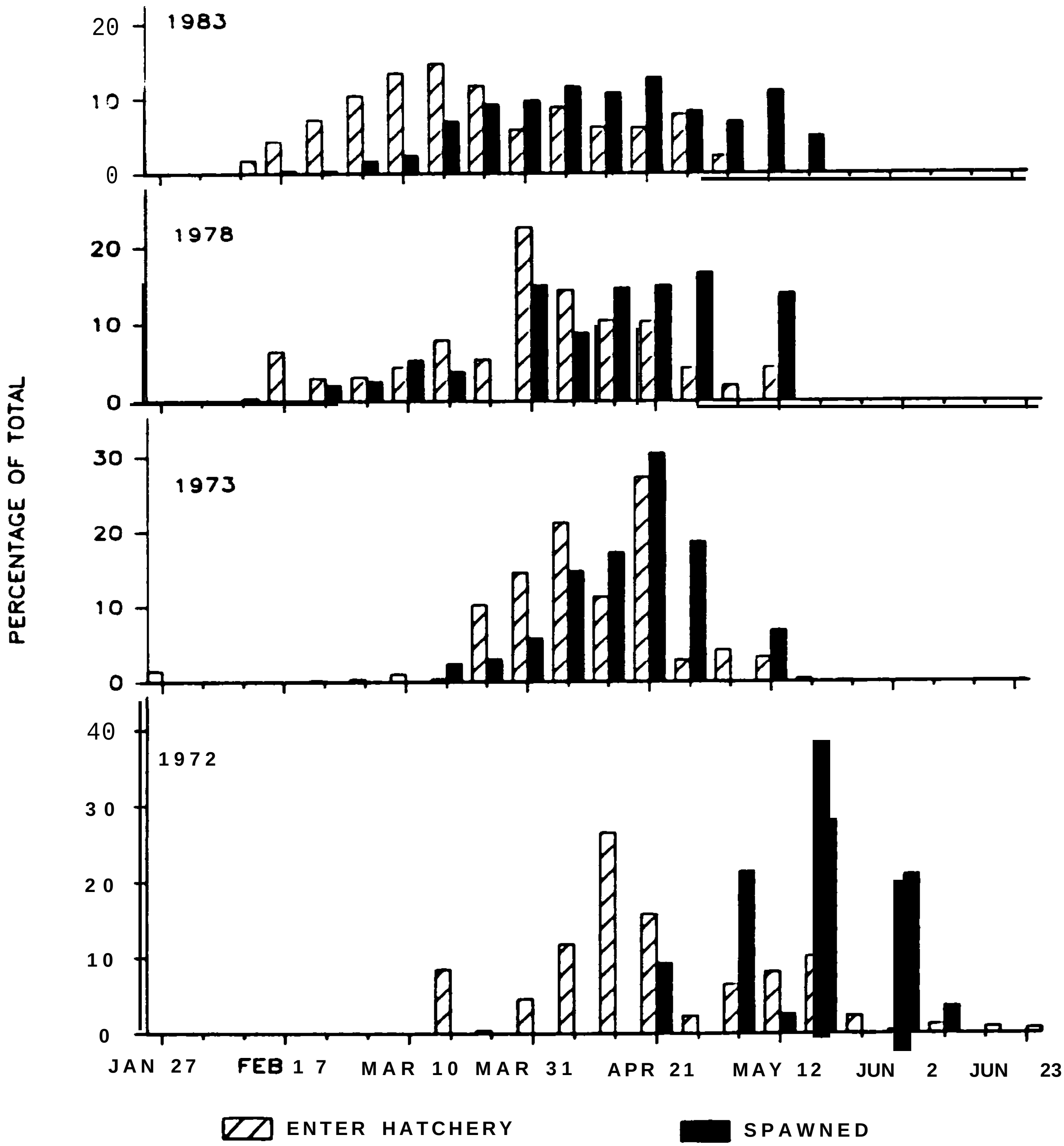

Figure 9. Timing of adult steelhead entry and spawning at Dworshak National Fish Hatchery in 1972 (natural timing) and 1973, 1978, and 1983 (timing affected **by** reservoir releases and selection for early spawners in 1973).

purposely changed; other changes are made inadvertently, and still others are unavoidable. Time of spawning of steelhead trout at Dworshak Hatchery is an example of the change that can occur in a relatively short time. Natural timing of movement up to the spawning areas in spring and spawning of the North Fork Clearwater River run of steelhead is indicated by the time of entry into the hatchery and of hatchery spawning for 1972, when only wild fish were trapped at the dam and the hatchery. Dworshak Dam was not finished, and North Fork flows were merely passed through it. The median timing of entry of fish into the hatchery was mid- to late April. Hatchery spawning peaked in mid-Yay, the same timing that had been observed for natural spawning (Figure 8).

One effect of the completion of the dam and the release of reservoir water into the lower 40 miles of the Clearwater River was that fish overwintering in that stretch accumulated more temperature units than they had without the dam: water released from the reservoir in winter was at about 39" F, in contrast to the near 32" F temperature of the river, pre-dam. Spawning in the hatchery in 1974, 1975, and 1976 was about two weeks earlier than it had been (Figure 9), a change attributed to the environmental modification rather than any genetic factors.

Genetically based changes have also occurred in the time when steelhead spawn at Dworshak Hatchery. In 1973, there was a large run of fish, and eggs were taken only from the first half of the run. The offspring of those selected adults spawned in mid-April, 1978, four weeks earlier than normal (Figure 9). For that brood year, both genetic and environmental changes were operating.

Dworshak Hatchery was one of the places where we recognized the selection problem early and tried to minimize changes. Since 1973, the policy has been one of collecting eggs and rearing offspring from the full spectrum of the spawning run.

At other hatcheries, managers have purposely selected early-spawning adults. Such selection may be desirable in some cases, but it is surely detrimental in others. If we outplant steelhead smolts that will return as adults to spawn 4 to 8 weeks earlier than normal, we may reduce the viability of the fish -- wild, hatchery, and crosses -- spawning naturally.

2.5 EFFECTS OF HATCHERY ENVIRONMENTAL FACTORS ON SMOLTIFICATION

Hatchery Design for Optimum Production (H. Westers)

Water Supplies (J.W. Warren)

Water Quality Engineering (D. Owsley)

HATCHERY DESIGN FOR OPTIMUM PRODUCTION

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INTRODUCTION

Today's hatcheries are often complex facilities consisting of many complex components. However, the fish still must be reared in water flowing through containers of one kind or another. This paper specifically addresses fish rearing units in terms of optimums relative to rearing space and available flow, selected water quality parameters, and fish size and species. I will also attempt a rational answer to the question of how much, and what kind of rearing space should be provided for a given flow, water quality, fish size, and species to deliver both quality and quantity. The economic optimum, i.e., the greatest number or weight of fish per unit space, and the product optimum, best quality fish produced under the least amount of stress, must be mutually satisfied. Where is this proper balance of quality and quantity? As we shall see, it seems to be a moving target.

THE FLOW-SPACE RELATIONSHIP

There are two aspects to carrying capacity. One aspect is based on flow and is termed loading; the other, is space related, and is termed density. Loading is expressed as kilograms/liter per minute (kg/ℓpm) or pounds per gallon per minute (lb/gpm), density as kilogram/cubic meter (kg/m^3) or pounds per cubic foot (lb/ft^3). Loading depends primarily on dissolved oxygen, water temperature, pH, and fish size and species; density depends on fish size and species. Density is the most difficult parameter to ascertain, and is still highly controversial.

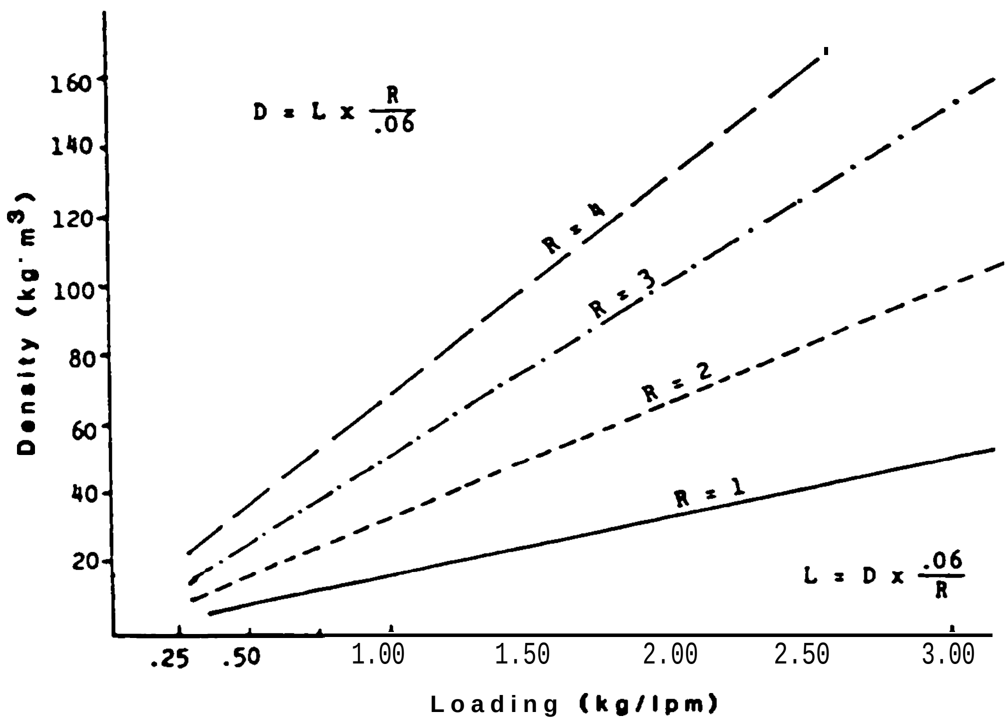

Figure 1. Relationship between loading and flow for four values for R (R = water exchanges per hour).

The relationship between loading and density can be expressed as follows:

$$\text{Loading } (kg/\ell pm) = (kg/m^3 \times 0.06)/R; \text{ and}$$

$$\text{Density } (kg/m^3) = (kg/\ell pm \times R/0.06$$

$$\text{or } (kg/\ell pm/.06) \times R.$$

where R represents the number of water changes per hour (Figure 1).

For one change per hour (R = l), a loading of 1.0 $kg/\ell pm$ (8.5 lbs/gpm) equates to a density of 16.7 kg/m^3 (1.0 lb/ft^3). The value 0.06 represents 0.06 m^3: 1 liter/m equals 60 liters per hour or 0.06 m^3. The exchange rate (R) is an important variable and, as will become obvious, relates significantly to the design of rectangular flow-through rearing units.

LOADING

Loading is determined on the basis of dissolved oxygen (DO), water temperature, fish size, species, and pH. The loading equation for salmonids is:

$$kg/\ell pm = \frac{(\text{Available DO in } mg/l)}{2 \times \% \text{ body weight } (=BW)}$$

It is derived as follows:

(a) $\ell pm/kg$ food fed = (g O_2/kg food)/(Available DO)

(b) $\ell pm/kg$ fish = [(g O_2/kg food)/(Available DO)] x (% BW/100)

(c) kg (fish)/ℓpm = (Available DO x 100)/(g O_2/kg food x % BW).

Considerable data support the idea that at optimum feeding levels salmonids consume about 200 g of oxygen per kg of food. This makes Equation (c) a practical loading formula:

$$kg/\ell pm = (\text{Available D0})/(2.0 \times \% \text{ BW}).$$

Should the oxygen demand be 250 g, the equation becomes:

$$kg/\ell pm = (\text{Available DO})/(2.5 \times \% \text{ BW}), \text{ etc.}$$

It must be pointed out that the loading equation is based on a 16-hour day rather than a 24-hour day. The greatest metabolic activity takes place during the 16-hour "feeding" day. Since each mg/ℓ DO per ℓpm flow represents 1.44 g of oxygen over a 24-hour period, the formula for a 24-hour period would be:

$$kg/\ell pm = (\text{Available DO} \times 1.44)/(2.0 \times \% \text{ BW}).$$

Over a 16-hour period, 960 mg O_2 (16 x 601, is delivered per ℓpm or 1.0 g for all practical purposes. This makes the loading formula slightly conservative and at the same time simplifies it.

The other part of the loading formula is based on allowable unionized ammonia in mg/ℓ. It is assumed that this metabolic byproduct is the second limiting factor. The equation to use is:

$$mg/\ell\ NH_3 = (\text{Available DO} \times g\ NH_3/kg\ \text{food})/(g\ O_2/kg\ \text{food})\ 1.44$$

For salmonids, which generate between 25 and 35 g of NH_3 per kg of food, the equation becomes (using 30 g):

$$mg/NH_3 = (\text{Available DO} \times 30) / (200 \times 1.44) = (\text{Available DO} \times 30)/288.$$

This, once again, can be simplified into an easy-to-use equation without invalidating it since 301288 = 0.104166:

$$mg/\ell\ NH_3 = 0.1 \times \text{available DO}.$$

To determine this in terms of un-ionized ammonia (UA), the toxic form, Table 1 must be consulted. A recent review of the literature (Meade 1985) on the toxicity of un-ionized ammonia on fish has resulted in the conclusion that the "traditional" value of 0.0125 mg/ℓ (Smith and Piper 1975) as the upper level is too conservative. Selecting the upper limit as 0.02 mg/ℓ instead appears to be more realistic. This level will be used in this paper for the UA design parameter. The equation for un-ionized ammonia is thus:

$$mg/\ell\ UA = (mg/\ell\ NH_3 \times \%\ UA)/lOO.$$

(For the value of % UA at a given temperature and pH, see Table 1).

The factor DO loading versus NH_3 loading is:

$$mg/\ell \text{ allowable UA } (.02\ mg/\ell)/mg/\ell \text{ actual UA}.$$

For example, assuming the maximum loading on the basis of available DO is:

$$kg/\ell pm = 4.0/(2.0 \times 2.0) = 1.0\ kg/\ell pm.$$

Where DO-in is 10 mg/ℓ, DO-out is 6 mg/ℓ, and feeding level is 2% BW; for ammonia the loading would be (assuming pH = 7.8 and temperature = 12' C):

$$mg/\ell\ NH_3 = 0.1 \times 4.0 = 0.4\ mg/\ell;\ \text{and,}$$

$$mg/\ell\ UA = (0.4 \times 1.35\ ^*)/loo = 0.0054. \quad (^*\text{ from Table 1})$$

TABLE 1. PERCENTAGE OF UN-IONIZED AMMONIA IN SATURATED AMMONIA SOLUTIONS AT DIFFERENT pH'S AND TEXPERATURES.

		Temperature							
	C:	6	8	10	12	14	16	18	20
pH	F:	(43)	(48)	(50)	(54)	(57)	(61)	(64)	(68)
7.0		.14	.16	.198	.21	.25	.29	.34	.40
7.1		.17	.15	.23	.27	.32	.37	.42	.50
7.2		.22	.25	.29	.34	.40	.46	.53	.63
7.3		.27	.32	.37	-43	.51	.58	.67	.79
7.4		-34	.40	.47	.54	.64	.73	.84	.99
7.5		.43	.50	.59	.68	.80	.92	1.06	1.24
7.6		.54	.63	.74	.85	1.00	1.16	1.33	1.56
7.7		.68	.80	.92	1.07	1.26	1.45	1.67	1.96
7.8		.85	1.00	1.16	1.35	1.58	1.82	2.09	2.45
7.9		1.07	1.25	12.46	1.69	1.98	2.29	2.62	3.06
8.0		1.34	1.58	1.83	2.12	2.48	2.86	3.28	3.83
8.1		1.68	1.98	2.29	2.65	3.11	3.58	4.09	4.77
8.2		2.11	2.48	2.86	3.32	3.88	4.46	5.10	5.94

Source : Trussell, 1972.

The loading factor for DO vs. ammonia under these assumptions is 0.02/0.0054 - 3.7. In other words, on the basis of ammonia, 3.7 kg/ℓpm fish can be produced per unit of flow, which is 3.7 times as much as on the basis of available oxygen. When re-aerated to the original DO level, 2.7 reuses of the water are possible before ammonia becomes limiting. In summary,

a) kg/ℓpm = (Available D0)/(2.0 x % BW)

b) mg/ℓ NH_3 = 0.1 x Available DO

c) mg/ℓ UA = (mg/ℓ NH_3 x% UA) /l00

d) kg/ℓpm = (0.02/mg/ℓ UA) x (kg/ℓpm based on DO)

This last equation can be simplified to:

$$kg/\ell pm = 10/(\%\ UA \times \%\ BW).$$

DENSITY

This is the elusive and controversial parameter. Salmonids have been maintained and reared at very high densities: 335 kg/m^3 or 20 lbs/ft^3 (Westers 1966); 540 kg/m^3 or 32 lbs/ft^3 (Buss et. al. 1970); 179 kg/m^3 or 10.7/ft3 (Clary 1978); 234 kg/m^3 or 14 lbs/ft^3 (Poston 1983). Michigan State fish hatcheries routinely operate at rearing densities from 50 to 100 kg/m^3 (3-6 lb/ft^3), and are expected to go up to 150 kg/m^3 or 9.8 lbs/ft^3 in certain instances. Once an upper limit has been decided, this parameter can be plugged into rearing unit design to establish space requirements. Attempts have been made to develop a method to determine the upper limit, such as Piper's density index (Piper 1970), which states that salmonids can be reared at a density in pounds per cubic feet equal to half their length in inches. This equates in metric measure to 3 times the length in centimeters in kg per cubic meter. Thus, 10-cm trout can be reared at a density of 3 x 10 or 30 kg per cubic meter.

