An Overview of the Recent History of the Spring Creek National Fish Hatchery

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Introduction

The Spring Creek National Fish Hatchery (SCNFH) had once observed consistently high post release survival in the tule fall chinook salmon (*Oncorhynchus tshawytscha*) raised there, but for nearly the last two decades they have achieved only moderate returns. Estimated survival rates in the early 1970s were commonly greater than one percent, some even higher than three percent, but for brood years released in the 1980s through early 1990s most survival estimates have fallen within the range of 0.1 to 0.5 percent. Since 1985 the management and staff of the SCNFH have put forth a great deal of effort to improve their fish culture practices and facilities toward the goal of releasing healthier fish with higher survival rates. However, they have been frustrated by continuing low adult returns.

This report is an evaluation of the SCNFH tule fall chinook salmon production program. It will detail some of the recent history of the SCNFH: what brought about the changes in fish culture; what the results of those changes were; and possible explanations for the results. It will also present evidence that the declines in survival to the adult stage are due to changes in climatic / ocean conditions rather than to the changes in fish culture practices.

Why Change?

The need to examine and improve fish culture practices at this hatchery was brought to light by a catastrophic loss of fish due to bacterial gill disease (BGD) in 1985. At this time newly ponded upriver bright fall chinook salmon (URB) were being reared in the same reuse water as were older, larger tule fall chinook salmon.

Wedemeyer and Wood (1974) summarized the occurrence of fish diseases by saying that an epizootic is the product of the interaction between a host and a pathogen in an environment which causes the host to become susceptible to the pathogen. The accounts written shortly after the epizootic by Steve Leek (Area Biologist, Lower Columbia River Fish Health Center), Jerry Rogers (Assistant Project Leader, SCNFH), and Paul Handy (Division II Manager, Fisheries Resources, Portland Regional Office) and the recollections of Ed LaMotte (present SCNFH Project Leader) identify factors which contributed to the accumulation of potential pathogens and to the creation of environmental stressors which predisposed the fish to disease:

1. **Feeding to excess** - The standard practice was to place a garbage can filled with fish food at each pond and feed the fish to satiation. Waste feed particles suspended in the water cause gill irritation. Wasted feed and fish feces that accumulate on the pond floors become growth media for bacterial pathogens.

2. **Condition of the reuse system filter beds** - The reuse system was not operating as efficiently as it does today. One of the filter beds was regularly used for experimental purposes rather than for maintenance of production water quality, another was used exclusively as a settling basin for solid waste, and an unknown number were probably left unused early in the rearing cycle to minimize the amount of backwashing work (Ed LaMotte, personal communication). The filter beds that were in use contained only rock substrate, which does not serve as a biological media as well as whole oyster shells do.

3. **Temperature** - The hatchery used heat exchangers to warm the incubation building's water supply to 52°F and the reuse system's water to 50°F.

   Records indicate that during the period January 5, 1985 through February 8, 1985 the pond water temperature (as measured in the aerator tower) ranged from approximately 9.8°C (49.6°F) to about 10.3°C (50.5°F). From February 8, 1985 through March 13, 1985, the range was roughly 9.2 °C (48.6 °F) to about 10.6 °C (51.1 °F).

   The intention was to accelerate growth of the URBs in the warmer incubation building trough water before they were ponded with the older and larger tules in the cooler water of the reuse system.

4. **Density and flows** - At the time of the outbreak, the density index in the pond containing the URBs was reported to be 0.12 pounds of fish per cubic foot per average fish length (inches). This pond contained slightly more than 600,000 fish and its flow had been adjusted to approximately 260 gallons per minute (gpm) for a flow index of 1.55 pounds of fish per gpm per average fish length. (Spring Creek presently ponds approximately 364,000 fish per pond with an initial flow of 400 gpm for a flow index of 0.56).

   The density index in the ponds containing the tules was reported to be 0.252 pounds of fish per cubic foot per average fish length. This averages out to approximately 385,000 fish per pond, although ponds destined for earlier releases may have contained more fish and ponds destined for later releases may have held fewer fish. It is also possible that this estimate of the average pond population is low because hatchery personnel contend that there were often more fish in the ponds than were on the records. Flows in the tule ponds were approximately 607 gallons per minute.

5. **Nitrogen supersaturation** - Jerry Rogers noted that he suspected the URBs suffered from a gas bubble problem while they were still in the hatchery troughs. Steve Leek

documented 105% saturation in both the hatchery troughs and in the ponds and his opinion was that this caused a stress. We don't know how much this problem contributed to the disease outbreak, but it was mentioned in all the written accounts so it is included here.

The first pond to show signs of BGD was the pond containing the URBs. It seems that water quality problems stemming from the semi-functional condition of the filter beds, the use of only part of the reuse system facilities, the minimal pond flow and the overfeeding, all in combination with the slight nitrogen supersaturation caused these fish to become stressed, rendering them susceptible to infection by bacteria which thrived in the unclean pond environment. Placing the URBs in the same reuse water as the older and larger tules gave the bacteria an ideal host for amplification and dispersal to the tule ponds through the reuse system.

Rates of bacterial growth and reproduction were inadvertently accelerated by the use of the heat exchangers, which were shut down three days after the first diagnosis of the disease. Mortality in the tule ponds escalated very quickly, as efforts to bring the disease under control failed. These efforts amounted to releasing the March group on February 25 and administering a Hyamine 1622 treatment (one hour, 1.7 ppm) on February 26. The remaining tules were released on February 28 to prevent their total loss. The ponding to release mortality was recorded as being 12.90 percent, however, some estimated total loss to be fifty percent or more.

One of the reasons for the use of the heat exchangers and the excessive feeding was to grow the fish to tagging size before tagging began. The tules needed to be approximately 200 fish per pound by mid February, at which time they would be tagged with full length coded wire tags (CWTs). Some of the URBs needed to be approximately 600 fish per pound by late March / early April so they could be tagged with half length CWT wire. The remaining URBs would not be tagged until June, when they had reached a size of about 100 fish per pound.

Contributing to any density problem was that one (or two) pond(s) was (were) left unused (Ed LaMotte, personal communication). Fish were placed into these empty ponds as they were tagged.

A number of actions were taken to ensure that this would never happen again:

- Management decided that URBs should not be raised in the same water as tules. The URB program was discontinued after Brood Year 1985 (BY85).
- All ponds would be used for hatchery production. None would be left unused.
- Packed columns were installed in the hatchery deaeration tower in 1986 to reduce dissolved gas problems in the incubation building.
- The rock substrate of the reuse system filter beds was covered with whole oyster shells.
- All of the filter beds were put into use as functional components of the reuse system in 1986.
- Initial pond flows are set at 400 gpm. Flow is increased to 550 gpm about two weeks after ponding and again to 700 gpm about two weeks after that.
- Ponds are flushed more frequently, feed rates are more controlled, and organic sludge

reducing bacteria is used to maintain a clean pond environment and to minimize the need for pond cleaning.

- Water temperatures are maintained between 48 and 50°F as much as possible. Holding temperatures much higher than this increases the risk of disease.
- Use of the Big White substation as a thinning site for excess tule production was discontinued.
- Crowding and handling of both adults and juveniles has been minimized to reduce stress.
- Annual disinfection of the hatchery water supply springs was initiated in 1985. In years since 1996 the springs have been cleared of brush and detritus, but not chlorinated as in previous years.
- A study was conducted over the brood years 1989 through 1992 to address the question of rearing density. Banks (1996) concluded that the greatest number of adults were produced from ponds having the highest density (ponded at 364,000 per pond). Contributions from ponds of even higher densities were not evaluated because management felt that raising many more than 364,000 fish per pond on a production scale could be beyond the capabilities of the reuse system.

Many other smaller modifications have been made to both the physical facilities of the hatchery and to the fish rearing methods employed there. In 1989, the staff of the SCNFH began writing procedures for doing every fish culture related job. These were written to ensure that fish culture work is consistently carried out according to the highest standards in order to achieve specific goals regarding pre release survival, genetic integrity and diversity, and worker safety. The standards and goals were incorporated into a document titled, "Spring Creek National Fish Hatchery: Five Year Production Plan, Goals, and Standards" in 1995. They will be revised as necessary. The fish culture related goals are stated at the top of each column in Table 1.

Have These Changes Resulted in Positive Outcomes?

Hatchery data indicates that these changes have resulted in positive outcomes. Over the period from BY80 through BY97, survival to the eyed egg stage has increased (Graph 1) as has survival from ponding through release (Graph 2). Both graphs demonstrate that performance has become much more consistent in both areas since BY89. Changes in the management of the reuse system have resulted in increased water quality. Graph 3 shows that the annual peak concentration of ammonia per million fish released (not including releases of unfed fry) has been significantly lowered ($P < 0.01$, using a two sample t-test assuming equal variances) during the period from BY88 through the present from what it had been during the period from BY80 through BY87. A later section of this report will show that improvement has also been achieved in the health of these fish.

We feel that these improvements in water quality, pre release health condition and on station survival indicate that post release survival has been increased over what would have otherwise been achieved without modification of the reuse system and fish culture practices. However, to prove this would have required a multiple year tag study in which treatment groups (reared in the "improved" SCNFH) were released simultaneously with control groups (reared using the culture techniques thought to have contributed to the BGD oubreak of 1985 in the reuse system in its prior condition and pattern of use). This would have been impossible because there is only one reuse system at this facility. Although it may have been theoretically possible to evaluate some of the changes in culture techniques with tag studies, that was never done because many of those changes were based on commonly accepted rules of fish culture:

- Maintain a clean living environment.
- Handle the fish as little as possible.
- Maintain water temperatures to promote fish growth yet minimize growth and reproduction of bacterial pathogens.

Despite all these improvements, survival to adulthood remained discouragingly low (Graph 6).

Why Hasn't Post Release Survival Improved?

SCNFH tule fall chinook spend only a portion of their lives in the hatchery and are subsequently released into an environment where they must overcome challenges of both natural and human origin. These fish must successfully pass through Bonneville Dam, escape predation, adapt to life in salt water, and forage for prey species before they can be counted among those who have "survived."[1] How well they deal with these challenges is likely, at least in part, determined by their condition (health, smolt status) at release. The benefits of improved hatchery practices and facilities, however, could be obscured by changing conditions in the outside environment. Therefore, the failure to increase post release survival to the levels achieved in the early 1970s, despite the previously mentioned on station improvements, is likely due to changes in the outside environment which resulted in conditions unfavorable to salmon survival.

The main focus of this paper will be to attempt to illustrate the influence of certain factors over the post release survival of SCNFH tule fall chinook. Sections 1 and 2 will examine factors which occur at the hatchery. Sections 3 and 4 will provide some details regarding the river and ocean environments.

1. Pre Release General Health Condition

In BY86, the Lower Columbia River Fish Health Center began sampling juvenile fish immediately prior to each smolt release according to the protocol of Adams et al (1993). Individual fish are autopsied, and any aberrations in their morphology (external and internal) or

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[1]Both contributions to fisheries and hatchery rack returns are considered to be "surviving fish" in survival estimates. Hatchery returns include fish that returned to the SCNFH as well as those that return to other hatcheries, such as the Bonneville State Fish Hatchery operated by the Oregon Department of Fish and Wildlife.

blood parameters (hematocrit and serum protein) are quantified with a rating system. Normal traits receive a "zero" rating; abnormal traits are rated "ten", "twenty" or "thirty", depending on the severity of the aberration. The ratings of all the abnormalities are summed for each individual fish as a total score. The average total score, for the group as a whole, is reported as the Health Assessment Index (HAI), which rates the overall health of the population. The closer the HAI is to zero, the better the health condition of the population.