As was shown earlier, the relationship between space and flow (density and loading) can be expressed with:

$$kg/m3 = (kg/\ell pm/.06) \times R.$$

Earlier, a loading value of 1.0 kg/ℓpm was assumed, along with a temperature of 12 C, pH of 7.8, DO of 10 mg/ℓ; available DO of 10.0 - 6.0 = 4.0 mg/ℓ, and a feeding level of 2% BW. The fish are further assumed to be 10 cm long.

The appropriate loading, according to available DO, is:

$$kg/\ell pm = 4.0/(2.0 \times 2.0) = 1.0.$$

On the basis of an upper limit of .02 mg/l un-ionized ammonia, appropriate loading is:

$$kg/\ell pm = 10.0/(1.35 \times 2.0) = 3.7.$$

If Piper's density index is used, the maximum allowable density is 3 x 10 or 30 kg/m^3. If space and flow are operated in balance with these two values, 30 kg/m^3 and 1.0 kg/ℓpm, the exchange rate (R) is:

$$R = (kg/m^3 \times .06)/(kg/\ell pm) = (30 \times .06)/1.0 = 1.8.$$

WATER VELOCITY

This variable, too, must be considered in rearing unit design. Relatively high velocities may be beneficial to the health (stamina) of the fish. This is one of the premises on which the Burrows' circulating pond was developed (Burrows and Chenoweth 1970). Recent studies with brook trout (Leon 1983) support the idea that high velocities (l-5-?.0 times the length of the fish) contribute to better health and growth rates.

Such high velocities are not practical in unmodified rectangular flow-through rearing units, and fish culturists have had to resort to circulating ponds to accomplish such objectives. High velocities, however, keep solids in suspension for long periods of time and thus degrade water quality. It is better to operate at velocities that are low enough to permit rapid settling of the solids. In rectangular flow-through ponds, these solids can then be swept by means of baffles to a quiet section of the raceway, while simultaneously offering the fish velocities of up to 0.3 m/set (1 fps) (Boersen and Westers, 1985). The velocity in a rectangular rearing unit can be expressed as:

$$V\ (m/sec) = (L \times R)/3{,}600,$$

where L represents the length of the unit in meters and 3,600 the number of seconds per hour.

Thus, the length (m) of a rearing unit can be expressed as:

$$L = (3{,}600 \times V)/R.$$

To achieve desirable hydraulics, a velocity ranging from 0.015 m/sec for indoor rearing tanks to 0.035 m/sec for outdoor raceways is desirable. These velocities are low enough to permit the settling of solids, yet high enough to make baffles effective. Having established the velocity parameters, let us return to the previous example of 1.0 kg/ℓpm; 30 kg/m3 and R = 1.8. To meet all of these in perfect balance, along with a selected velocity of 0.03 m/sec, a rearing unit length of 60 m (200') is needed. This is a rather long distance, but increasing R to a value of 4.0, the length of the pond becomes:

$$Lm = (3{,}600 \times .03)/4 = 27\ m.$$

For a desirable pond configuration, a ratio of D:W:L of 1:3:10 is recommended. (For units over 30 m long, a width of approximately 3.0 m and a depth of 1.0 m should be retained.) A 27-m pond, to accomplish four changes per hour and a velocity of 0.03 m/sec would have a rearing volume of 27 x 3.0 x 0.8 = 64.8 m^3. At 30 kg/m^3 (for 10-cm fish), the maximum biomass allowed is 30 x 65 = 1,950 kg. To accomplish the four changes per hour, a flow of 4 x (65/.06) or 4,333 ℓpm is required. On the basis of a maximum allowable loading of 1.0 $kg/\ell pm$, the pond can carry 1.0 x 4,333 or 4,333 kg fish. There is no balance between density and loading; instead of an oxygen consumption of 4.0 mg/ℓ, it is only (2.1/4.3) x 4, or 1.95 mg/ℓ, which leaves 6 + 2.15 or 8.15 mg/ℓ DO in the pond effluent.

As determined earlier, based on an un-ionized ammonia limitation of 0.02 mg/ℓ, 2.7 reuses are possible, provided each unit (raceway) consumes the full amount of available oxygen. Because only 1.95 mg/ℓ DO is used, the number of possible reuses has now increased from 2.7 to 2.7 x (4.0/1.95) = 5.5.

To make full use of the production potential of the available flow, seven rearing units should be provided in series. A total of 2.7 x 4.0 = 10.8 mg/ℓ oxygen must be provided to a flow of 4,333 ℓpm, which represents 4,333 x 1.44 x 10.8 = 67,387 g, or 67.4 kg, of oxygen per day. The most attractive way to provide the oxygen is by means of industrial PSA oxygen generators. At a 50 percent absorption rate, 134 kg of oxygen has to be provided per day. This equals 134,000/1.43 g or 93,706 liter. An oxygen generator with a capacity of 200 cubic feet per hour (3.3 cfm) will more than adequately meet the oxygen requirements.

Should all the parameters be in balance, the rearing density would be:

$$kg/m^3 = (1.0 / 06) \times 4 = 67\ kg/m^3 \text{ or } 4.0\ lb/ft^3.$$

This density is generally acceptable in Michigam's hatcheries.

SUMMARY

Critical design and operational parameters for rectangular fish rearing units are the following:

1. Loading: $kg/\ell pm$ = (Available D0)/(2.0 x % BW)
2. Density: kg/m3 (Select on basis of experience/preference)
3. Loading/Density relationship: $kg/\ell pm$ = (kg/m3 x .06)/R
4. Density/Loading relationship: (kg/m^3) = $([kg/\ell pm]/.06)$ x R
5. Ammonia production (mg/ℓ): NH_3 = 0.1 x Available DO
6. Un-ionized ammonia production (mg/ℓ): UA = $(mg/\ell$ NH3 x % UA)/LCO
7. Ammonia loading for reuse: $(kg/\ell pm)$ = 10.0/(% UA x % BW)
8. Rate of exchange: R = $(kg/m^3$ x .06)/$(kg/\ell pm)$
9. Velocity (m/sec): v = (L x R)/3,600
10. Rearing unit length (m): L = (3,600 x V)/R
11. Flow: ℓpm = R x (volume [m3]/.06)
12. % BW: $(T[C^o]$ x 2.0)/(100 k x l_{cm}). (Westers, 1987)

Once again, the weak link is the ability to select rationally the appropriate maximum allowable (optimum) density. Low densities cause one or more of the following: poor water exchange rates, waste of water (oxygen), large numbers of reuses, and much space (concrete).

The ideal design is to strike a healthy balance between density and loading while operating at exchange rates of over 2.0 per hour and velocities from 0.315 to 0.03 m/sec.

REFERENCES

Boersen, G. and H. Westers. 1985. Solids control in baffled raceways. (Submitted for publication.)

Burrows, R.E. and H.H. Chenoweth. 1970. The rectangular circulating rearing pond. Prog. Fish-Cult. 32(2):67-80.

Buss, K., D.R. Graff, and E.R. Yiller. 1970. Trout culture in vertical units. Prog. Fish-Cult. 32(4):187-191.

Clare, S.D. 1978. Realistic control of fish diseases through hatchery sanitation and water conditioning. Salmonid Jan/Feb.

Leon, K.A. 1983. The effect of hatchery velocity on the feed consumption, growth, food conversion, and stamina of brook trout. Proc. ?&i Fish Cult.. Workshop.

?leade, J.W.. 1985. Allowable ammonia for fish culture. (Submitted for publication.)

Smith, C.E. and R.G. Piper. 1975. Lesions associated with chronic exposure to ammonia, in The Pathology of Fishes (W.E. Ribeling and G. Migaki, eds.), pp. 497-514. Univ. Wisc. Press, Madison.

Trussell, R.P. 1972. The percent un-ionized ammonia in aqueous anunonla solutions at different pH levels and temperatures. J. Fish. Res. Board Can. 29(10):1505-1507.

Westers, H. 1987. Feeding levels of fish fed artifical diets. Accepted for publ. Prog. Fish Cult. 48(3).

Piper R.G. 1970. Know the proper carrying capacities of your farm. Am. Fishes1U.S. Trout News. 15:4-6.

Poston, H.A. 1983. Effect of population density of lake trout in cylindrical jars on growth and oxygen consumption. Prog. Fish-Cult. 45(1):8-13.

Westers, 9. 1966. A density-feeding study with coho salmon. Unpublished.

Westers, H. 1983. Principles of Intensive Fish Culture. Unpublished.

WATER SUPPLIES

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The basis of my presentation is the relationship between the host and the pathogen as affected by the environment. This also seems to be the guiding motive in modern epidemiology, expressed felicitously in the following quotation from George Bernard Shaw's Doctor's Dilemma:

> The popular theory of disease is that every disease had its microbe duly created in the Garden of Eden, and has been steadily propagating itself and producing widening circles of malignant disease ever since. It was plain from the first that if this had been approximately true, the whole human race would have been wiped out by the plague long ago, and that every epidemic instead of fading out as mysteriously as it rushed in, would spread over the whole world. It was also evident that the characteristic microbe of a disease might be a symptom instead of a cause.

Was Shaw right? I shall leave this question unanswered.

Modern epidemiology is based on the premise that epidemic outbreaks are caused by an imbalance between the host, the pathogen or other disease agent, and the environment. Aquatic cold-blooded animals are much more affected by the environment than are warm-blooded animals, and therefore outbreaks of diseases of fish are strongly affected by ecological factors.

John Gowen, in a 1952 article in the American Journal of Human Genetics, put it this way: "A clinically manifest disease only results when the proper combination of the genotype of the victim and the genotype of the pathogen, where one is necessary, are properly synchronized with the environment."

Rene Dubos, in Scientific American in 1955, said, "There are many situations in which the microbe is a constant and ubiquitous component of the environment but causes disease only when some weakening of the patient by another factor allows infection to proceed unrestrained, at least for a while."

And finally, Aidan Cockburn, in his book The Evolution and Eradication of Infectious Diseases, published in 1963, summed up the developing concept this way: "Infectious disease is composed of three variables, the host, the pathogen, and the environment. It is in a constant state of flux, capable of changing in step with any variation in any of its components. Sew diseases appear, old ones alter, and some may disappear completely."

The epidemiolcgist treats dtsease in the mass much as the physician treats a single individual. When a patient presents himself, the physician tries to find out what his complaint is. He then attempts to establish a diagnosis by getting a good history, examining the patient, iearning about his background, and obtaining assistance from the laboratory. If a diagnosis is established and the cause of illness determined, he treats the patient with specific or symptomatic medication and attempts to remove the source of illness.

The epidemiologist, studying the occurrence of disease in a community, attempts to establish the nature of the disease. He obtains a careful history of the community, learns about its previous experience with this and related diseases, and observes characteristics of the disease as they affect individuals. He obtains data from the laboratory, the sanitarians, and others, which help him to determine the cause and spread of the illness. Be observes the geographic distribution, the number and kinds of people under attack, and the time relationships of the occurrence of the disease in groups of individuals. He is now ready to make an attempt at control, by attacking the agent, by increasing the host's resistance, or by modifying the environment. Often he is successful. Occasionally, as in the case of the clinician with his single patient, he is only partly successful. Like the clinician, he cannot work alone. He needs the assistance of the microbiologist, the chemist, the sanitarian, the geographer, the biologist, the computer specialist, and others.

Since this is not a fish disease conference, I will leave discussion of disease agents for another time. I will leave discussion of the host to others at this meeting. My assignment was to discuss water supplies. Water supplies largely determine the quality of the aquatic fish cultural environment and the role the environment plays in the quality of the fish we rear. Assuming that we have fish susceptible to disease and that virulent pathogens capable of causing disease in those fish can gain entry, what role does the environment play?

The causative agent and the susceptible host do not carry on their struggle in a vacuum. The environment in which they live may be favorable to one or the other. One can think of this graphically as a balanced scale in which one of the pans represents the agent, the other pan the host, and the weights the environment. If the agent and host balance each other, the scale remains at rest. If either pan gets heavier or weights are added to one side without an equal counterbalance, the balance will tilt to one side or the other. Changes in the environment, natural or manmade, may shift the balance from one to the other and may help to determine whether the host will survive or succumb. A knowledge of the environment is essential in all epidemiological investigations.

In the lives of human beings, the physical environment is largely a matter of geography. The location of a community on land that is fertile or unproductive, near or far from a water supply, will determine the type of flora and fauna that can grow and multiply, and the ability of these to maintain a population. Closely allied to geography are season and climate.

They are particularly important in determining whether certain vectors of disease can or cannot survive. Obviously, malaria cannot be a problem in the arctic, since the temperature is too cold for the survival of Anopheles mosquitoes. Season and climate may play a part indirectly in the causation of illness or death. Epidemiological studies show that drownings are more common in summer than winter, while automobile accidents are more common during icy or foggy weather.

The social and economic environment of a society frequently determines not only its level of education, but also its desire and ability to undertake community health measures and to provide facilities for medical care. The level of sanitation, provision for a good water and milk supply, proper waste disposal, and proper housing facilities are among the measures that are essential for healthy community life. A community that has an effective immunization program for children and college students will not suffer much from measles or polio. F!ood control, prevention of soil erosion, and reforestation programs are of great importance in certain localities, and their effectiveness depends on the extent to which the community has developed socially and economically.

From this it takes little imagination to see numerous parallels in the communities of fish reared in hatcheries. The source, temperature, and abundance of fresh water determines the species and numbers of fish that can be reared. Season and climate are closely linked to growth rates, water flows and hatchery loadings. Economics and polltics can determine levels, commitment, and effectiveness of disease prevention or control, the size, design and constructlon of rearing facilities, and the numbers and training of fish culturists. Obviously, a fish hatchery with an adequate, clean, pathogen-free water supply will have fewer "built-in" problems with infectious disease.

The hatchery water supply must be considered as a key determinant in the quality of smolts and their eventual ability to migrate successfully into salt water. First and foremost, any pathogens reaching the intake pipe could be expected to be found in the fish. If disease occurs, some fish may become clinically ill and die. Dead fish don't migrate. This is one end of the smolt quality spectrum. If disease occurs, some fish may become infected and impaired for migration or entry into salt water. This can be the result of bacterial and parasitic diseases of the gills or systemic infections such as bacterial kidney disease. Finally, even if disease occurs some fish may not be affected at all.

Wedemeyer, Meyer, and Smith (1976), in their book, Environmental Stress and Fish Diseases, nicely describe the interplay between salmonids and the water in which they live. They list in considerable detail the environmental parameters that must be met to produce quality fish. I would like to touch on the meaning of quality and the relationship between a quality smolt and the quality of hatchery water supplies.

I opened my talk with some references to the human condition and to the relationship between the susceptible host, the virulent pathogen, and the determining factor: the environment. Physical and chemical parameters for water for fish have been identified and extensively reported by physiologists and toxicologists. Fish culturists can prescribe limitations on loading, density, and water flow for safe production of fish. But there are no standards set for fish pathogens in hatchery water supplies. It seems logical that in order to get quality smolts, you need quality water.

Assuming that quality standards exist for physical and chemical factors for fish culture water sources, what about biological standards? Part of the problem is sensitivity. Another part is the tenuous lifeline, or technical fix, flung in our direction by high technology. A third is cost. Sensitivity is a public relations issue. If as many rabbits or robins died in a park as fish may in a hatchery, I imagine the little old ladies in tennis shoes would be up in arms. We simply don"t see most fish that die. If it weren't for hatcheries, screens on dams, and sometimes trucks and barges, we would seldom see a sick or dead fish. But they are there. Our data tell us so. Secondly, the "technology lifeline" often dangles before us hope of finding the vaccine, drug, or other "magic bullet" that will end a disease problem once and for all. "If we can only find the answer . . ." It could cost a lot of money to fix every water supply to prevent the influx of pathogens, so less expensive alternatives are irresistible.

In the meantime, we do the best we can to manage what fish we have in the water and facilities given us. We are challenged to grow top quality smolts capable and ready to migrate to salt water, in poor quality environments. The word "quality" sticks out and needs definition.

Phillip Crosby in the book Quality Is Free states, "Quality is not goodness, luxury, size, or weight. "Quality is the conformance to requirements." Let us write that five-word definition down: "Quality is the conformance to requirements." This means conformance to clearly stated requirements that can be used to judge a smolt, a hatchery program, a release strategy, or a fishery management program. Before you can be assured you have quality, you must have clearly defined requirements against which you can measure accomplishment. If the requirements are not set, you cannot measure how well your nuts and bolts, your computer chips, or your smolts meet the needs of your customer--in our case, the fishery resource and its users. The key is setting requirements to aim for. A top quality smolts or a top quality population of smolts would have virtually no variation from the set standard. In the jargon of the quality control professionals, the term "zero defects" does not mean perfect. It means zero deviation outside the clearly defined bracket of requirements that has been set. To get at the quality issue means that a consensus must be reached on the requirements of smolts and cn management requirements.

The same definition of quality applies to hatchery water supplies. If we know that certain physical and chemical (and, I will add, biological) factors are essential to the production of quality fish, then any deviation outside acceptable ranges is a defect. Again, consensus standards for water supplies for each life stage of fish we rear are an important element in rearing quality smolts. Water quality defects could then be fully identified and addressed according to their significance. Some water supplies are OK as is, some could be fixed, and some may have to be abandoned or replaced. The bottom line is simply that water quality is an integral part of smolt quality.

At the outset, a rhetorical question was asked regarding whether or not the presence of "the characteristic microbe of a disease might be a symptom instead of the cause." In many situations, cultured fish live healthy, normal lives in the continuous presence of pathogens. When environmental stresses occur and the balance tips in favor of disease, however, the characteristic microbes flourish. If the fish cannot adjust adequately, or if fish culture corrections are not made, disease may manifest itself. If losses mount in typical patterns, the fish culturist must act. By resolving environmental problems and applying effective therapeutants, a balance between the host and the pathogen can be restored. The question still remains: Was the disease caused by the microbe or were the microbes and the fish merely players in a larger environmental scenario? A disease outbreak often is a symptom of environmental failure and an urgent signal that conditions must be changed. Successful fish culture then hinges on whether correction of adverse environmental conditions can be achieved in time to prevent losses. The need for fish culture skills to maintain the balance between the host and the pathogen in the face of changing environmental conditions indicates that there is still a great deal of "art" in the "science" of fish culture. Quality hatchery water supplies can do much to tip the balance in the favor of the fish and enable the fish culturist to meet fish production standards that will ensure smolt quality and readiness to migrate.

In the course of this discussion I have focused on the significant role of the environment in the relationship between the host and the pathogen. The hatchery water supply is a key determinant of smolt health and quality. Disease prevention starts here. Biological criteria should be set for hatchery water supplies, just as we set them for temperature, flow, gas supersaturation, and ammonia levels. I also touched on the topic of quality.

The problem here is that quality is too often in the eye and the mind of the beholder. Too often the term "quality" is used to signify the relative worth of things.

Quality then ends up meaning something different to every one of us. This is precisely the reason Phillip Crosby's definition of quality as the conformance to requirements is so important to us here today.

The consistent production of quality fish is dependent on a quality environment. If you accept the premise that "fish are what they swim in", then we must fully confront the issue of water supply quality before we can be assured of the reliable, consistent production of quality smolts, fully capable of meeting the objectives for which they are reared.

WATER QUALITY ENGINEERING

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The first question one needs to ask about water quality is, "What is it?" Some of the parameters you might want to keep in mind are pH, alkalinity, sodium, potassium, and calcium and magnesium (remember that calcium and magnesium are two constituents of hardness, which is generally regarded as very important). There has been discussions lately about calcium and pH in regard not only to fish health but also to fish disease. Frankly, I believe that there is much research to be done regarding water quality at fish hatcheries and smolt survival.

To the fish culturist, water quality may simply be clean water. If the water is low in oxygen, we aerate it; if the pH, alkalinity, or hardness is too low or too high, we frequently learn to live with it and manipulate the fish species we are rearing to adapt them to the water quality.

To the fish, water quality is whatever the fish culturist gives them. Sometimes it is good and sometimes it is poor. Sometimes it is raw water--water used once. Sometimes it has been used by other fish five or six times before the fish is exposed to it. And there are still other times when the water is reused as much as 10 times.

Everyone talks about water quality, but not too many of us do anything about it. This is partly of necessity. After all, how do you chemically alter a flow of 10 cubic feet per second? Roger Burrows talked about water quality a number of years ago, and he did something about it in the form of the Burrows oyster-shell filter bed for reuse systems. The oyster shells worked well in enhancing water quality because they furnished water hardness as well as a sub-strate for bacteria, but there were other problems associated with reuse systems.

I can offer you a first-hand example of the importance of water quality in the production of steelhead smolts. Dworshak National Fish Hatchery in Idaho is located below a high dam and receives its water supply from the reservoir. The water is largely snowmelt and of poor natural quality. Its hardness is only about 10 parts per million, and the water is basically devoid of mineral content. This water quality led to a phenomenon known as the "Dworshak Syndrome". In this syndrome, the health of the young steelhead deteriorates during smoltification. The larger and healthier fish developed large lesions, and smolts migrated in such poor health that it is doubtful that the hatchery made a large contribution to the run in those years.

The hatchery sought the help of Dr. Thomas Yeade of the University of Rhode Island and Dr. Gary Wedemeyer of the LSFKS Seattle laboratory. After several years of testing and adding various minerals in various concentrations, the problem was identified. The fish were suffering from sodium and potassium deficiencies during smoltification. Dworshak Syndrome was essentially eliminated through the addition of 20 parts per million of sodium and 8 parts per million of potassium to the rearing water.

This improvement was easily accomplished at Dworshak SFH because the fish are raised in a reuse system. Only 10 percent of the flow had to be treated. Salts, such as SaCl and KC1 are purchased in bulk form and metered into the reuse sys tern.

We recently confirmed the theory that sodium and potassium deficiencies were the cause of Dworshak Syndrome. For the first time in seven years, we had a problem with the chemical supply system. One of the three reuse systems in the hatchery broke down, and :hose fish were taken off the mineral-suppiement system and put into single-pass raw reservoir water. The fish that had not completed smoltification began to show Dworshak Syndrome again. Again it was corrected by the addition of the salts supplement. With careful monitoring of the fish and the water, this type of event should be completely preventable.

Thus, we now know that hatcheries with water reuse systems can economically add sodium and potassium to avoid deficiency syndrome. What about the other 95 percent of the hatcheries, that use once-through flows? Should they all be changed to reuse hatcheries? It might be feasible, but I nevertheless do not think they should.

What can we say in general about water quality, which is always listed as one of the major requirements for aquaculture? First, we may be creating problems for the fish by selecting water quantity without regard to quality. When that is done, we try to live with the consequences. Managers need to know more and think more about the effects of changes in rearing-water quality. We need to take a more careful look at water quality in the hatcheries. We need guidelines to follow and we need to learn how to improve water quality. Farmers fertilize their crops, and even warmwater fish culturists add supplements to their ponds. Perhaps coldwater fish culturists should do the same.

I believe we need to take a closer look at water quality relative to of each specie of smolts. It may well be that some of the problems of descaling, BKD, IHN, etc., could be alleviated with changes in water quality. I am not here today to tell you how to do it, especially since I am not sure that the relationship is clear, but I can tell you that it must be done.

Finally, when we have learned the specific relationships between water quality and smolt quality, hatcheries should monitor their water quality, and not just once a year, but frequently over the course of the year. If it seems necessary and possible to improve water quality at a hatchery, managers could consult with experts in the field over what steps should be taken.

Research managers need to keep water quality in mind and studies need to be done in this area. It is hard to deal with a foreign environment like water especially in the volume magnitudes used at fish hatcheries. But for the future of salmonid culture, answers need to be found.

2.8 EFFECTS OF HATCHERY PRACTICES ON SMOLT SUCCESS

Hatchery Loading and Flow (F.K. Sandercock)

Effects of Health Treatments on Smolt Success (H. Lorz)

Hatchery Management (W. Hopley)

Nutritional Considerations (W.F. Hublou)

HATCHERY LOADING AND FLOW

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If any of you have ever tried to identify the rearing capacities in a given hatchery or pond, you know that it is a fairly difficult subject. This is because there are several factors to consider simultaneously, and because they are all compounding and going in different directions. When Dick Noble told me that he was traveling to China, I was reminded that it took the Chinese from 413 BC until about 1960 or 1970 to learn how to load ponds. They now do an excellent job of it, and one of the keys to their success is standardization of the size of the ponds. They have drained and excavated ponds so that they are all a standard size. When the ponds are a standard size and have flat bottoms, it is easy to estimate their volume. A recipe is then followed which details how many of up to six species are to be put into the ponds, so that each species occupies a different niche. It is very sophisticated and very impressive in a rural commune.

I would like to try to reduce the question of hatchery loading to some simpler questions and make some generalizations. I was impressed yesterday with Harry Westers's comment that "We do not listen to the fish." I think it would be wise to spend more time "listening to the fish" because there are some great benefits to be had. A paper this morning on the size and time of release of smolts indicated that there are many confounding things going on. Sometimes the peak survival occurred in fish released in June; in other years, it was the May or July releases. But the maximum survival rate for these fish was about 1.5 percent, whereas the smolt-adult survival rate for coho in British Columbia is about 15 percent on average. Craig Clarke reported this morning that in Bilton's work on time and size of release, the peak in survival was

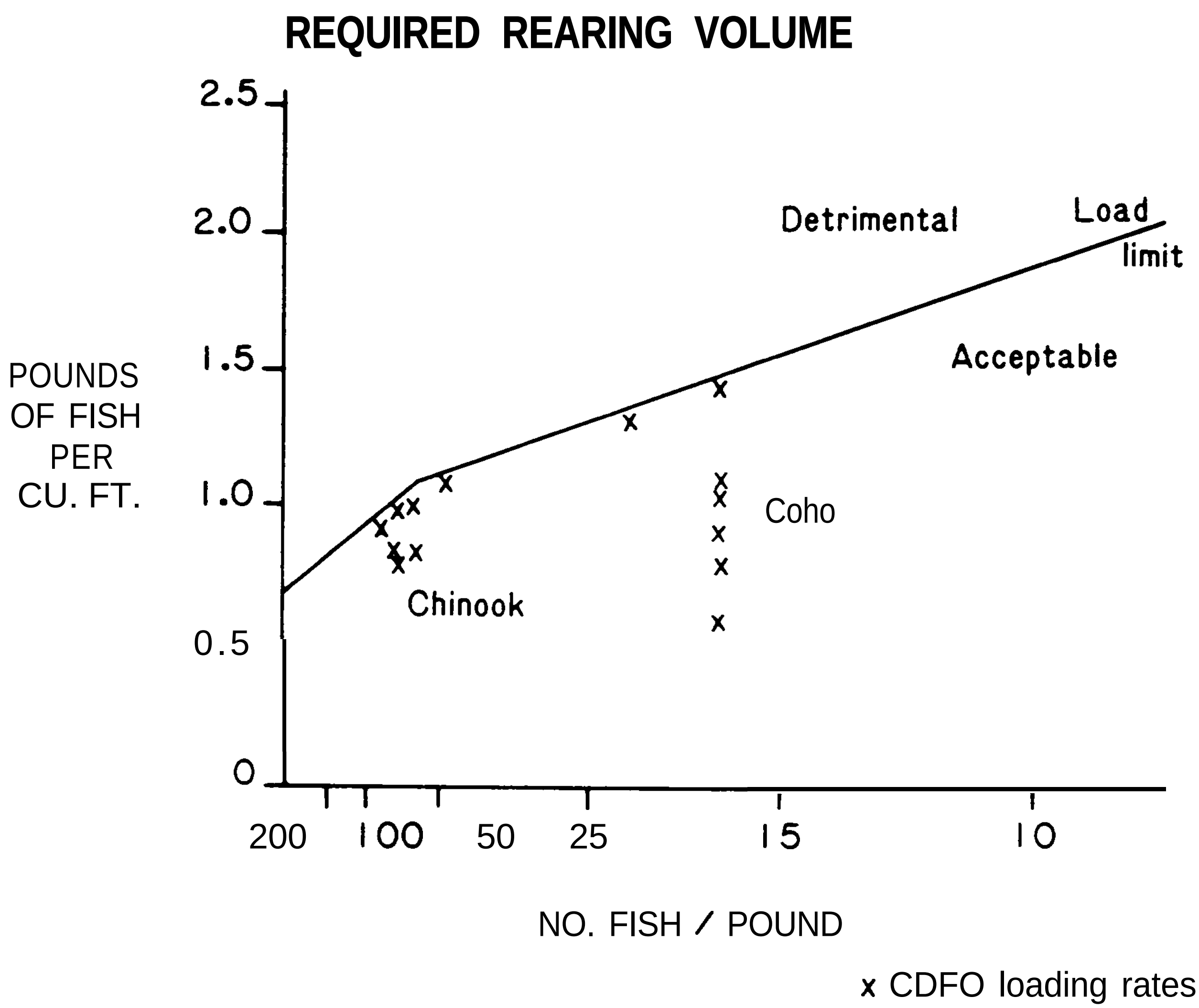

Figure 1. Loading rates (volume) for chinook and coho salmon. Load limit prescribed by Mayo (1971).

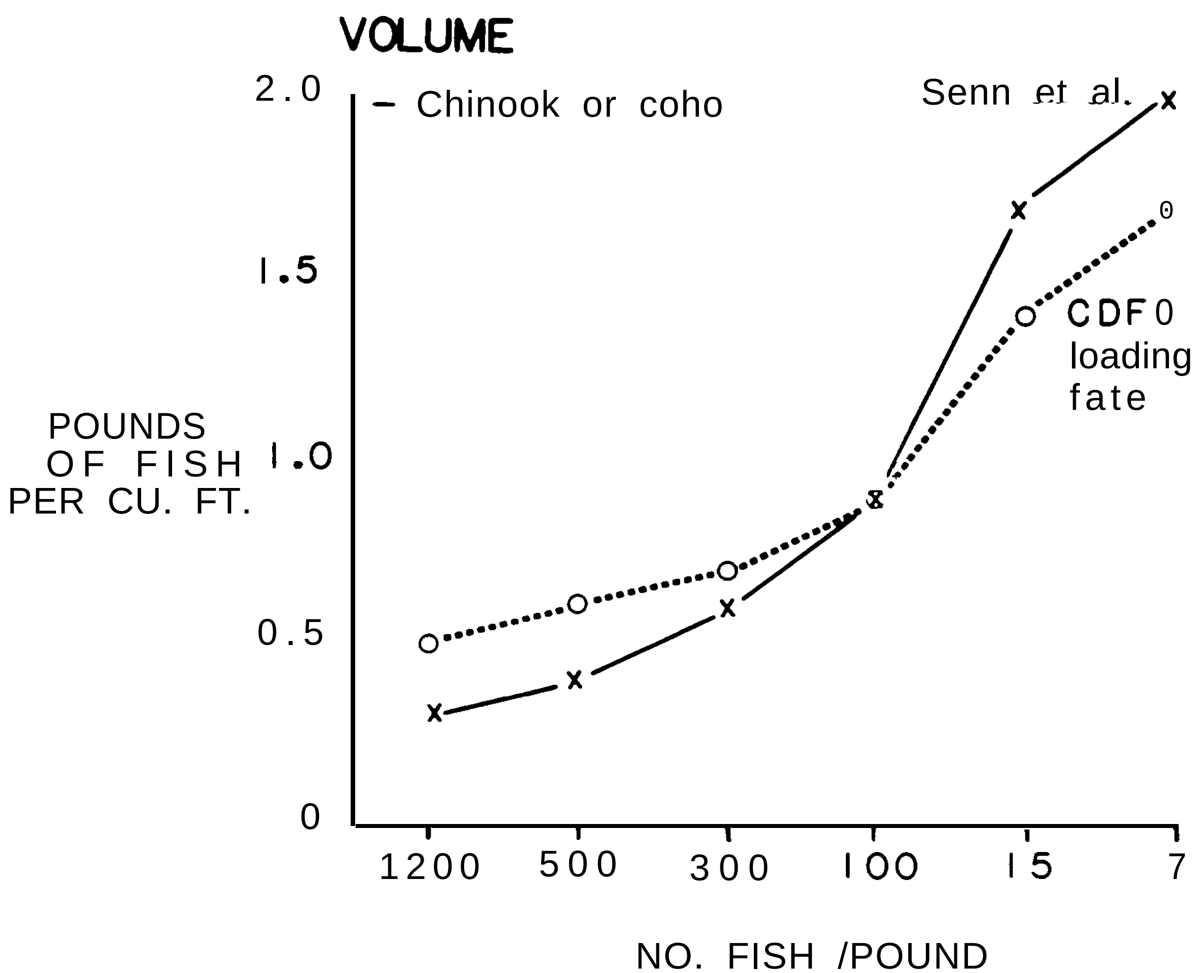

Figure 2. Loading of Burrows ponds, by pond volume, recommeded in Senn et al. (1984) and those used by CDFO (see Shepherd 1984) for rearing young chinook and coho salmon.