Graph 4 depicts month of release versus HAI and percent survival for BY86 through BY98 (survival data is incomplete beyond the May, 1993 (BY92) release). It shows that some groups performed very well in spite of marginal health. For example, the April release fish of BY86 had the second highest HAI on record, but they also had the highest survival on record from BY86 through BY92 (>0.7%). The May release of BY89 had the highest HAI of all the groups, but still survived well relative to many other groups.

Conversely, other release groups were in better health, but survived at a much lower rate than the two previously mentioned releases. Survivals from BY90 through BY92 were significantly lower than those of BY86 through BY89 ($P < 0.01$, using a two sample t-test assuming unequal variances) despite the fact that they were healthier (lower overall average HAI) than the BY86 through BY89 group. However, the difference in health was not found to be significant ($P > 0.05$) due to the high variability of the BY86 through BY89 group.

These examples fail to show any effect of HAI on survival to the adult stage, at least in the range of HAIs encountered here. This, however, should not be taken to mean that pre release health is of no consequence to post release survival. This data was not the product of a controlled experiment with differentially tagged "healthy" and "unhealthy" groups of fish being released simultaneously into the same environmental conditions. Those conditions may have been positive enough in some years to overcome the negative effects of health problems and poor enough in other years to obscure the benefits of increased health. BY73 and 84 had been afflicted with BGD prior to release. Section 4 will explain that their survival was lower than one may have expected in light of the prevailing conditions during their ocean residency. Therefore, the likelihood exists that survivals would have been even lower had the SCNFH not accomplished the previously mentioned improvements in fish culture operations.

2. Pre Release Smolt Status

Pre release smolt status can have a profound effect on post release survival. Zaugg (1996a) stated that those releases of fish from the SCNFH (over the period 1978 - 1993) which experienced the greatest changes in gill Na/K ATPase activity during their hatchery residence had undergone a more complete smolt development. They survived at significantly higher rates than releases which experienced minimal changes over time in their pre release gill Na/K ATPase activity. However, he noted that the releases which he placed in an "intermediate recoveries" category had ATPase profiles similar to the releases in his "best recoveries" category.

Zaugg (1996b) described a two year effort to stimulate similar smolt development in SCNFH juvenile fall chinook salmon through the manipulation of feeding rates. He found that BY93 experienced much more change in gill Na/K ATPase activity than did BY94. He posed the possibility that there may have been subtle differences between the two years during the rearing cycle (including egg incubation) which could account for the differences in smolt status. One of the factors which he suggested may have had an effect was the temperatures encountered during incubation and pond rearing. Giorgi (1990) cited studies which suggested that temperature and photoperiod play critical roles in smolt development. Therefore, weather variables such as cloudiness and temperature may play much more important roles in initiating smoltification than do feeding rates. Subjecting the fish to an advanced photoperiod, as was done by Giorgi (1990), may stimulate gill Na/K ATPase activity and subsequently increase their post release survival. However, using photoperiod manipulation on a production scale would require a large investment in lighting equipment which this hatchery cannot presently afford.

Absent an ability to artificially induce smoltification, the SCNFH presently gauges pre release smolt status with a simple and inexpensive saltwater challenge test. This test was designed by Fowler and LaMotte (1990), who concluded that Spring Creek tules experience less change in condition factor (resulting from saltwater related dehydration) as their ability to tolerate seawater increases: "The change appeared to be below 4% when the fish were best able to tolerate seawater at 30 ppt." Graph 5 compares the results of these saltwater challenges with survival to adulthood. Unfortunately, saltwater challenge work did not begin until BY90 and survival data is incomplete beyond BY92, so there are only three years (nine releases) available for comparison. There does not appear to be a correlation between survival and the results of these saltwater challenges. However, as with the previous comparison of HAI and survival, this does not mean that pre release smolt status is not an important factor affecting post release survival. Each of these groups were released at different times and under different environmental conditions.

3. River Conditions

Bonneville Dam is the only dam standing between the SCNFH and the ocean. Operations at Bonneville in the days immediately following juvenile releases have the potential to affect the survival of Spring Creek tules. Ledgerwood et al (1990) compared recovery rates (at the head of the estuary) of fish which had passed through Bonneville's spillway with fish which had passed through the bypass system and with fish which had passed through the turbines of the North Shore Powerhouse. They recovered a significantly higher percentage of spilled fish than bypassed fish or turbine-passed fish.

Another factor which can reduce survival during the downstream migrations of Spring Creek tules is the abundance and activity of predators in the river. The northern pikeminnow (*Ptychocheilus oregonensis*), native to the Columbia Basin, is widely recognized as a major predator of salmon smolts. There are also non-indigenous fish in the Columbia Basin such as walleye (*Stizostedion vitreum*), channel catfish *(Ictalurus punctatus*) and smallmouth bass

(*Micropterus dolomieui*) that can prey on salmonids. In a study of piscine predators in the John Day pool, Poe et al (1988) concluded that the northern pikeminnow is the most important predator of salmonid smolts of the four species mentioned here. The Caspian Tern (*Sterna caspia*) is an avian predator that has moved into the Columbia River estuary in large numbers to Rice Island, an island created by the dumping of dredged materials. These birds have been found to be consuming a substantial percentage of the Columbia Basin's smolts. Efforts are now underway to relocate the Tern colony to an area closer to the ocean where resource managers feel they will switch from a diet consisting mainly of salmon smolts to a more varied diet.

High river temperatures have the potential to impact survival of Spring Creek tules, as piscine predators such as the northern pikeminnow are more active in warmer water. The effects of increased feeding activity in predators of salmon could be exacerbated when the rate of salmon emigration is slow due to delayed smoltification. The more extended their residency in the river is, the longer they are exposed to predation.

The effect of river flows on salmon survival is a controversial issue. Dawley et al. (1986) did not find a relationship between river flow and emigration rates of fall chinook salmon released from the SCNFH and the Little White Salmon NFH. They proposed that the differences in emigration rates were due to differences in the overall smolt status of the groups (some groups contained higher numbers of smolting fish than other groups). Furthermore, they alluded to later data that suggested there is some relationship between flow and emigration rate when all the study fish are actively migrating.