14.1 percent. However, in some earlier work that Bilton did, the optimum was 43 percent. If you had asked me 10 or 15 years ago what the maximum survival was for coho, I would never have guessed that it might be as high as 40 percent, or probably even 50 percent if we do everything right.

Back to a somewhat simplistic view of loading. The "loading limit" line shown in Figure 1 dates from 1971, and I think it is what people are generally using nowadays with respect to loading chinook and coho. I should emphasize that most of my paper concerns chinook or coho, and that I do not intend to deal with the other three salmon species, or with steelhead.

The crosses (Figure 1) are the levels at which we are loading in a variety of facilities, with the chinook released at a size of 50 to 100 to the pound and coho generally at about 17 to the pound. The data points that are well below the upper limit, if it is a limit, are from Big Qualicum hatchery. We had three successive release groups of coho from that hatchery that survived at rates between 25 and 30 percent. Obviously we are doing something right at Big Qualicum, and I think that there is a message in that loading.

Bonneville Power Administration (BPA) recently published a volume by Senn et al. (1984) on low-cost techniques for enhancement. In Figure 2, the solid line indicates Senn's recommended loading rates for chinook and coho (assuming moderate temperatures); the broken line indicates the Canadian Department of Fisheries and Oceans standard loading rates. We tend to load fish smaller than 100 per pound at a heavier rate (considerably heavier in our Capilano troughs) than the one recommended by Senn, because we think it is desirable to have the fish at higher density so they initiate feeding better. when fish reach a size larger than LOO/lb, it is desirable to reduce the loading rate.

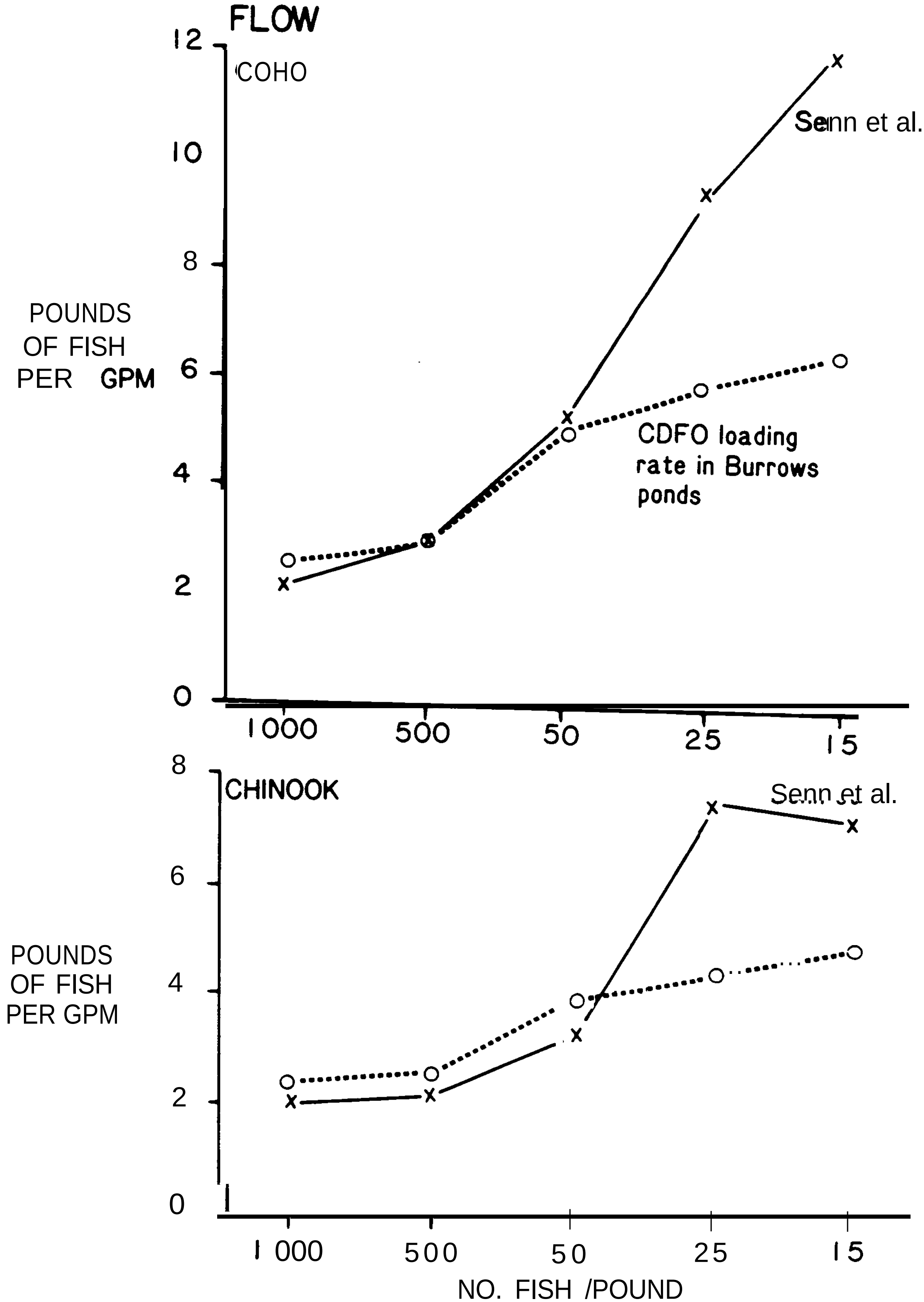

Figure 3. Loading of Burrows ponds, by flow rate, recommended in Senn et al. (1984) and those used by CDFO (see Shepherd 1984) for rearing young chinook (at 90% ration) and coho salmon (at 50% ration assuming a temperature of 58°F.

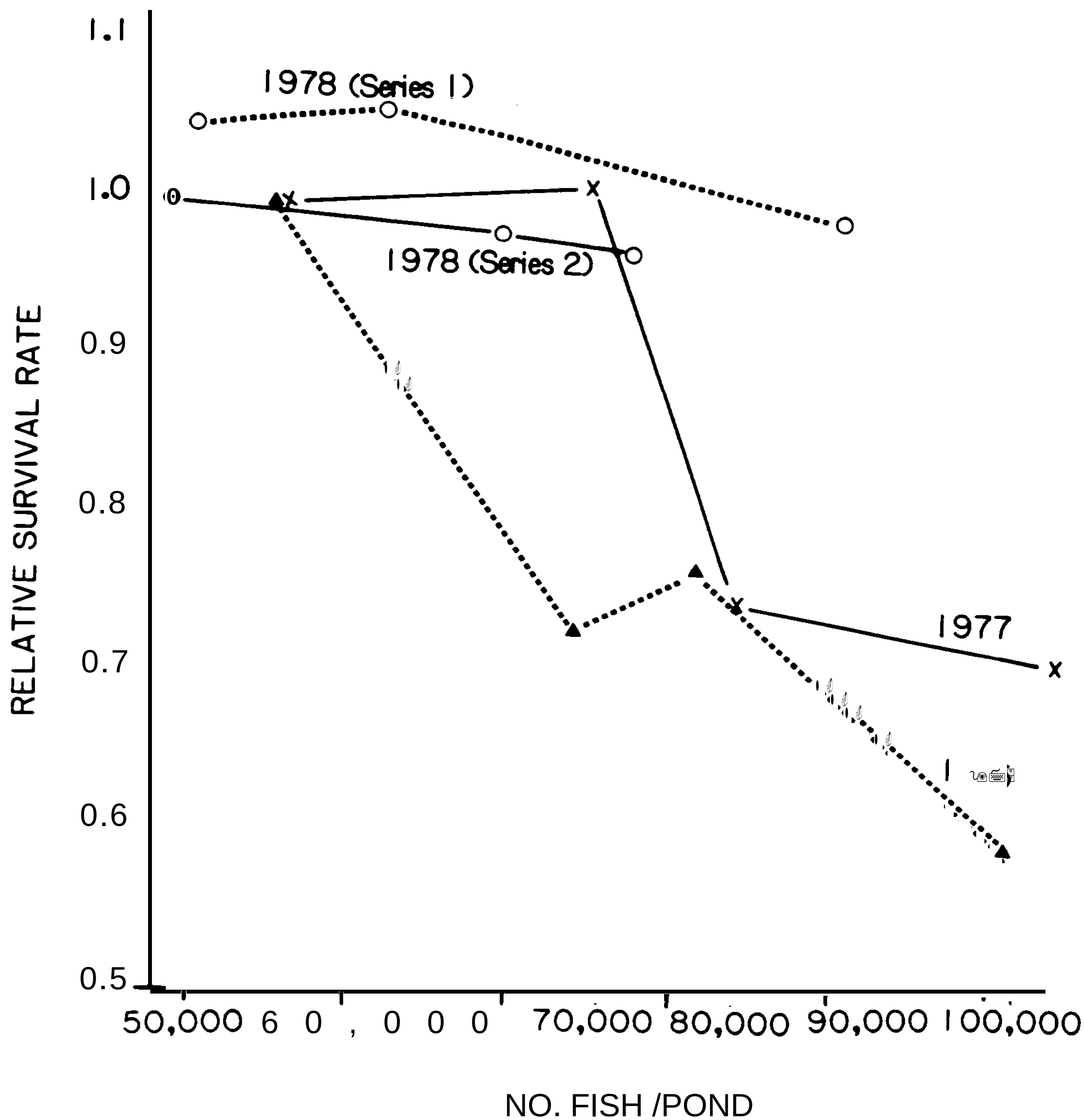

Figure 4. Relative ocean survival of Capilano coho reared in Burrows ponds at various densities, 1975, 1977, and 1978 brood years.

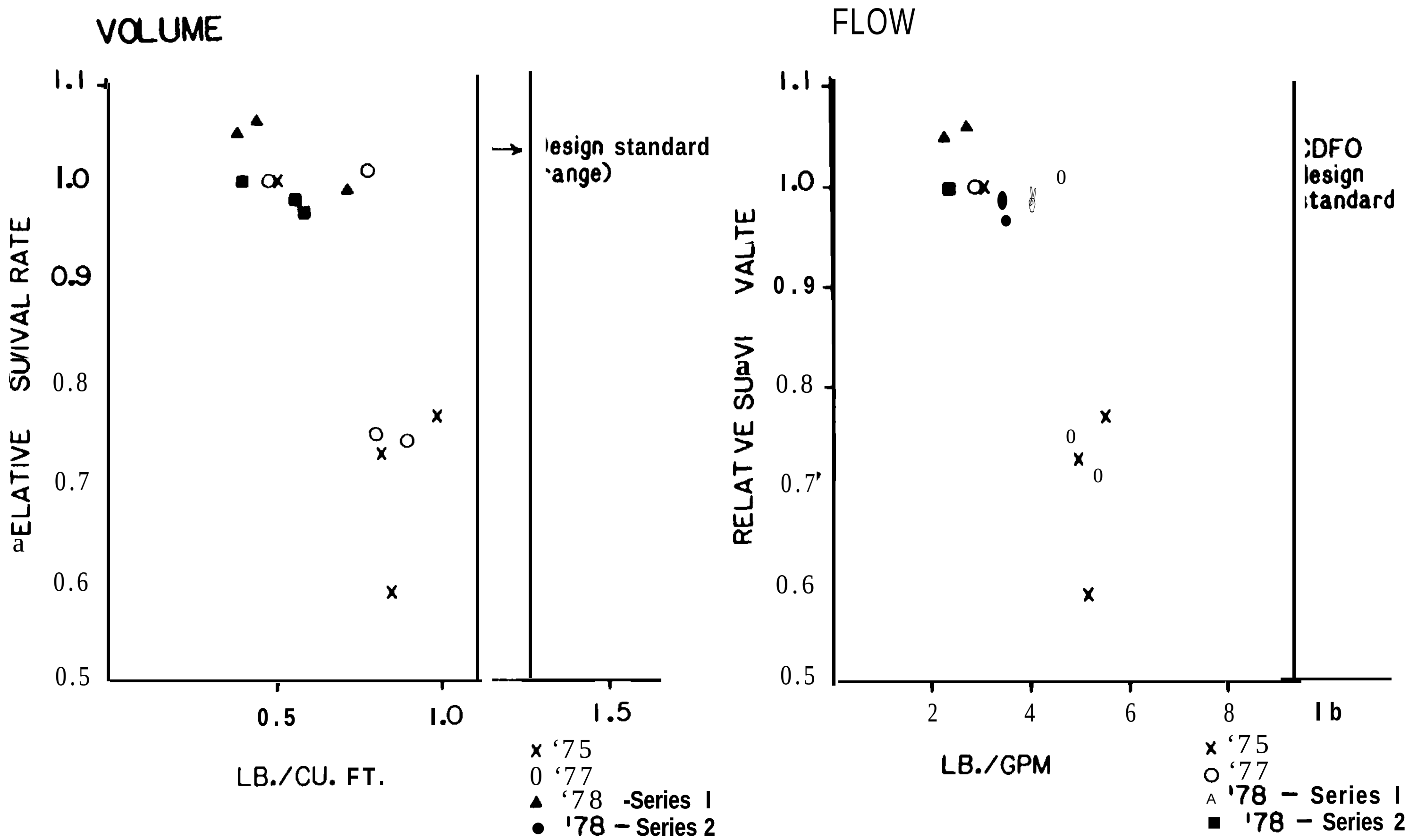

Figure 5. **Relative** survival of coho salmon reared in Burrows ponds at Cap**ilano Hatchery** at different volume and flow loadings, 1975, 1977, and 1978 brood years.

Figure 3 shows the recommended loading rate for chinook and coho based on flow into the pond, assuming a temperature of 58″ F. I should add that although I have mentioned Big Qualicum and its irregularly shaped earthen channels, the smolt-adult survival rate information that follows is all based on concrete Burrows ponds. At least in a Burrows pond you know how much water is there, so that is the only example I am going to present.

In December 1979, we attended the Northwest Fish Culture Conference and described an experiment that we had run at Capilano Hatchery where we reared coho at four different densities and presented the resulting survivals. On the basis of our results for 1975 and 1977, we thought the message was very loud and clear (Figure 4): If you rear at high densities, you get low survival. I know that these results generated considerable interest here, and that some experiments were started on the Columbia involving both chinook and coho. I have not seen the results of those experiments although I have heard that the results were not as dramatic as our 1975 and 1977 studies. For that matter, some of our own subsequent experiments were not as clear-cut either.

It was interesting to read in the Senn et al. (1984) report that recent studies by all Northwest agencies have suggested that rearing reduced numbers of salmonids in a given environment will produce a higher survival to adults, and will often result in a greater return for the dollar invested. I think that Is true, and I think you could intuitively guess that anyway. If the fish are not crowded, they are less stressed and presumably should survive at a greater rate.

In both the 1975 coho experiment and our repetition of it in 1977, the densities that were established were maintained for 12 months. A subsequent experiment was described in a technical report by Fagerlund et al. (1983) that examined the influence of culture density on juveniie coho salmon production and ocean survival. Coho smolts of 1978 brood were released in 1980 (see Figure 4, Series 1,2). The conclusion drawn from the adult survival was that there was a greater influence of rearing density at the younger stages, because when these fish were only reared under the experimental

Figure 6

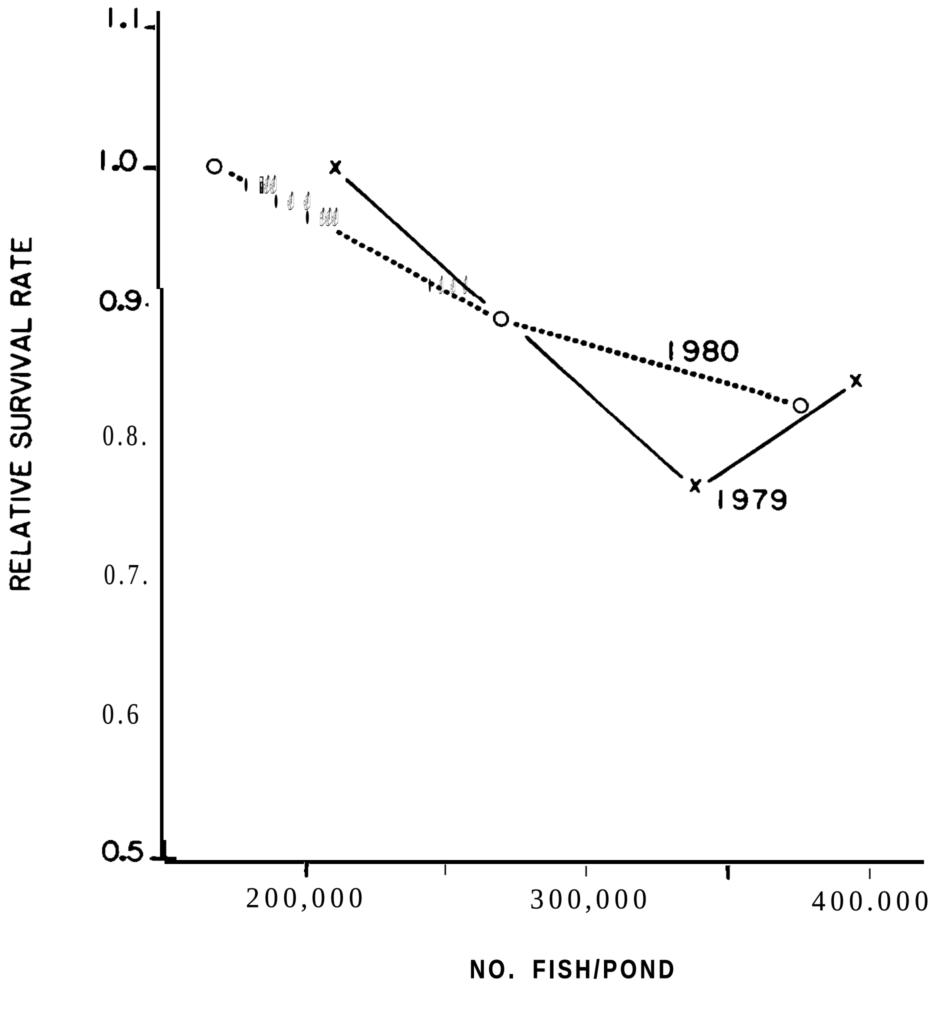

Figure **6.** Relative survival of Capilaoo chinook reared in **Burrows** ponds at various deosities, **1979,** 1980 brood years.

Figure 7

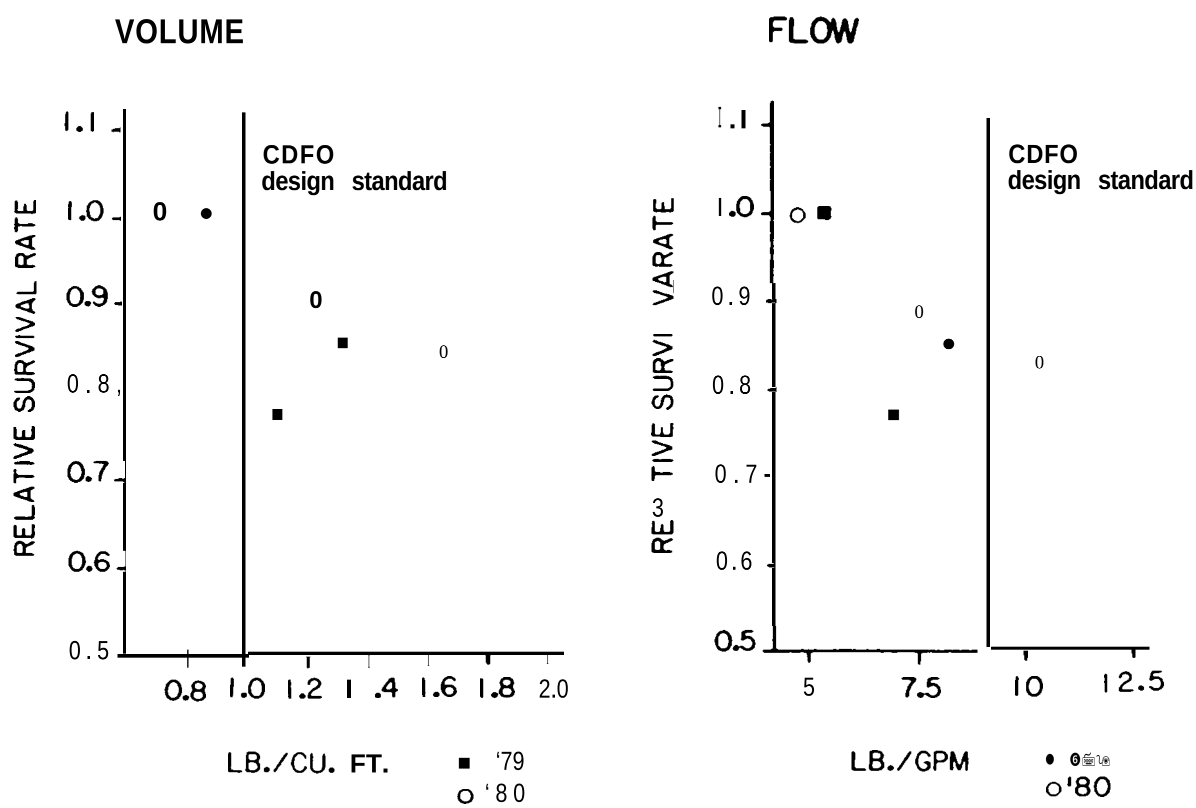

Figure 7. Relative survival of chinook salmon in Burrows ponds reared at Capilano Hatchery at different volume and flow loadings, 1979, 1980 brood years.

densities for 5-1/2 months, they did not exhibit the same survival rates. Thus, the end result was not nearly as clear as before, but remember that the 1975 and 1977 brood fish were reared for 12 months at the established densities, whereas the 1978 brood fish were only held at the experimental densities for about 5-l/2 months. In addition, the highest rearing density was not repeated. Scientifically, the 1978 brood experiment was better designed because the result was the cumulative of six different ponds with two replicates. There was a slight trend in the data, but no significant difference.

The data shown in Figure 5 came as a bit of a shock to Bruce Shepherd, our design biologist. In this case, I have shown the design standard that we would use for the given set of conditions with the load rate program that we have. If you look at the experiments that we ran, it is obvious that the fish were trying to tell us something. Shepherd was suprised to discover that we were in fact loading our ponds at much lower rates than what was considered an acceptable and conservative design. For both volume and flow, adult survival is plotted as relative survival compared to the group reared at the lowest density. For coho rearing, we were operating at a fair amount below design.

In Figure 6, I have shown the results of a loading density experiment involving chinook. Again there is some indication of the same sort of trend that we have seen throughout. This, of course, is for juveniles only, reared at those densities for between 2-l/2 and 3 months, so perhaps we should not expect to see as much effect. Using those same survivals (Figure 7) and looking at volume and flow with the design standard, we exceeded the design standard with respect to volume, but less so for flow. In general, higher loading rates have resulted in reduced survival.

REFERENCES

Fagerlund, U.H.?l., J.R. McBride, B.S. Dosanjh, E.T. Stone, and F.K. Sandercock. 1983. Influence of Culture Density on Juvenile Coho Salmon Production and Ocean Survival. Canadian Tech. Rept. Fish. Aquat. Sci. (1229).

Yayo, R.D. 1971. Hatchery design and operation information, in Aquaculture: A New England Perspective (T.A. Gaucher, ed.), New England ?lar. Resour. Info. Progr., Univ. Rhode Island, Narragansett.

Senn, H., J. Mack, and L. Rothfus. 1984. Compendium of Low Cost Pacific Salmon and Steelhead Trout Production Facilities and Practices in the Pacific Northwest. Bonneville Power Admin., U.S. Dept. Energy, Portland, Oregon.

Shepherd, B.G. 1984, The biological design process used in the development of Federal Government facilities during Phase I of the Salmonid Enhancement Program, Can. Tech. Rept. Fish Aquat. Sci. (1275).

EFFECTS OF HEALTH TREATMENTS ON SMOLT SUCCESS

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My involvement in this topic is really an offshoot of some contractual work that we were doing for the U.S. Environmental Protection Agency (EPA) a number of years ago. Bouck and Johnson (1979) also looked at specific chemicals used to treat fish and monitored their survival following saltwater challenge, but I found little new information in the literature or additional experiments as a follow up to their work.

In getting material together for this talk, I called on friends in the pathology and physiology fields, and acknowledge their assistance. If I have failed to cover the existing literature adequately, the fault is mine.

In the preface of Nelson Herwig's 1979 book, Handbook of Drugs and Chemicals Used in the Treatment and Control of Fish Diseases, he stated, "The art and science of fish medicine is in the dark ages, but it does exist, [and] many say, 'Try, who knows, it might work,' and it is into this seething cauldron of confusion that I pour this effort." Although the history of fish disease treatment goes back at least to Hofer (1904), the lack of people power and funding has made a systematic search for fish disease therapeutants much less successful than that for veterinary and human medicine. Schnick and Meyer (1978) estimate that it would cost $8.8 million for contract research to meet the registration requirements for 33 well-known chemicals that are used or considered for use in fish culture and management. Although the research continues and many chemicals are being used under Investigational New Animal Drugs (INAD) permits, until the necessary information is obtained, only a handful are approved for use on food fishes. The Fish and Wildlife Service has indicated that, because of a lack of funds, it is very limited in the research it can do to assist in registering the chemicals presently in use, let alone develop new techniques or screen new drugs.

In the following tables I have listed some of the common chemicals and drugs being used to treat fish or algae and their registrational status. Reference to unregistered drugs and chemicals should not be construed as approval or endorsement for use. The material was compiled basically from Schnick and Meyer's (1978) publication and Fish Hatchery Management (Piper et al. 1982).

Table 1 lists some therapeutants and disinfectants used against bacteria or parasites in the treatment and prevention of disease in fish. The research and registration of fish culture chemicals is an ongoing process. In 1984, Romet (formerly R 05-0037) was approved for use in salmonids against furunculosis. Investigations into the toxicity and efficacy of Chloramine T for bacterial gill disease control are presently being conducted. Screening studies to accelerate the search for candidate protozoicides and fungicides to replace malachite green have been initiated, but results to date have not been promising.

Table 2 shows the status of a number of herbicides used in fish culture, some of which are also proposed as therapeutic agents. A British chemical company has shown interest in pursuing registration of Diquat as a fish therapeutant.

What do we know about the effects of these chemicals or drugs as they effect smoltification, tolerance to seawater, or effects on smolt migration following their release? In work that Barry McPherson and I published in 1976, we provided data showing that chronic low-level exposure to copper had deleterious effects on downstream migration, gill sodium-potassium ATPase activity, and survival at seawater challenge. In some later work with herbicides (Lorz et al. 1979), it was found that Diquat reduced seawater survival and the migratory urge but had no apparent effect on ATPase activity.

Table 3 summarizes information on the survival of coho salmon in seawater following treatment with therapeutic agents or herbicides. The table is a composite of the published material of Bouck and Johnson's (1979) work and our data.

None of the chemicals, as used, produced mortality in fish that were treated and returned to fresh water. High mortality occurred, however, among fish treated with copper, Diquat, Hyamine 1622, potassium permanganate, malachite green, or heavy doses of MS-222, when they were transferred to seawater. Endothal produced 100 percent mortality in one test but no mortality in a replicate. The reason for the difference is unknown, but caution is probably warranted. When Bouck and Johnson (1979) gave the fish a four- or five-day rest following treatment prior to seawater challenge, the mortalities in seawater were considerably reduced.

Sow that I have discussed the problems or potential problems that may be encountered with the use of some chemicals or drugs, I will show some of the benefits that may be achieved. In 1983, Zaugg et al. published data :hat showed that the addition of salt (NaC1) to the diet cf juvenile fall chinook salmon for six weeks prior to release resulted in a 65 percent greater adult recovery in the fishery and return to the hatchery than the corresponding controls.

Amend et al. (1980) noted a 19.3 percent increase in adult steelhead returns to the hatchery as compared to control groups of juveniles vaccinated against two serotypes of <u>Vibrio anguillarum.</u> A similar benefit in survival was noted

TABLE 1 CHEYICALS USED IN FISH CULTURE

Chemical	Status	General Uses
Acriflavine	NR	Bacteriostat used to treat external bacterial infections and for prophylaxis in hauling tanks
Iodophors Betadine	NR	Therapeutant, fish egg disinfectant, most required research complete for registration.
Argentyne	NR	Disinfectant--fish eggs, general hatchery
Wescodyne	NR	Same as above
Calcium Hypochlorite	R	Disinfectant
Erythromycin (diet)	NR	Treatment of bacterial kidney disease; present use under INAD
Formalin	R	Therapeutant for external parasites, fungi on fish eggs. Very effective on Trichodina costia and Ichthyophthirius
Nitrogurans Furanace (p-7138)	RNF	Therapeutant - bacterial infections (Nitrofurpirinol) probably will not be registered for use on food fish
Furazolidone (NF-180)	NR	Furunculosis and enteric redmouth
Furox-50) (diet)	NR	
Furacin (nitrofurazone)	NR	

Note: R = registered; NR = not registered; RFF = registered for food fish; RNF = registered for nonfood fish only.

TABLE 1 CHEMICALS USED IN FISH CULTURE con't

Chemical	Status	General Uses
Quaternary ammonia compounds		
Hyamine 1622	NR	Therapeutants; disinfectant; bactericidal; not effective on ectoparasites
Hyamine 3500	NR	
Roccal	XR	
Lime (calcium hydroxide, slaked or hydrated lime)	R	Pond sterilant
Malachite green	NR	Therapeutant--excellent in control of fungi and protozoans, often used in combination with formalin; ISAD to FWS for use on adult salmon or eggs
Masoten (Trichlorfon Dylox)	RNF	Therapeutant, control of ectoparasites
Potassium permanganate	R	Oxidizing agent, therapeutant; treatment of gill problems in trout and salmon
Sulfonamides		
Sulfamerazine (diet)	R	Osmoregulatory enhancer, also to reduce excessive mucus in fish infected with BGD or external parasites
Terramycin (oxytetracycline: diet; also injected into adult salmon to keep them alive until spawning)	R	Broad-spectrum antibiotic used to control external and systemic bacterial infections

TABLE 2 HERBICIDES AND ALGAECIDES USED IN FISH CULTURE

Chemical	Status	General Uses
Copper sulfate	RFF	Herbicide, algaecide; also effective to control ectoparasites and external bacterial infections
2,4-D	RFF	Herbicide
Dichlobenil	RNF	Herbicide. Used in ponds, lakes, and reservoirs with non-flowing water
Diquat	RFF	Herbicide: also for treatment of bacterial gill disease, columnaris, cold-water disease
Diuron	NR	Herbicide
Endothall	RFF	Herbicide
Fenac	RNF	Herbicide
Silvex	RNF	Herbicide; control of emergent or submerged vegetation
Simazine	RFF	Herbicide

Note: R = registered; NR = not registered; RFF = registered for food fish; RSF = registered for nonfood fish only.

by Deegan (1981) for vaccinated coho salmon in New Hampshire, although prior studies in Oregon of vaccinating coho juveniles did not show increased survival at the time of adult return.

Yesterday, John Rohovec referred to work in Oregon with regard to feeding erythromycin to spring chinook juveniles. This is work being conducted at Cole Rivers Hatchery by the Oregon Department of Fish and Wildlife and supervised by Mike Everson. The data to date indicate:

1. high variability between years in the detectable incidence of bacterial kidney disease (BKD) in adults held at the hatchery;
2. the ability to reduce BKD levels and mortality of adults injected with erythromycin in years when the detectable incidence rate was high;
3. greater survival to adulthood for groups of juveniles treated with erythromycin-medicated feed (two 21-day feedings); and
4. no consistent survival benefit to progeny of adults injected with erythromycin (11 mg [active]/kg body weight).

The return rates of juveniles treated with erythromycin in their feed in 1979 and 1980 are shown in Table 4.

SUMMARY

What needs to be done?

1. We need to get on with the registration of chemicals and drugs for fishery use. We are limited at present to one or two compounds that are both effective and registered for food fish use. The loss of a single approval could create a major void if the federal agencies were to enforce regulatory control.

2. There is a vital need to know more about the effects of chemical treatment of juveniles and subsequent survival. For example, what types of recovery times (if any) are necessary following treatment?

TABLE 3. SURVIVAL OF COHO SALMON IN SEAWATER FOLLOWING TREATMENT WITH THERAPEUTIC AGENTS OR HERBICIDES

	Treatment		Mortality (%) in Seawater	
Chemical Tested	Concentration (mg/liter)	Duration (min.)	Direct Transfer	4-5 days post-treatment
Control			0	0
Copper sulfate	37	20	100	20
Copper chloride	30 ug/l	24 h	25	
Copper chloride	30 ug/l	144 h	65	10
	10 ug/l	144 h	41	10
2,4-D	30	60	0	0
2,4-D	200	144 h	0	0
Diquat	10	144 h	43	NT
Endothal	5	60	100 (0)	4 (0)
Formalin	167	60	12	0
Hyamine	2	60	68	4
Malachite green	67	0.5	0	0
	1	60	24	4
	1	60	44	12
Xasoten (Trichlorfon)	0.5	60	0	0
MS-222	100	6	100	12
	75	8	20	0
	50	10	0	0
Nifurporinol	1.5	60	80	0
Oxytetracycline	1	60	20	12
Potassium permanganate	2	60	80	12
Quinaldine	2.5	10	0	0
Simatine	2.5	80	4 (0)	0

TABLE 4 ESTIMATED CATCH AND ESCAPEMENT OF SPRING CHINOOK SALMON ERYTHROMYCIN TEST GROUPS 1979, 1980

Group	Fish/ kg	Prerelease Mortality 45-day (%)	Percentage Return Catch	Escapement	Total
		1979 Brood			
Large					
Control	18.5	1.09	0.53	0.36	0.89
Erythromycin	18.5	0.25	1.66	1.11	2.77
Small					
Control	19.2	1.34	0.90	0.44	1.34
Erythromycin	22.9	0.94	1.30	0.76	2.06
		1980 Brood			
Control	11.7	1.21	0.14	0.32	0.46
Erythromycin	12.3	0.41	0.31	0.64	0.95

REFERENCES

Amend, D.F., R. Antipa, and T.H. Kerstetter. 1980. Increase in ocean survival of freely migrating steelheads vaccinated against Vibrio anguillarum. Trans. Amer. Fish. Soc. 109:287-289.