I was unsuccessful in my attempts to find a relationship between survival to adulthood and such river conditions as temperature, flow, and spill. However, it would be more proper to compare these river conditions with survival of juveniles from release to ocean entry, similar to what was done by Ledgerwood et al (1990). Obviously, a lot can happen to a salmon from the time of ocean entry to the time of return. Data on survival from release to ocean entry, however, is not regularly collected as is data on post release survival to adulthood. I also lacked historical information on flow through the Bonneville Dam north shore powerhouse turbines during emigration periods of SCNFH juveniles, data regarding predator (both northern pikeminnow and Caspian Tern) abundance, and average pikeminnow size. It was for these reasons that I made this section more qualitative than quantitative, citing just a few of the many fisheries research articles regarding the potential effects of river conditions on SCNFH smolts.

4. Ocean Conditions

Background

Marine feeding conditions are an important component of survival throughout the ocean residence of salmon. Most SCNFH tule fall chinook salmon migrate in the ocean off the coast of Washington and the west coast of Vancouver Island, British Columbia (Ed LaMotte, personal communication). Pearcy (1997) included this area in a region called the Coastal Upwelling Domain and said that productivity there is influenced mainly by two sources of cool, nutrient rich water: water from the north Pacific incorporated into the California Current, and water from the ocean depths brought to the surface by coastal upwelling.

There are many references in the literature to trends in the climate of the Pacific Ocean which affect its biological productivity, its species distribution, and the abundance of its salmon populations. These trends can be categorized on the basis of their longetivity. Francis and Hare (in Emmett and Schiewe 1997) referred to long term, multidecadal trends as regimes. El Niño and La Niña are shorter term, interannual trends.

The National Research Council (1995), in writing about long term trends, cited numerous works which together concluded:

1. the Aleutian Low Pressure Index has been shown to affect the abundance of copepods in the North Pacific. These copepods are near the base of the food web of which salmon are a higher level predator, and changes in their abundance should result in changes in salmon abundance.
2. climate changes may affect the distribution of piscine predators such as Pacific hake (*Merluccius productus*) and mackerel (*Scomberomorus* species), bringing them in greater numbers into areas in which salmon migrate. These fish prey on salmon and salmon prey species such as Pacific herring (*Clupea pallasi*) (DFO 1997) and Northern anchovy (*Engraulis mordax*) (NWFSC 1998).
3. the first year of ocean residency is a critical period for a salmon, and its fate will largely be decided by the state of the ocean climate during this period.

Francis and Hare (in Emmett and Schiewe 1997) called changes in these long term climate trends regime shifts. The most recent shift occurred in 1977. Anderson (1996) stated that this shift was from a regime of cool / wet weather in the Pacific Northwest to one of warm / dry weather. Parrish (in Emmett and Schiewe 1997) elaborated on the physical processes of this regime shift. He noted that the winter Aleutian low pressure system intensified and moved eastward, causing changes in wind patterns, which in turn affected sea surface temperatures, ocean currents, upwelling, and the depth of the upper layer of the ocean which is subject to mixing.

Francis and Hare (in Emmett and Schiewe 1997) referenced studies demonstrating that the regime shift of 1977 caused summer zooplankton populations to greatly increase in the central Gulf of Alaska and to greatly decrease in the Coastal Upwelling Domain, which includes the area where SCNFH tules migrate. The Canadian Department of Fisheries and Oceans (DFO) (1997) attributed the decline of the herring stock found off the west coast of Vancouver Island to the effects of this regime shift. This herring stock has been in a state of low productivity since 1978. The DFO said that the shift to a warm regime decreased productivity of coastal copepod and krill populations and increased the summer migrations of herring predators such as Pacific hake and mackerel to this area. This also has implications for chinook salmon: copepod and krill are important sources of nutrition for herring as well as for smaller chinook salmon. Healey (1991) reported that the herring themselves become an increasingly important component of a chinook salmon's diet as it grows, and cited a study of chinook diets off southern Vancouver Island that found herring to be the most important prey item of larger chinook.

The widely publicized shorter duration phenomenon, El Niño, can also have dramatic effects on the survival of salmon. Melsom et al. (1999) and Norton and McLain (1994) stated that El Niño events alter northern ocean conditions locally (through changes in the wind patterns which are normally favorable to upwelling) and remotely (through creation of equatorial-origin coastal-trapped Kelvin waves). Brodeur (in Emmett and Schiewe 1997) reviewed events in the Pacific Ocean during the 1982 - 1983 El Niño, finding that coastal upwelling was much reduced, and that even when upwelling was present it was ineffective because the thermocline was deepened, allowing only warm, nutrient poor water to be upwelled. This dealt a major blow to the base of the food web, causing a decrease in the abundance of preferred prey species for salmon. Brodeur (in Emmett and Schiewe 1997) cited other studies which indicated that El Niño events may cause salmon to concentrate nearer to coastal areas, increasing their vulnerability to predation. Hargreaves (in Emmett and Schiewe 1997) discussed the effect of El Niño on stocks of chinook salmon off the west coast of Vancouver Island, an area where SCNFH tules migrate, stating that El Niño conditions in the period from 1991 through 1995 had severe consequences for the survival of at least three brood years (BY90 through BY92). He believed that predators killed many of the salmon during their first year at sea.

Coastal Upwelling

This section will examine how the survival of SCNFH tules is affected by coastal upwelling. All upwelling data was downloaded from the National Marine Fisheries Service, Pacific Fishery Environmental Group's website (http://www.pfeg.noaa.gov/data_gate/pfeg_data_avenue.html).