Bouck, G.R. and D.E. Johnson. 1979. Medication inhibits tolerance to seawater in coho salmon smolts. Trans. Amer. Fish. sot. 108:63-66.

Deegan, L.A. 1981. Increased estuarine survival of juvenile coho salmon vaccinated against Vibrio anguillarum. Trans. Amer. Fish. Soc. 110:656-659.

Herwig, N. 1979. Handbook of Drugs and Chemicals Used in the Treatment and Control of Fish Diseases. Thomas, Springfield, Illinois.

Hofer, B. 1904. Handbuch der Fischkrankheiten. Schweizerbart, Stuttgart. 384 p.

Lorz, H.W. and B.P. McPherson. 1978. Effects of copper and zinc in fresh water on the adaptation to sea water and ATPase activity and the effects of copper on migratory disposition of coho salmon (Oncorhynchus kisutch). J. Fish. Res. Board Can. 33(9):2023-2030.

Lorz, H.W., S.W. Glenn, R.H. Williams, C.M. Kunkel, L.A. Norris, and B.R. Loper. 1979. Effects of selected herbicides on smolting of coho salmon. Rep. EPA 600/3-79-071. U.S. Environmental Protection Agency. Corvallis, Oregon. 103 p.

Piper, R.G., I.B. McElwain, L.E. Ormer, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. USDI Fish and Wildlife Service, Washington, D.C. 517 p.

Schnick, R.A. and F.P. Meyer. 1978. Registration of thirty-three fishery chemicals: status of research and estimated costs of required contract studies. No. 86. Investigations in Fish Control. Fish and Wildlife Service, D.C. 19 p.

Zaugg, W.S., D.D. Roley, E.F. Prentice, K.X. Gores, and F.W. Waknitz. 1983. Increased sea water survival and contribution to the fishery of chinook salmon (Oncorhynchus tshawytscha) by supplemental dietary salt. Aquaculture 32(1-2):183-188.

HATCHERY MANAGEMENT

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There is scarcely anything on the agenda of this workshop that doesn't ultimately deal with hatchery management--in its broad sense, at least. What little research I did at one time has already been covered by the other speakers; they haven't left much undescribed. But it may be fortuitous to be speaking at this point in the agenda. With few exceptions, all these presentations have addressed factors affecting the smoltification process. These factors can be influenced by the way a hatchery is programmed and the way it is operated. Hatchery management really represents the translation of accumulated knowledge into the applied operation of a hatchery. It is really hatchery management that should be the culmination of your research efforts. Later on I'm going to present a story about hatchery management. But first I want to go back over some information that is fairly familiar to all of us.

Let us look at what we know about smoltification and then compare that to how we apply that information in hatchery management. Let me simply list the items that we see as important in the actual process, the developmental process of smoltification. First, there are photoperiod, temperature, and environmentai factors, and possibly some factors like fish size and genetics. These are the most prevalent factors involved in smoltification as addressed in the literature.

Photoperiod seems to be universally identified as the major environmental stimulus that triggers the onset of the smolt process itself. We see temperature referred to most often as the single most important controlling factor. Temperature sets the pace and the ranges for these various processes involved in smoltification. Then there is another unidentified group of environmental factors that seem to have roles in maintaining and coordinating a synchronized status among all the behavioral and physiological changes that are occurring during the smolt process. Of course, the endocrine system is represented as being the central control system: it actually converts all these external inputs to biochemical inputs. Finally, there is that group of intrinsic factors like size and genetic makeup that certainly have some role in the smolt development process.

What do we see in the literature as to what happens to the smolt process when some of these environmental factors are out of phase or not coordinated during smolting? Again, beginning with photoperiod because it seems to be the primary stimulus to the smolt process, we would expect a serious disruption in the smolt process if the photoperiod itself was atypical--and the literature supports that contention. We all know that photoperiod can be applied as a tool to help regulate or control smoltification. But we also find in the literature that prolonged exposure to light inhibits growth and the smoltification processes: we find it can affect the ability to maintain osmotic balance, and an improperly enhanced photoperiod can result in asynchronous smoltification, for instance producing an animal that shows some of the typical characteristics of smoltification at a time when the rest of the process, whatever that total is, is not in synchrony.

What about temperature? We know that temperature can induce several responses in development, for instance, in ATPase activity. If we accept the notion that ATPase is somehow involved in smolt preparation, we also have to assume that a stimulus that affects the ATPase development cycle is probably also affecting the smolt process. We know, for instance, that temperature affects the elevation of Atpase; that higher temperature can result in an elevated level of ATPase in some species and in a more rapid increase in ATPase activity. We know that high temperatures can also limit the duration of that elevation, and that temperatures that are too high can suppress the activity. High temperature can also reduce saltwater adaptability and migration response, at leas: in steelhead. On the other hand, smoltification can benefit from temperature: for instance, a variable temperature routine found in an ambient water system might actually lead to better smolt development than you might find in constant-temperature rearing systems, as in a wellwater hatchery.

Then, of course, there are those environmental factors that include not only natural factors but also factors found in a closed environment and related specifically to hatcheries and hatchery management. There must be a host of these factors which, either collectively or independently, have the potential to negatively affect the smolt process. We know, again from the literature, that many of the physiological and behavioral aspects of smolt transformation are especially vulnerable to these undefined environmental impacts. However, the literature is not very prolific on the more subtle environmental factors that might play a role in this process. We could generalize that the net effect of these negative environmental factors, be it, handling, or high density in the rearing ponds, is, in fact, stress.

We understand, again from the literature, that the endocrine system is the chemical link between the environment and the physiological response to that environment. We also find that stress affects hormonal responses involved in smoltification, so we must conclude that practices that produce a stressful environment are quite probably detrimental to the smolt process. Of course, the literature supports that notion, too.

What have we done so far? I know that there are a few factors that are commonly identified as part of the smolt process, and I have briefly identified at least a few of the responses that smolting fish show to environmental stimuli which provide circumstantial natural evidence that smolting could be disrupted by the hatchery environment. Let us examine how effectively hatchery management acknowledges these ideas. One way to examine this, and the way I will do it, is to describe a typical production season. Because this workshop should be fun, I think we can all play along.

If you will, think of the Sunday morning comic section. It usually has one cartoon that instructs the reader to find five things wrong with a picture.

One curtain may be shorter than the other, the leg of the chair is shorter than the other three legs, etc. As I describe a hypothetical hatchery, try to identify the things that are wrong with the picture and how they could affect the smoltification process. We are going to talk about a multi-species hatchery, releasing yearling coho and zero age fall chinook.

My hypothetical hatchery is a fairly simple operation consisting inpart of one half-acre rearing pond used for final release. All of fish in the hatchery pass through that pond for a period of rearing. Of course, the hatchery has a few raceways for starting fish and the obligatory number of incubators. The hatchery is run on ambient river water, and the temperature is probably a little bit cool for good growth. You have to pick an arbitrary starting point, say November just after spawning. At that point, you would find a crop of yearling coho from the previous brood year in the half-acre pond, and those coho would be staged for release on the first of May at a size of about 18 fish per pound. The current fall chinook are stiil in the incubators as eggs; this scenario would have them then move eventually into the small raceways. After the coho are released in May, the fall chinook would go into the same half-acre pond to be reared for a month and released on June 1 at 100 per pound. Remember that the water is cool, so to achieve that LOO-pound target size, we have to rear fail chinook until at least June in this particular hatchery. Of course, the baby coho are in the incubators behind the chinook. So far, all is well and good, and that is what it should look like in a simple hatchery.

Sow I choose to put some reality to it. I call it the confessions of a hatchery prograer. One of the things that might happen is that a programmer calls the hatchery manager and has him send 200,000 of those fall chinook eggs to another hatchery where the well-water supply is a constant 50 degrees. This is intended to accelerate the hatching and get a higher growth rate on those fish. I would have them return those fish when they reach 100 per pound in March, rather than in June. The chinook transfer goes off as ordered and this group is brought back at 100 per pound and planted directly from the tanker.

By April 15, we are half a month away from release of our yearling coho. They are happy as can be in the pond, and everything is going along like it should. The programmer calls the hatchery manager and instructs him to hold those yearling coho until the first of June rather than the first of May, as we programmed earlier. "And by the way, keep them at 18 per pound; we still want that size." You hatchery guys in the audience have guessed already that by the 15th of May, the hatchery manager is calling the programmer because the coho smolts are sick; they are damaging themselves trying to get out of the pond. Next, they have to be treated for 10 days. Of course, the chinook that are now in the raceways have bacterial gill disease because they weren't moved to the half-acre pond since the coho were still on the station. Of course, the baby coho are sick because they are in one raceway when they should be in five raceways. We couldn't spread them out because the chinook haven't moved yet. The programmer's response is to call the manager back and say, "Okay, the minute the coho are off that 10-day treatment, go ahead and release them. I sympathize with your situation." As you might guess, if our hypothetical hatchery was on the Columbia River, the temperature would be someplace over 60 degrees by now.

Another spinoff is that we must hold the chinook until July, instead of planting them at 100 per pound in June. We have to hold them until July to get them healthy again and to avoid planting them on top of the coho that we just finished planting. But we are not done yet: adding insult to injury, the administration finds out that we still have these chinook on hand and gives instructions to go into the half-acre pond and seine up half of these chinook smolts and put a coded wire tag in them, put them on a truck and take them someplace else and plant them. Since we are in the pond anyway, why don't we go ahead and seine up the remaining half and weigh them out in a screen bucket? This is so we can get an accurate enumeration of the number of fish we released.

That is the end of my horror story. I can think of at least nine different events in this story that show potential conflict with the promotion of the smolting process. First, we pushed the 200,000 fall chinook, using increased temperature, at a constant-temperature station. Sow what do we know about the effects of temperature? We know that temperature can affect the ATPase curve, and we also know that it can truncate ATPase development at least in some species. We know that it can accelerate the onset of smoltification. But we also know that we can disrupt the migratory response by temperature strategies. We know that we can promote asynchrony in the smolt process by having one environmental factor out of phase with the remainder. After we finished doing those things--potentially--we trucked the fish all the way back to the original hatchery, and then planted them directly out of the truck with no recovery time for any stress response.

In delaying the yearling coho from May until June, the first thing we ignored their migratory inclination. We know that if coho are delayed long enough, they will lose the migratory response and tend to revert. We held back the food ration to maintain their size for another month. We note in the literature that the period of smoltification is about the fastest growing time for coho smolts. It doesn't make sense to try to hold them back, since normally they wculd be growing at a faster rate. We released the fish directly after a 10-day treatment, which the evidence suggests we should not do. The literature suggests at least a two-week clearance before releasing after treatment. We also waited until the temperature in the receiving water was high, which, in steelhead trout at least, is known to suppress the ATPase level. We placed a zero age chinook in a high-density situation. High density is known to suppress ATPase activity in zero-age chinook--among other problems. We also released the chinook immediately after disease treatment with no clearance time. We have imposed a tremendous handling stress on the chinook at release by seining them out of the pond, tagging them, and transpcrting them. We imposed a stress on the remainder by seining them, netting them into a screen bucket, hanging the screen bucket from the scale or whatever process you happen to use, and releasing them directly from that.

Well, this hcrror story may be a bit far-fetched for just a single hatchery, but believe me, every one of these processes goes on every year in some hatchery in the Columbia River system. Probably several of these factors go on at several locaticns. Don't get the idea that I'm trying to apologize for all of this. The truth is that despite the fact that these practices should have a negative effect on smolt quality, they often also result in increased survival. For instance, the accelerated chinook rearing is probably an important factor in higher survival from some hatcheries than others. It also might be an indication of how bad the Columbia River system really is. You can get away with using some of these practices and still gain a net benefit in terms of survival!

Finally, I don't think that we are likely to be spared altogether such things as changing release schedules or transporting smolts or enumerating our releases. That is common practice in at least some hatchery systems. We are unlikely to operate hatcheries in a way that is completely conducive to normal smoltification--that's a reality. What, then, are the alternatives we face? Well, one approach is to develop tools to manipulate smoltification so that it more adequately fits a management system from which we are not going to escape. That is, we need to be able to produce a smolt, a capable, functional, smolt--more or less at our command.

I was intrigued to hear Jim Warren's quote about quality equaling conformity to requirements. What I propose may constitute carrying that to the extreme. This is especially true in the Columbia River system, where it may be that the natural smolting sequence doesn't even fit the environmental status of the river or the receiving waters. So how can this need be met? Can we develop a capability of manipulating salmon, as Dan Mulcahy suggested the other day, the way we do livestock animals?

The first level of achievement, at least for this approach, will come from continued research into the basic physiology of smoltification. By this I mean research at the primary level of biochemical control of smoltification. It seems to me that if you can understand the basic control, then you have unlocked a key to its manipulation. The second level of progress will be the development of a reliable smolt index, which is exactly what that 704(H) measure asks for--reliable smolt indices. It will be based on basic physiological behavior, and it might actually turn out to be an arsenal of indices to be used concurrently. It would be a tool that would allow us to be comfortable that we have produced a fully capable smolt, a tool of detection. The availability of that set of smolt indicators is really a key element, that is, a bridge toward the ultimate capabilities, which goes in two directions. The first is a hatchery manager's litmus paper--opportunity to monitor smoltification and make reasonable decisions about releases. That is the simple avenue. The really intriguing avenue is the opportunity to manipulate smoltification. To provide capable smolts at opportune time. I believe that should be the end result of smolt research. The ability to actually manipulate smoltification will result from being able to monitor change during smoltification. That ability will come from the recognition of the primary biochemical controls.

NUTRITIONAL CONSIDERATIONS

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Diets that fully meet specific nutritional needs of the fish being reared at Columbia Basin fish hatcheries are an elementary requirement in producing quality smolts capable of surviving to adults. This is true regardless of the many and varied environmental and management manipulations that may be applied.

Nutrition is a very broad science, and a number of scientific disciplines are needed to consider and investigate our questions if we expect to get intelligent answers. For example, nutritionists determine what is needed and the balance of required nutrients in fish diets, in addition to providing recipes. Food scientists are needed to consider the functional properties of food ingredients and other specifics. Biochemists are called on to provide an understanding of the metabolic machinery involved. Physiologists are asked to consider digestion and energy balance problems, and to determine how the food is being utilized. Microbiologists are often needed because many fish food ingredients come in contaminated form. And last, but far from least, fish biologists are needed to produce an understanding of the resource goals and objectives and an understanding of why this work is needed. With so many things to consider, it is obvious we can only skim the surface here today.

What is the status of our knowledge of fish nutrition, and how is it being applied? If diets currently being fed and feeding techniques being used are not satisfactory, what problems can be identified? And what can we suggest doing or what needs to be learned to overcome the problems we see? These are the questions we need to answer for BPA. I do not have the answers, but I will outline some of the considerations and make some suggestions on how we might proceed.

There are several important things to consider before we get into what we do or do not know and the problems we see. First, it is important to recognize that food commonly fed to hatchery fish is completely artificial. This makes the problems very different and more difficult than if we simply needed to pick and choose among natural foods. This makes it very important to consider the scientific disciplines already mentioned before we try to provide answers.

It is also important to recognize that fish feed is one of the major costs in hatchery operations. Usually, personnel, feed, and utilities are the most expensive of all hatchery costs, depending on the kind of facility involved and size of fish being reared. So, economics is a major factor in everyday choosing of diet to be used.

Another important consideration is the fast-growing variety of fish rearing facilities over practically any environmental condition available. Standardization of fish hatcheries is practically unheard of. We try to raise fish almost anywhere; consequently, we are constantly encountering new environmental conditions with which our artificial diets are supposed to cope. Diet chemical composition, diet form, particle size, and food consistency needs can vary according to the needs of individual facilities.

We should also recognize that answers to nutritional problems are usually very difficult, time-consuming, and costly to obtain. Well-designed and properly controlled and conducted tests are required to obtain reliable answers to many of our nutritional problems.