Graph 6 compares overall brood year percent survival to adulthood with the total upwelling index units accumulated over the three summers following release along the northern U.S. coast (42, 45, and 48 North Latitude by 125 West Longitude). It shows that trends in survival are fairly well correlated with trends in upwelling from BY72 through 87. Three notable exceptions are BY73, 82, and 84. BY73 and 84 did not survive as well as the upwelling data seems to indicate they should have. Both, however, had problems with BGD. The outbreak suffered by BY73 wasn't nearly as disastrous as the BY84 outbreak, but it was serious enough to prompt the fish health pathologist to recommend releasing the fish a week early (in May). These examples underline the importance of the pre release health condition of the fish to their post release survival.

BY82 survived much better than one might expect in light of the relatively low amount of coastal upwelling which occurred during their ocean residency. This group only had tags present in the April release. Overall brood year survival to adult may have averaged somewhat lower if tagged fish had also been present in the March and May releases. BY83 also had tagged fish released only in April, but its survival rate was a better fit for the upwelling conditions shown on the graph. It is possible that BY82's high survival did not just happen by chance. Maybe these fish found a localized area of good feeding conditions with a low abundance of predators. However, these are merely theories, and I cannot presently offer any other explanations.

In the late 1980s upwelling surged, yet survival declined. This coincides with a rapid increase in annual maximum monthly mean sea surface temperature (SST) at 48 North Latitude x 124 West Longitude, as shown by Graph 7. This graph was created using monthly mean SST data from the EarthInfo COADS Global Marine Database CD. A subset of data points was made by taking only the highest monthly mean SST of each year from 1950 through 1995. These values were then averaged in three year series on the graph to illustrate the highest temperatures our fish may experience in three years of ocean residency. The increase in the late 1980s was to some of the highest maximum temperatures on record. As previously stated, the ability of upwelling to bring nutrients to the surface layers to fuel primary production may be greatly diminished if the thermocline is sufficiently deepened by a large mass of warm, nutrient poor water. DFO (1998) noted that such an increase in SST may also be accompanied by increased northerly migrations of predators such as Pacific Mackerel which compete with salmon for herring prey and may also prey on the salmon themselves.

Hayward, et al. (1997 (?)) found that the upwelling index may not always be an accurate indicator of ocean productivity. The data presented here support this observation. With the exception of BY82, the upwelling index appeared to explain most of the variation in survival to adult when the three year average of annual maximum monthly mean SST indicated mild temperatures. This relationship between upwelling and survival broke down when temperatures became extremely warm in the late 1980s / early 1990s.

It should be noted here that these results are vulnerable to criticism because the graphs are composed of a small number of data points. However, these graphs show trends which, although they may not be statistically significant, seem to indicate some relationship between coastal upwelling, SST, and survival of SCNFH tule fall chinook salmon. Collection and analysis of additional future data may confirm this relationship.

Conclusions

The management and staff of the SCNFH have made many improvements in the physical facilities and in the fish culture practices they employ in order to improve the health and increase the chances for survival of the tule fall chinook salmon they raise. Post release survival has remained low despite noticeable improvements in reuse system water quality and on station survival (survival to the eyed egg stage and survival from ponding to release). This is likely due to conditions in the marine environment which have been inhospitable to salmon. SCNFH tule fall chinook are released in a relatively downstream area of the Columbia River, they have only one dam to migrate through (as opposed to some upriver stocks which may have to pass through as many as eight mainstem dams), and they spend the majority of their lives in the ocean. The data presented in this report suggests that ocean conditions are *usually* the most important factor influencing survival of this stock. However, this is not to detract from the importance of conditions in the hatchery, in the river, and in the physiological (smolt) status of the fish themselves. Section 4 (Graphs 6 and 7) described two instances where disease in the hatchery had a noticeable effect on post release survival. While Graph 6 illustrated the relationship between overall brood year percent survival and coastal upwelling, Graphs 4 and 5 showed that survival can vary widely between the individual releases within a brood year. The reason for this may lie in the interaction between such factors as the readiness of the fish to emigrate, river flow and temperature, abundance and activity of predators in the river and estuary, and the route of passage through Bonneville Dam.

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Table 1

SPRING CREEK NATIONAL FISH HATCHERY QUALITY GOALS
DATED DECEMBER 7, 1998

YEAR	FEMALE DIP % (<= 2.0 %)	TOTAL DIP % (<= 5.0%)	GREEN FEMALE % (<= 2.0%)	F:M SPAWN RATIO (<= 2)	JACK SPAWN % (=> 2.0%)	EFFECTIVE POPULATION SIZE (=>5,000)	% EYE-UP (= >95.0%)	NH3 (ppm) (<= 0.30)	D.I.* (<= 0.28)	F.I.* (<= 1.50)	% POND MORTS (<= 2.5%)	MILLIONS RELEASED
1980	15.10	15.60	29.10	6.56	0.00	4,658	77.20	0.460	0.35	1.86	5.30	16.70
1981	22.60	19.10	16.00	3.23	0.00	8,272	81.70	0.295	0.26	1.36	10.50	13.70
1982	32.10	35.90	19.40	4.11	0.00	7,080	79.70	0.616	0.32	1.71	8.20	15.80
1983	15.40	15.20	4.70	3.33	0.00	4,353	85.70	0.533	0.33	1.73	8.30	13.90
1984	1.10	3.80	6.40	4.71	0.00	3,392	80.10	0.428	0.22	1.19	12.90	13.90
1985	2.10	4.60	6.30	5.09	0.00	1,916	85.90	0.325	0.29	1.26	7.90	10.60
1986	3.80	7.10	3.30	3.92	0.00	1,533	91.80	0.330	0.27	1.48	2.83	10.60
1987	5.20	8.70	7.00	4.95	0.00	1,664	81.96	0.412	0.27	1.50	1.80	8.80
1988	4.80	7.90	2.90	5.86	0.00	2,378	80.16	0.162	0.26	1.43	9.50	15.30
1989	1.80	2.90	2.30	2.29	6.40	2,821	93.00	0.269	0.30	1.45	3.10	10.20
1990	22.10	18.10	1.60	3.33	N/A	3,586	91.70	0.286	0.31	1.45	2.30	14.30
1991	2.60	4.50	0.90	1.58	9.00	9,499	95.50	0.309	0.31	1.49	4.50	15.90
1992	2.30	4.40	0.40	1.74	N/A	6,868	96.30	0.310	0.27	1.29	3.60	14.30
1993	2.10	4.90	1.20	1.47	2.50	6,795	96.11	0.320	0.28	1.32	2.80 **	15.40
1994	1.35	2.65	0.94	1.35	3.30	9,064	95.44	0.250	0.30	1.44	1.20	15.65
1995	4.35	7.52	1.60	1.93	2.90	6,730	93.10	0.340	0.29	1.42	2.51	16.44
1996	5.74	11.62	0.97	1.55	4.02	5,727	93.18	0.260	0.29	1.40	2.02	14.55
1997	0.80	2.09	0.92	1.83	2.74	7,451	96.63	0.170	0.30	1.39	1.91	15.62
1998	2.14	2.28	0.90	1.55	5.87	4,396	95.73	0.300	0.31	1.50	3.72	10.59
AVE.=	7.76	9.41	5.62	3.18	1.93	5167.51	89.00	0.34	0.29	1.46	4.99 ***	13.80
10YR AVE =	4.53	6.10	1.17	1.86	3.67	6293.68	94.67	0.28	0.30	1.42	2.77 ***	14.30
5YR AVE =	2.88	5.23	1.07	1.64	3.77	6673.55	94.82	0.26	0.30	1.43	2.27 ***	14.57

* = Highest density and flow indexes attained in production year, as measured the day before release.

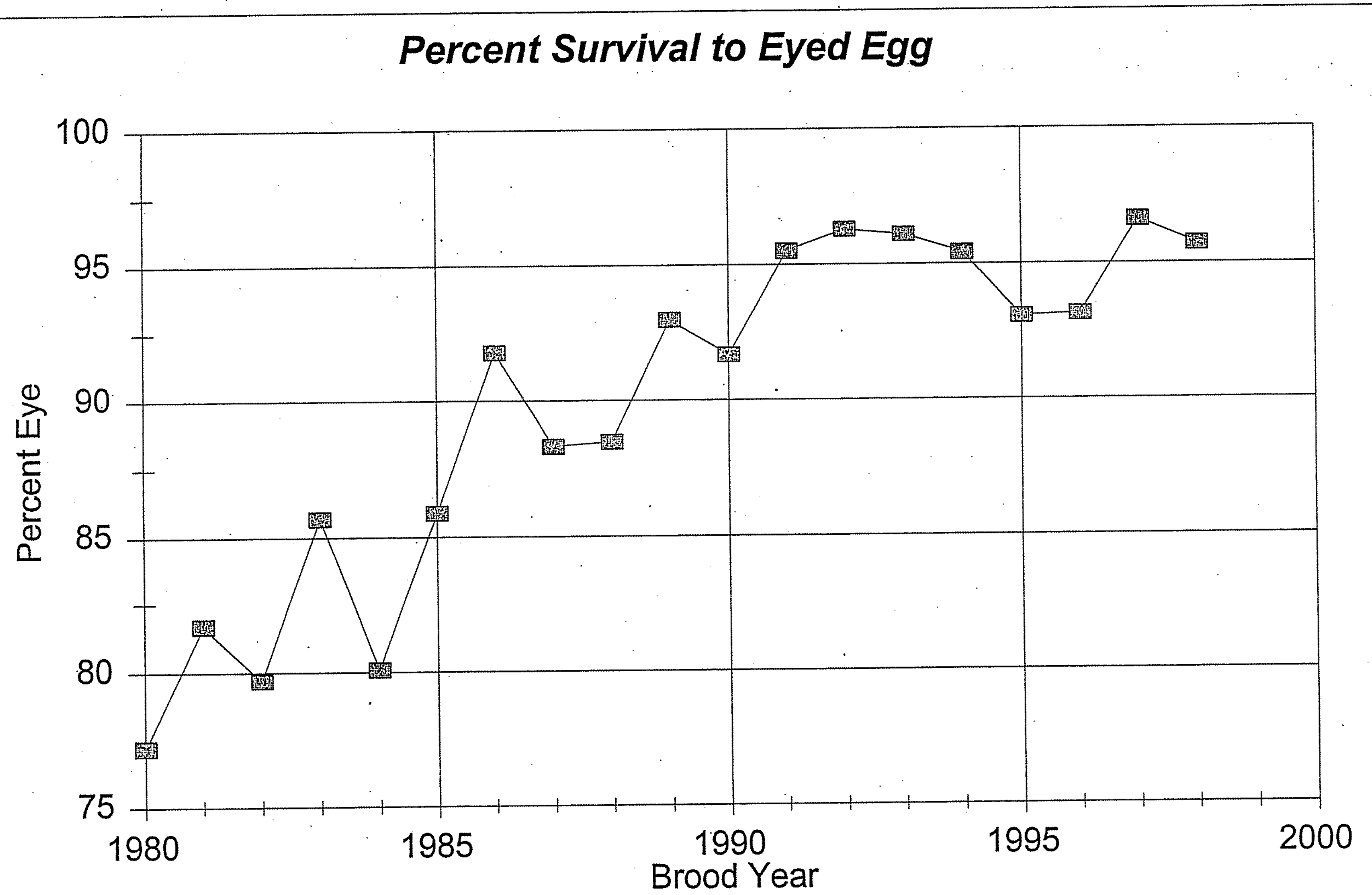
** = Does not include Lagoon fish. Of the 497,368 fish planted in the two cages and loose in the lagoon, only 190,903 are assumed to have survived to release due to heavy bird predation.