It is also very important to recognize that work in nutrition is never done. We will simply never know all we need to know to produce the best smolts from a nutrition standpoint. We must keep working constantly to try to raise our level of understanding as high as we can.

There is ample evidence in the hatchery that in many instances we are still not providing entirely satisfactory nutrition for the fish. Diet is having demonstrable effects on sunburn, dropout, anemia associated with red cell inclusion bodies, and caudal fungus, to name just a few common problems. Some relationship between diet and bacterial and viral diseases appears to be very likely.

What is the status of our knowledge of fish nutrition? Surprisingly, and very disturbing to me, many fishery workers and administrators apparently believe that our current knowledge of fish nutrition is satisfactory and further information is not critical. I consider this view very naive and sadly misinformed, but perhaps people thinking this way should be forgiven, since:

1. nutritional requirements of salmonids have been published;

2. nutrient composition and digestibility of common diet ingredients have also been published;

3. ingredient market prices and availability are known; and

4. least-cost linear programming methods are available.

What more do we need to know? Let us look at some examples:

EDUCATION AND PEOPLE PROBLEMS

One of the more important things we need to do is to increase awareness among fishery workers about nutritional requirements. We need to obtain a higher level of understanding of what comprises feed, and what ingredients are needed in fish diets. At best, most fish growers might be able to identify the major classes of foods, such as protein, fat, carbohydrates, minerals, and vitamins. It is doubtful they know much about the role of each of these, and it is much more unlikely they have any understanding at all of 53 or so nutrients that make up the building blocks of the food classes. People raising chickens and cattle know the importance of these elements. Our understanding of fish nutrition is probably still about 20 years behind what is known for poultry and livestock. We have been slow to recognize what is needed and even slower in trying to obtain the information.

NUTRITIONAL REQUIREMENTS

Although many requirements are known, many are not. For example, vitamin requirements were established for fish in the 5 g range. What about requirements from there on up to fish in the 30-40 g range, typical of many smolts? Or requirements for maturing fish and developing eggs? About 80% of all feed costs are usually incurred at fish sizes larger than 5 g, if you are releasing fish in the 30 g range. We may not only be missing something of vital importance for the fish, but we may also be wasting money by continuing to provide levels of things that may not be needed.

What do we know about dietary requirement differences between freshwater and saitwater rearing? This is a very obvious gap in our knowledge that must be worked on as we get into programs that require saltwater rearing.

Another example is how nutrient requirements might vary during structured growth regimes, such as when growth is accelerated during warm-water conditions or only enough food is being fed to maintain the fish with practically no growth under cold-water winter conditions. The more we manipulate and refine our rearing techniques, the more we need to know the effect of this sophistication on nutritional requirements.

RAW MATERIALS

We should never cease investigating the utilization of raw materials. One of our very most important problems is availability and quality of fish meal.

The method of preparation of fish meal to produce the best product is critical because we depend on fish meal as the basic ingredient for protein in fish feed. Investigations for suitable substitutes for herring meal are needed as well as tests of the effects of combining natural protein substances supplemented with various amino acids and minerals.

Thousands of tons of fish scrap are being wasted every year. It is possible to use much of this scrap if it can be obtained cheaply and transported to where it can be made into fish meal or hydrolyzed and used as a silage. There is a lot of work that should be done in this area.

FOOD DELIVERY VEHICLES

Food is being delivered to the fish in several forms: moist (70% moisture), semi-moist, both frozen and nonfrozen (20-35%); soft-dry (12-14x); and dry (about 10%). Not only the cost of the food, but also its effect on fish physiology, such as digestion, differs between forms. Convenience differs. Palatability differs greatly. Each diet form has a role, but none, thus far, have all the assets we seek. This is where most of the attention is at this time (e.g., moist vs. dry feed), but it is also where much yet remains to be learned (e.g., we do not even know at this time whether the difference in palatability between moist and dry diets is because of texture or flavor differences or a combination of factors). Cost often affects the fish grower's choice of feed, even though information may be lacking on the ability of the cheaper ration to produce viable fish capable of surviving.

DIETS

We must continue to investIGATE performance of different ingredient combinations that are compounded to produce certain results. High-energy, highly digestible diets are needed in certain instances, whereas it may be just as important elsewhere to feed a diet that provides all the necessary nutrients, but in a low-energy, high-fiber package. It is not easy to supply a diet that will only provide minimum growth yet will contain adequate trace elements and other nutrients to maintain good health. Such a diet cannot be just "sawdust", as so many people think. It will not be a cheap diet, either.

One of the most important areas to continue investigating is that of growth-producers. We know that fresh, natural food is capable of producing growth that almost always exceeds what is possible with prepared diets of artificial feeds. At some hatcheries, it is critical to feed diets that produce maximum growth. Much more work is needed in this area and should include tests with hormones.

QUALITY CONTROL

We are definitely at the bottom step concerning our knowledge and application cf quality control standards for fish feed. There are several differentq aspects I am including in this category. First is the ability to list and test for presence of essential nutrients. We need to be able to check the feed we buy and make sure it is what we want chemicaliy. Of course, this assuines we know what it is we want--and we may well not. Next, we should be able to list and test for things we want to control, such as oxidized fat or microbial load.

Microbial load is an issue particularly important to semi-moist feeds such as Oregon Pellets. We should be setting limits on bacterial contamination to protect overall quality of the feed.

We also have the problem of open-formula vs. closed-formula diets. The ideal situation may be to gain adequate knowledge of nutritional requirements so that when feed is ordered, nutrient levels can be specified and then let the manufacturer provide these from a list of acceptable ingredients.

PHYSIOLOGY

Perhaps this is not a proper title for this category, but we need much more information on the effects of dietary substances on physiology of the fish. For example, dietary chloride can affect smoltification. How much salt should the diet of pre-smolts contain, and for how long before release to assist in preparing the fish for transition to salt water?

EARLY MARINE SURVIVAL

We know that most mortality after release of hatchery fish takes place within the first few mcnths, and usually in the estuary or ocean. What we do not know is the effect of hatchery diets on increasing fish survival through this stag2 of life. The interrelationship with disease is also critical to know; e.g., if bacterial kidney disease is encouraged by the diet, the food is indirectly decreasing ability of the fish to survive.

I have gone through a smorgasbord of fish nutrition concerns for you, but I have not gotten very specific--on purpose. It is really not for me to try to list specific, prioritized needs of the various fish growers. And, in my view, it is not really for this group to review suggested needs and then incorporate these items into a priority list. Instead, I strongly suggest that nutritional concerns in general be identified to be of high priority, and that a system be established to identify and rank specific needs. One way would be to establish a panel of nutrition experts charged with developing a priority list. BPA could then send out RFD's on the top items.

APPENDIXES

APPENDIX A: FINAL RANKED PROJECTS

APPENDIX B: DIRECTORY OF PARTiCIPANTS

APPESDIX C: WORKSHOP SCHEDULE

APPEMDIX D: STRUCTURE OF THE WORKSHOP

APPENDIX E: UNREFINED PROJECT DESCRIPTIONS

APPENDIX A: FINAL RANKED PROJECTS

THE RANKING PROCESS

Five sets of project descriptions were written up for each of the major categories of research in each of the five working groups in this workshop. Subsequently these lists were consolidated and revised by one of five new working groups, each of which worked within a major research category. These groups produced a list of project descriptions that synthesized the previous sets of lists. The new project description lists were presented to the meeting as a whole; after some discussion and some small revisions, the projects appeared on the first ballot. In the first ballot, the participants were asked to list the five highest- ranked projects in each of the five research categories (presented in Appendix E). The outcome of the first ballot was a list of 28 project descriptions.

in the second balloting, each participant allocated 100 “priority points” among as many of these descriptions as they saw fit. The number of points given to each of the second-ballot project descriptions by each participant and the corresponding totals are shown in Appendix A. These totals represent the sense of the workshop participants regarding the highest priority of research to be implemented by BPA. However, BPA recognizes that these projects and priorities do not necessarily represent the views of other entities.

RANK	POINTS	PROJECT TITLE/DESCRIPTION
1.	(265)	Conduct a comprehensive, integrated size and time of release study which includes the following critical components: a. Develop data base on fish releases and then use it to correlate survival data with size and time and health, etc. at release at all basin facilities. b. Conduct system-wide basic size and time studies at many facilities for all species. C. Conduct detailed size and time/smolt index studies at one low, one middle, and one upper river site on representative natural stocks which would provide a comprehensive correlation betweeen size and time, and many smolt indices with survival to the lower river, seawater adaptability (seawater challenge) at any estuarine monitoring station and survival to adult.
2.	(248)	Develop a system wide interagency hatchery data-base for compiling and analyzing records of hatchery practices and environmental factors as related to smolt survival.
3.	(247)	Develop and evaluate control measures for IHN and BKD.
4.	(223)	Develop practical means of manipulating the time of smolting to match desirable release periods using environmental (e.g. photoperiod, temperature, salinity) and hormonal techniques.

5. (178) Determine relationship between size and time of entry into seawater, nearshore distribution, nearshore oceanic conditions (determined by oceanographic and remote sensory techniques) and survival to adulthood, utilizing retrospective data search and experimental approaches.

6. (167) Define smolt quality and develop a standardized hatchery smolt quality control and environmental monitoring and analysis program (disease history, physiological status, etc.).

7. (166) Review existing agency "hatchery-operations-data collection-and-analvze-systems" to form a basis for the development of a central data base system for interagency information transfer regarding activities to evaluate and improve smolt quality and adult survival.

8. (160) Evaluate relationships between existing and new smolt indices and survival as monitored at different life stages thru adults.

9. (143) Establish correlations between physiological and behavioral responses at seawater entry and existing and new smolt indices and evaluate the merit of the indices as predictors cf SUCCESS.

10. (140) Measure and evaluate disease transmission during smolt collection/transportation, effects of disease during transportation, and develop techniques to reduce impacts of disease.

11. (133) Using existing information, evaluate rearing and release strategies for each stock comparing facilities which have high versus low survival rates (to adult stage).

12. (125) Increase smolt survival by fish transportation improvements (smolt transportation has become an unnatural but necessary fact of life because of hydroelectric developments on the Snake and Columbia rivers. Inland stocks of anadromous fish are highly dependent on transportation both from hatcheries to release sites and through the dam impact areas. It encompasses the use of acclimation ponds, recovery areas, and use of hatchery technique to better prepare the fish for survival through this stressful practice.) Work needs to be done in the following areas:

a. What can the hatchery management do better to prepare fish to withstand substantial periods of transportation?

b. The roles of chemicals/drugs on improved survival on transported fish and their ability of imprint/home.

c. The use of improved techniques and equipment in the transportation system. Development of new and improved systems of transporation.

d. The effects of transporation on hatchery fish straying, homing, and imprinting.

e. The use of final rearing ponds, acclimation ponds, and recovery/resting areas.

f. Predation at release sites after transportation and methods of minimizing those impacts.

g. Interspecies relationships in the transportation and collection system.

13. (120) Determine what hatchery practices contribute to, or reduce the spread of disease including:

a. Evaluate sanitation procedures at selected facilities.

b. Determine the incidence of certain pathogens at those facilities.

c. Correlate sanitation practices and disease incidence.

d. Set sanitation guidelines to reduce disease incidence.

14. (118) Identify water quality factors at all Columbia River hatcheries and determine their correlations with smolt/adult survival.

15. (112) Identify, evaluate and apply manipulating or controlling factors including environmental factors, drugs, and chemicals that protract duration of, or intensity of smoltification.

16. (112) Conduct a workshop of fish nutrition specialists to obtain recormnendations on priority of nutritional considerations in producing quality smolts.

17. (111) Quantify, qualify and develop criteria for loading and density of species, race, and life stage (with an eye toward cost-effective yield).

18. (105) Develop guidelines for outplanting hatchery fish including release techniques, where, when, which stocks, and methods to distinguish wild from outplanted stocks.

19. (86) Develop a standardized post-release fish quality control monitoring program (include seawater entry success, acquired diseases, injury and general smolt quality-factors.)

20. (78) Determine the effects of environmental factors (photoperiod, water temperature, etc.,) on smoltification.

21. (75) Develop a comprehensive model describing the relationship between various indices (of smoltification) and assorted measures of success.

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APPENDIX C: WORKSHOP SCHEDULE

Monday, May 20, 1985

Travel to Kah-Nee-Ta Lodge, Warm Springs Indian Reservation, Warm Springs, Oregon

2:00 pm - 5:30 pm Registration (Lower Lobby) - Optional tour of Tribal fish facilities

3:00 pm - 5:00 pm Steering Committee Meeting - Wasco-Paiute Room

5:30 pm - 6:60 pm Social Hour - Lobby Level Patio or Wasco-Paiute Room

Dinner - Kah-Nee-Ta Dining Room

Tuesday, May 21, 1985 - Confederated Room

8:00 am Welcome - Greg Drais, Chief, Biological Studies Branch, Bonneville Power Administration

8:15 am Purpose of Workshop - Jerry Bouck, Senior Biologist, Biological Studies Branch, Bonneville Power Administration

8:30 am Workshop Format - Jim Creighton, Creighton & Creighton (EA)

8:45 am Keynote Presentation: Biological Issues in Smoltification
Jack McIntyre, U.S. Fish & Wildlife Service

9:30 am Break

9:45 am Keynote Presentation: Implementation and Management Issues
Dale Evans, National Marine Fisheries Service

10:30 am Draft Criteria for Ranking Projects - J. Bouck

10:45 am "Fishbowl" Discussion of Draft Criteria

Initial Discussants:
J. Bouck, BPA
G. Drais, BPA
M. Schneider, Northwest Power Planning Council

11:45 am Lunch

12:4S pm Presentations: Use of Smoltification Indices
Convenor: Mark Schneider

Seawater Challenge Tests/Time Release Studies
Craig Clark, Canadian Fisheries and Oceans

Smolt Indices and Migration
Wally Zaugg, National Marine Fisheries Service

Smolt Indices and Adult Survival
Dick Ewing, Oregon Department of Fish and Wildlife

Endocrine Testing
Walt Dickhoff, University of Washington

2:25 pm Comments and Questions

2:45 pm Break

3:00 pm Presentations: Measurement of Smolt Health and Quality
Convenor: Herb Pollard, Idaho Department of Fish and Game

Disease Implications to Smolt Survival
Dan Mulcahy, U.S. Fish and Wildlife Service

Diseases in Migrating Smolts
John Rohovec, Oregon State University

Stress Measurements
Carl Schreck, U.S. Fish and Wildlife Service

Health Measurements
Lynwood Smith, University of Washington

4:00 pm Comments and Questions

5:00 pm Adjournment

Wednesday, May 22, 1985 - Paiute Room

8:00 am Rearing and Release Strategies to Promote S.molt Success
Convenor: Doug Arndt, U.S. Army Corps of Engineers

Sex Control Strategies
Ed Donaldson, Canadian Fisheries and Oceans

Lower River Release Strategies
Ron Gowan, Anadromous, Inc.

Ocean Release Strategies
Bill McNeill, Oregon Aqua-Foods, Inc.

Upriver Release Strategies
Ted Bjornn, University of Idaho

9:40 am Comments and Questions

LO:00 am Break

10:15 am Small Group Assignment - Jim Creighton

10:30 am Attendees will be assigned to small groups. Each group is to draft project titles and descriptions of high priority needs regarding:

- Indices of Smoltification
- Fish Health and Quality
- Rearing and Release Strategies

12:OO pm Lunch

1:00 pm Presentations: Effects of Hatchery Environmental Factors on Smoltification
Convenor: Einar Wold, National Marine Fisheries Service

Hatchery Design
Harry Westers, Michigan Department of Natural Resources

Water Supplies
Jim Warren, C.S. Fish and Wildlife Service

Water Quality Engineering
Dave Owsley, U.S. Fish and Wildlife Service

2:15 pm Comments and Questions

2:35 pm Break

2:50 pm Presentations: Effects of Hatchery Practices on Smolt Success
Convenor: Ron Morinaka, Bonneville Power Administration

Hatchery Loading and Flow
Keith Sandercock, Canadian Fisheries and Oceans

Effects of Health Treatments
Harry Lorz, Oregon Department of Fish and Wildlife

Hatchery Management
Bill Hopley, Washington Department of Fisheries

Nutritional Considerations
Wally Hublou, Aquaculture Advisor

4:30 pm Comments and Questions

4:50 pm Small Group Assignment - Jim Creighton

5:OO pm Adjournment until 8:00 pm

8:00 pm Group Activity: Each group is to draft project titles and descriptions of high priority needs regarding:

- Effects of Hatchery Environmental Factors on Smoltification
- Effects of Hatchery Practices on 8molt Success

9:30 pm EA will assemble all project descriptions generated by the **small** group activities, and will distribute them at the beginning of the Thursday morning session

Thursday, May 23, 1985 - Wasco Room

8:30 am Project Ranking Process - Jim Creighton

8:45 am Working Groups: Refinement and Consolidation of Project Titles and Descriptions

Participants will be divided into working groups to consolidate ideas, and refine the descriptions generated in previous small group sessions. Each working group will address one of the following topic areas:

- Use of Smoltification Indices
  Group Leader: Mark Schneider

- Measurement of Fish Health and Quality
  Group Leader: Jerry Bouck

- Rearing and Release Strategies
  Group Leader: Tom Vogel

- Hatchery Environmental Factors
  Group Leader: Greg Drais

- Effects of Hatchery Practices
  Group Leader: Ron Morinaka

12:00 pm Lunch

1:00 pm Reports from Working Groups:

- Use of Smoltification Indices
- Measurement of Fish Health and Quality
- Rearing and Release Strategies
- Hatchery Environmental Factors
- Effects of Hatchery Practices

2:00 pm Instructions on Balloting Process - Jim Creighton

2:15 pm Balloting to Rank Projects Within Each Area of Concern
In the first balloting, participants will be asked to pick the top five project descriptions within each of the following areas of concern:

- Use of Smoltification Indices
- Measurement of Fish Health and Quality
- Rearing and Release Strategies
- Hatchery Environmental Factors
- Effects of Hatchery Practices

2:30 pm Workshop Critique
Each participant will be asked to complete a workshop critique form.