10YR AVE = 1989 - 1998 5YR AVE = 1994 - 1998

Effective population size = (4 x (total female spawners) x (total male spawners (incl. jacks))) / total spawners (males, females, and jacks)

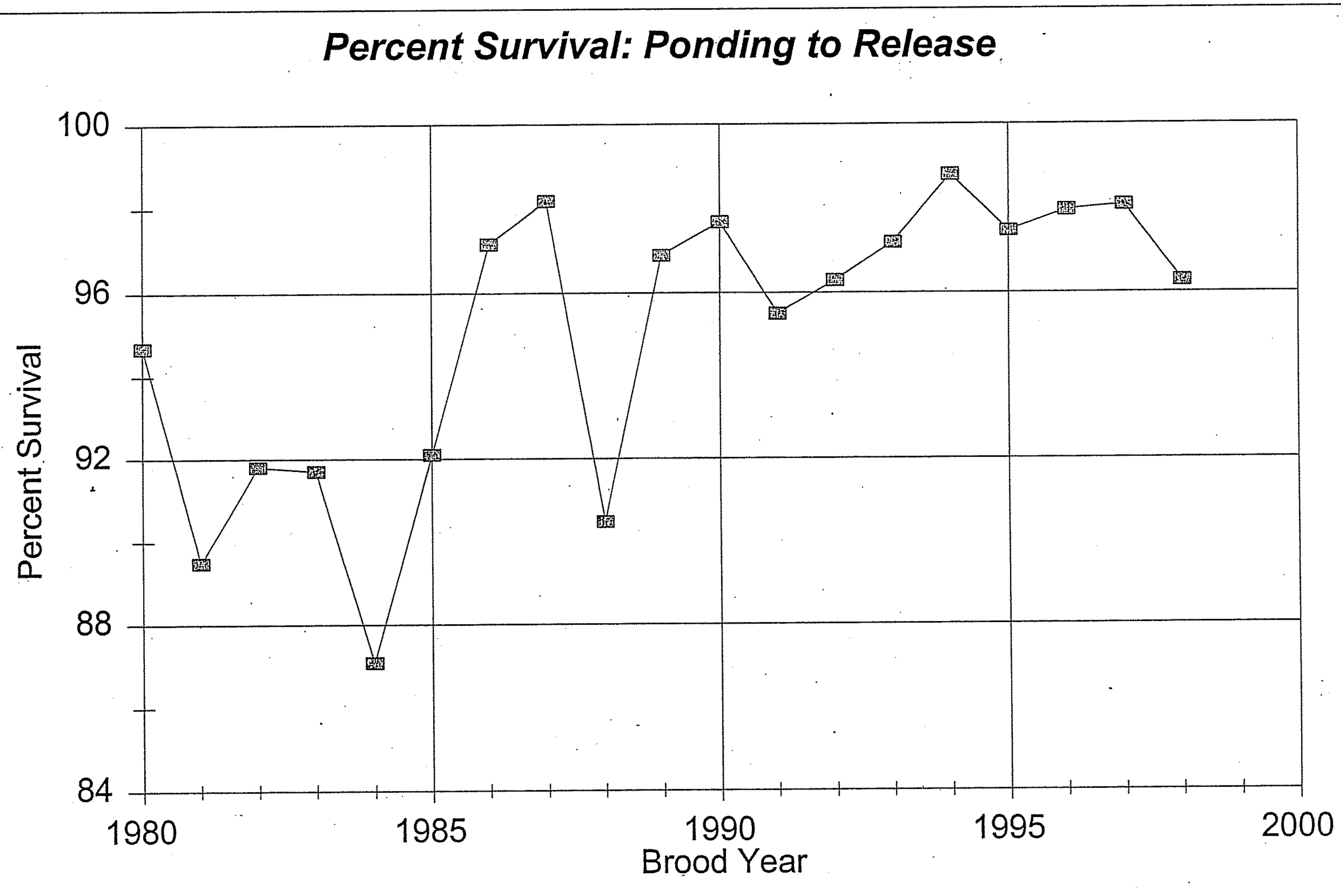
DIP = adult prespawn mortality (dead in pond)
D.I. = max. density index (pounds of fish per cubic feet of rearing space per average lengh fish (inches))
F.I. = max. flow index (pounds of fish per gallon per minute per average length fish (inches))

Graph 1



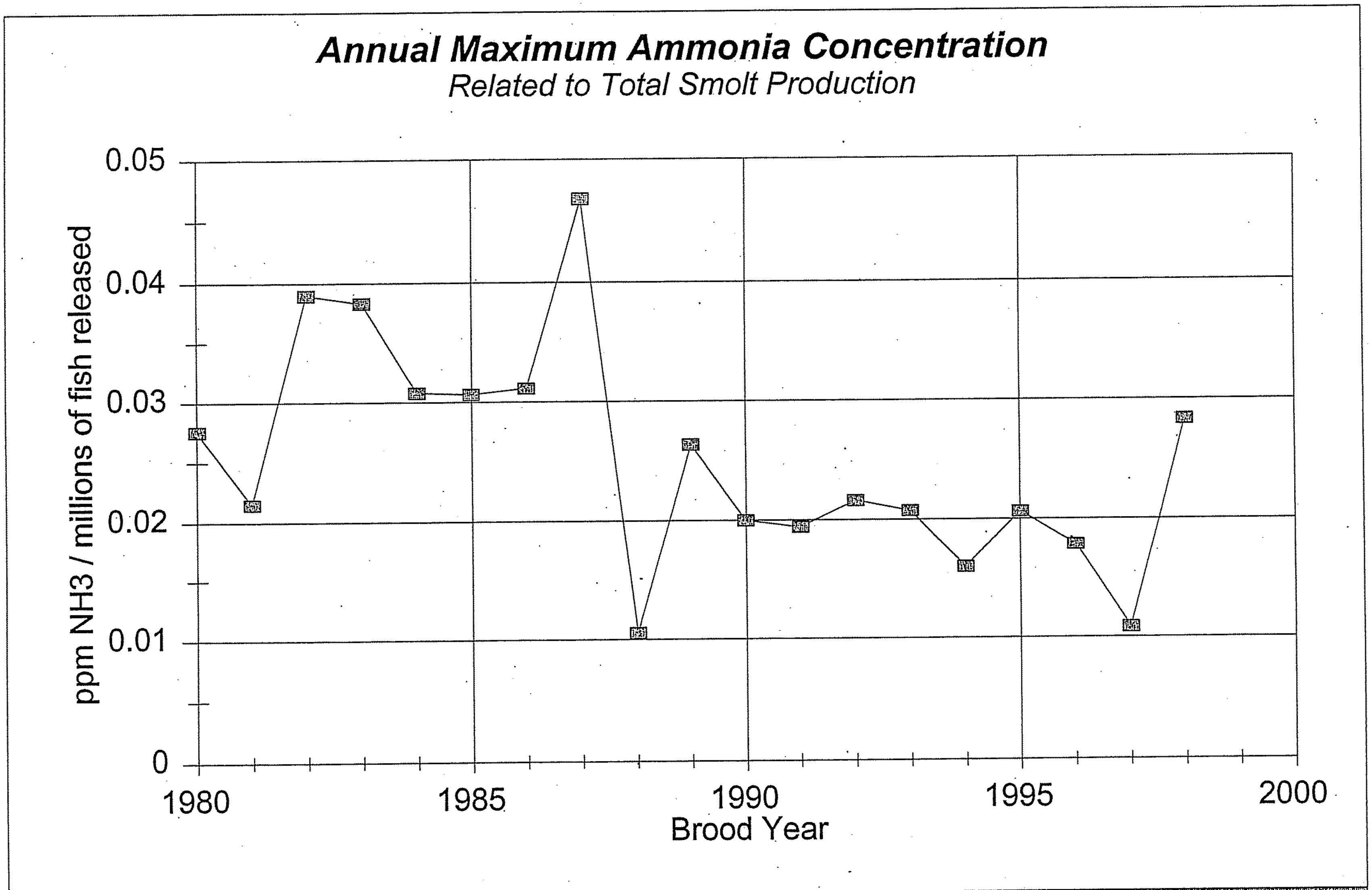
Data is from Table 1. Survival to the eyed-egg stage has been revised for Brood Years 1987 and 1988 to represent only eggs spawned at Spring Creek.