2:45 pm Balloting to Develop Overall Rank of All Project Descriptions
Each participant is given 100 points to distribute as he or she wishes amongst a list of all project titles and descriptions.

3:00 pm Workshop Ends

4:00 pm Ballot Results Available

APPENDIX D:

STRUCTURE OF THE WORKSHOP

The purpose and format of the workshop was presented on Tuesday morning, along with two keynote speeches addressing biological and management aspects of smoltification questions. The main thrust of the workshop was to identify research on smoltification-related practices that are likely to result in greater ocean catches and greater returns of spawning adults--in healthy and strong populations of salmon in the Columbia River Basin.

All participants were asked to contribute in four areas: (1) in the devising of criteria that will best select sound research projects in consonance with BPA's research mandate, (2) in the writing of project descriptions that are practical and meet the criteria, (3) in the refinement of the project descriptions produced by the workshop, and (4) in voting for the projects that represent the best mix of feasibility in the BPA research framework and usefulness in preserving and enhancing the salmon populations of the Columbia River Basin.

Refinement of Draft Criteria

On Tuesday morning, after introductions and keynote speeches, a draft set of criteria were presented. The term "fishbowl" in the schedule refers to the discussion format was used in refining those draft criteria. Four participants sat face to face and discuss the criteria, surrounded by the other participants. As a participant in the audience was inspired to make a contribution, they moved to the center and replaced one of the four discussants. Discussants were expected to yield their places in such a way that the purpose of the discussion -- refinement of the criteria for research project selection -- was best served. A recorder made notes on a flip chart, and a contractor produced a revised set of criteria and issue then to the meeting by Wednesday morning.

Writing of Project Descriptions

On Tuesday afternoon and early Wednesday morning, panel presented, and the meeting briefly discussed, three topics relevant to smoltification research issues: the use of indices, measurement of smolt health and quality, and rearing and release strategies. Participants separated into five to eight small groups on Wednesday morning, and from 10:30 to noon were asked to write, with the help of a recorder, research project descriptions for those three topics. The discussion process, was familiar to most participants. Participants were free to take appropriate notes during the presentations, and through informal discussion during and after the dinner meal on Tuesday evening.

On Wednesday afternoon, two more major topics, effects of hatchery environment and effects of hatchery practices, were presented and discussed. From 8:00 to 9:30 pm, participants were asked to devise project descriptions for these topics.

The project descriptions were compiled and combined and issued to the participants early on Thursday morning. Efforts were made to keep these neat, since they were needed for consultation during the balloting on Thursday afternoon.

Refinement of Project Descriptions

Participants were divided into five small groups on Thursday morning and each group added, combined, modified, and deleted project descriptions to refine the set of project descriptions of their topic. Copies of newly-written project descriptions that arise were added to the project description packets, but it was not possible to reissue entire sets of project descriptions in the time available, and thus some refinements was need to be marked by participants in their original copies when the working groups issue their reports at 1 pm Thursday.

Voting for Project Descriptions

From 1 to 2 pm, the topical work groups presented their refinements of project descriptions to the meeting. Participants were asked to mark any changes in their copies of the description packet, and these refined descriptions were vcted on by participants.

Ballots had been the titles of the project descriptions, and the titles were numbsred in the order of the corresponding project descriptions in the original (and suppiemental) packet. This nunbering was for indexing only, and did not indicate any implication of ranking. Ballots were anonymous and issued at random (but in two colors, so that the votes of the invited participants as a category may be compared with those of the independent participants), and participants were asked to vote their personal best judgement and expertise in the framework of BPA's research mandate and the interests of the Columbia River Basin salmon.

The first balloting was to chocse the five "best" projects in each major topic area. This was followed by a 15-minute period to critique the workshop while the first ballots are being tabulated. In the second balloting, participants were requested to divide 100 "research votes" as they see fit between any number of the 25 projects that were ranked highest in the first ballot (100 votes for one prcject, four votes for each of the 25 projects, or anything in between).

APPENDIX E:

UNREFINED PROJECT DESCRIPTICNS

The following five sets of project descriptions represent the synthesis of the original 25 sets that were the outcome of the Wednesday sessions. Each set was deemed appropriate for the major research area indicated. For the first ballot, participants in the workshop chose a set of five project descriptions in each category that they felt were the five most important. The projects that rece ived the largest number of "top five" rankings were put on the second ballot.

SMOLTIFICATION INDICES

1. Evaluate the smoltification process of wild stocks.

2. Estab lish correlations between downstream migratory behavioral responses and existing and new smolt indices, and evaluate the merit of the indices as predictors of success.

3. Establish correlations between physiological and behavioral responses at seawater entry and existing and new smolt indices and evaluate the merit of the indices as predictors of success.

4. Evaiuate Relationships between existing and new smolt indices and survival as monitored at different life stages through to adult returns.

5. develop a comprehens ive model describing relation between various indices and assorted measures of success.

6. Identify, evaluate, and apply manipulating or controlling factors including environmental factors, drugs, and chemical agents that protract the duratlin or intensity of smoltification.

FISH HEALTH AND QUALITY

1. Develop and maintain an effective means of transferring smolt health and quality information.

2. Define smolt quality and develop a standardized hatchery smolt quality control and environmental monitoring and analysis program (disease history, physiological state).

3. Develop a standardized post-release fish quality control monitoring program (include seawater entry success, acquired diseases, injury, and general smolt quality factors).

4. Determine influence of nutrition on smolt quality.

5. Determine influence of stress on smolt quality (tagging, handling, etc.).

6. Develop hatchery methods for enhancing smolt fitness (raceway design, exercise, water control, loading/density, and incubation techniques).

7. Compare performance of synchronous and variable populations with regard to state of smoltification.

8. Identify factors that have negative impacts on post-release migration (outplant, transport, predation, dam passage, behavior, and station release).

9. Measure influence of drugs, exogenous hormones, chemicals, etc., on smolt quality.

10. Develop and evaluate control measures for BKD and IHN.

11. Determine pathogen loads and how they relate to smolt survival/quality (BKD, IHN, etc.).

12. Develop sensitive, rapid disease diagnostic tools for diseases impacting smolt survival.

13. Determine how smoltification affects disease resistance (and how hatchery practices can modify resistance).

14. Evaluate effects of sub-clinical infections on ability of smolts to migrate and survive in seawater.

15. Evaluate transmission of pathogens between hatchery smolts and wild fish.

16. Measure and evaluate disease transmission during smolt collection/transportation, effects of disease during transportation, and develop techniques to reduce disease impacts.

17. Evaluate effects of stress on disease acquisition, susceptibility, and expression in smolts, and recommend methods to reduce effects.

REARING AND RELEASE STRATEGIES

1. Determine relationship between size and time of entry into seawater, nearshore distribution, nearshore oceanic conditions, determined by oceanographic remote sensing techniques and survival to adulthood, utilizing retrospective data search and environmental approaches.

2. Conduct a comprehensive integrated size and time of release study which includes the following critical components:

   a. Develop a data base on fish releases and then use it to correlate survival data with size and time and health, etc., at release at all basin facilities.

   b. Conduct system-wide basic size and time studies at many facilities for all species.

c. Conduct detailed size and time/smolt index studies at one low, one middle, and one upper river site on representative natural stocks which would provide a comprehensive correlation between size and time, and many smolt indices with survival to the lower river, seawater adaptability (seawater challenge) at an estuarine monitoring station and survival to adulthood.

3. Develop practical means of manipulating the time of smolting to match desirable release periods utilizing environmental (e.g., photoperiod, temperature, salinity) and hormonal techniques (e.g., thyroid hormones, etc.).

4. Using existing information, evaluate rearing and release strategies for each stock, comparing facilities which have high versus low survival rates.

5. Develop guidelines for outplanting hatchery fish including release techniques, where, when, which stocks, and methods to distinguish wild from outplanted stocks.

6. Determine optimal transport strategies including pick up and release locations and design of transport devices.

7. Determine release strategies that reduce predation mortalities.

8. Determine and evaluate volitional versus forced release strategies based on smolt and/or adult survival.

9. Evaluate smolt migration (especially summer) and adult survival as affected by flow regimes.

10. Examine advantages and disadvantages of releasing hungry smolts.

11. Develop procedures or strategies to minimize straying of smolts and returning adults.

12. Develop and implement coordinated system-wide releases for all stocks.

13. Compile standardized wild stock information to compare with hatchery rearing strategies.

14. Determine the impact of rearing densities and loadings on smoltification and survival.

15. Evaluate use of covered rearing facilities, holding facilities, and other fish handling facilities as means to reduce stress.

16. Develop methods for accelerating growth and maturation in hatcheries (through, for example, growth hormones, steroids, photoperiodic manipulation of ovulation, LHRH injection).

17. Study the benefits of pre-release acclimation of smolts to temperature, salinity, and olfactory cues.

18. Develop rearing strategies to reduce residualism and sexual precocity.

19. Develop basin-wide data base on fish reared, released, adult returns, and fish health.

20. Develop methods for assessing survival and smoltification of fish migrating down the Columbia River.

21. Examine how density of smolts in the river system affects smolt survival (e.g., predation, competition for food, displacement [competition for spece]}

22. Evaluate strategies for and effects of stamina as related to smoltification and survival.

23. Are indices site - or region-specific rather than of general utility?

24. Evaluate genetics of hatchery fish and conduct selective breeding program to increase harvestal fish, number of females, evaluate hatchery-wild crosses, reduce disease.

25. Evaluate the side effects of marking practices in order to recommend better practices.

26. Determine effects of marking techniques on smolt survival to survival.

HATCHERY ENVIRONMENTAL FACTORS

1. Develop management schemes (e.g., altering mineral/chemical qualities, temperatures, and physical and biological qualities of water supplies) to compensate for poor environmental factors.

2. Examine the feasibility of water decontamination systems at various capacities for fish pathogens in various types of hatchery water supply systems.

3. Evaluate the use of pure oxygen during incubation, rearing, and transportation.

4. Establish educational and training programs for hatchery personnel to introduce new and improved hatchery practices.

5. Determine the effects of environmental factors (photoperiod, water temperature, etc.) on smoltification.

6. Study the effect of pH and calcium on the incidence of BKD and IHN in hatchery stocks.

7. Study the effects of water quality (chemical, physical, and biological parameters) on smolt quality (fish production).

a. Carry out cost/benefit analyses of modification of water quality at specific hatcheries.

9. Determine the relationship of raceway water velocities to fish growth and success.

10. Quantify, qualify, and develop criteria for loading and density by species, race, and life stage (with an eye toward cost-effective yield).

11, Evaluate existing and investigate new or modified rearing unit designs (covers, baffles, etc.).

12. Evaluate existing and investigate new or modified incubation systems.

13. Evaluate effects of constant (vs. fluctuating and extremely cold) water temperatures on quality (smoltification) of hatchery fish. Develop standards (ideal and desired) for rearing temperature regimes.

14. Assess the effect of environmental microbiology in hatchery water supplies and hatchery environments relative to hatchery practices (disinfection, pond cleaning, etc.).

15. Examine and evaluate species-specific environmental limiting factors in hatcheries.

18. Determine species-specific oxygen consumption rates, particularly per unit of food, to determine appropriate levels of loading (weight per unit of flow, based on oxygen availability).

17. Survey techniques used for introducing water into raceways and ponds.

18. Identify water quality factors at all Columbia River hatcheries and determine their correlations with smolt-adult survival.

19. Develop a system-wide interagency hatchery data base for compiling and analyzing records of hatchery practices and environmental factors as related to smolt survival to adulthood.

EFFECTS OF HATCHERY PRACTICES

1. Assess impacts of marking and handling on smolt quality, health, and smoltification.

2. Evaluate effect of demand feeders on smolt quality and smolt to adult survival.

3. Determine the effects of feeding strategies on growth control as it relates to smolt to adult survival.

4. Evaluate feeding practices, delivery systems, and techniques as they relate to the production of quality smolts.

3. Develop and test diets according to life stage and fish species and determine effect on smoltification.

6. Determine desirable quality control tests for fish diets and recommend standards including labeling information.

7. Determine effect of microbial contamination in fish diets on health of hatchery smolts.

8. Determine nutritional requirements of hatchery smolts according to life stages.

9. Determine effects of nutritional manipulation on smoltification and fitness.

10. Conduct a workshop of fish nutrition specialists to obtain recommendations on priority of nutritional considerations in producing quality hatchery smolts.

11. Investigate and demonstrate practical manipulations of spawning time/rates to control ultimate schedule of smoltification (photoperiod, hormone treatment).

12. Demonstrate the potential for improved smolt success through optimization of raceway velocities and variations in velocities. Provide criteria for exercise regimes to enhance smolt preparation and success.

13. Determine the interactions between loading and density factors at all stages of rearing on the ultimate ability of the fish to carry out the smolt process.

14. Identify hatchery rearing or handling practices that suppress various smolt processes leading to inhibition of imprinting and homing.

15. Determine the role of inadvertent or incidental lighting on the smolt process, rate and synchronization, especially commonly encountered sources such as hatchery security lighting.

16. Determine the effect of very high loading rates and densities on the smoltification process. Apply presently available smolt indices at smoltification to monitor the effect of high loading/density at all life stages ranging from incubation through final rearing.

17. Drugs, chemicals, and hormones are commonly used in hatcheries. What effect do these have on smoltification and survival?

    a. Determine what drugs, chemicals, and hormones are currently being used, and how they are being used.

b. What chemicals, drugs, and hormones are potential candidates and show promise for future use to improve the hatchery product?

c. What short-term effects are known for a and b? What information is needed to evaluate or determine data gaps?

d. Determine short-term effects on smoltification.

e. Determine long-term effects on survival.

18. Determine what hatchery practices contribute to or reduce the spread of diseases.

a. Evaluate sanitation procedures at selected facilities.

b. Determine incidence of certain pathogens at those facilities.

c. Correlate sanitation practices and disease incidence.

d. Set sanitation guidelines to reduce disease incidence.

19. What chemical, drugs, and hormones are needed to improve smoltification and/or survival?

a. Determine and survey current use of chemicals, drugs, and hormones.

b. Which chemicals, drugs, and hormones are currently legal to use on specific species for specific purposes?

c. Determine needed information/research to register vital chemicals, drugs, and hormones.

d. Carry out needed research to complete the registration process.

e. Inform and train fish culturists in the most effective use of these chemicals, drugs, and hormones.

20 Review existing agency hatchery operations data collection and analysis systems to form a basis for the development of a central data base system for interagency information transfer regarding activities to evaluate and improve smolt quality and adult survival.

21 Systematically encourage improvements in the education, training, and skill levels of hatchery staff by establishing training and audio visual equipment and materials.

22 Increase smolt survival by fish transportation improvements--Smolt transportation has become an unnatural but necessary fact of life because of hydroelectric developments on the Snake and Columbia rivers. Inland stocks of anadromous fish are highly dependent on transportation both from hatcheries to release sites and through the dam impact areas. It encompasses the use of acclimation ponds, recovery areas, and use of hatchery technique to better prepare the fish for survival through this stressful practice. Work needs to be done in the following areas:

a. What can the hatchery management do better to prepare fish to withstand substantial periods of transportation?

b. The roles of chemicals/drugs on improved survival of transported fish and their ability to imprint/home.

c. The use of improved techniques and equipment in the transportation system. Development of new and improved systems of transportation.

d. The effects of transportation on hatchery fish straying, homing, and imprinting.

e. The use of final rearing ponds, acclimation ponds, and recovery/resting areas.

f. Predation at release sites after transportation, and methods of minimizing those impacts.

g- Interspecies relationships in the transportation and collection system.

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