Graph 2



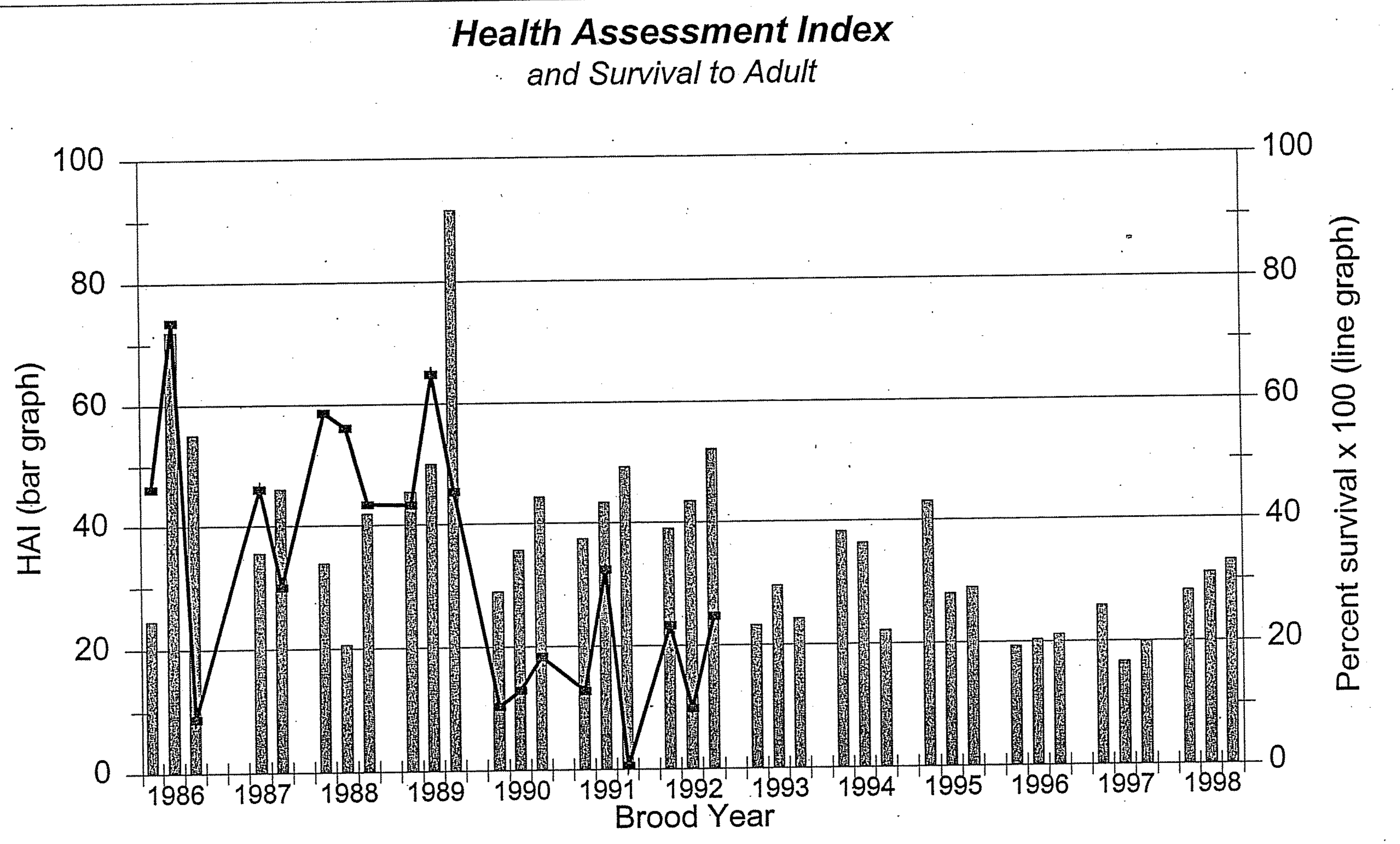
Data is from Table 1.

Graph 3



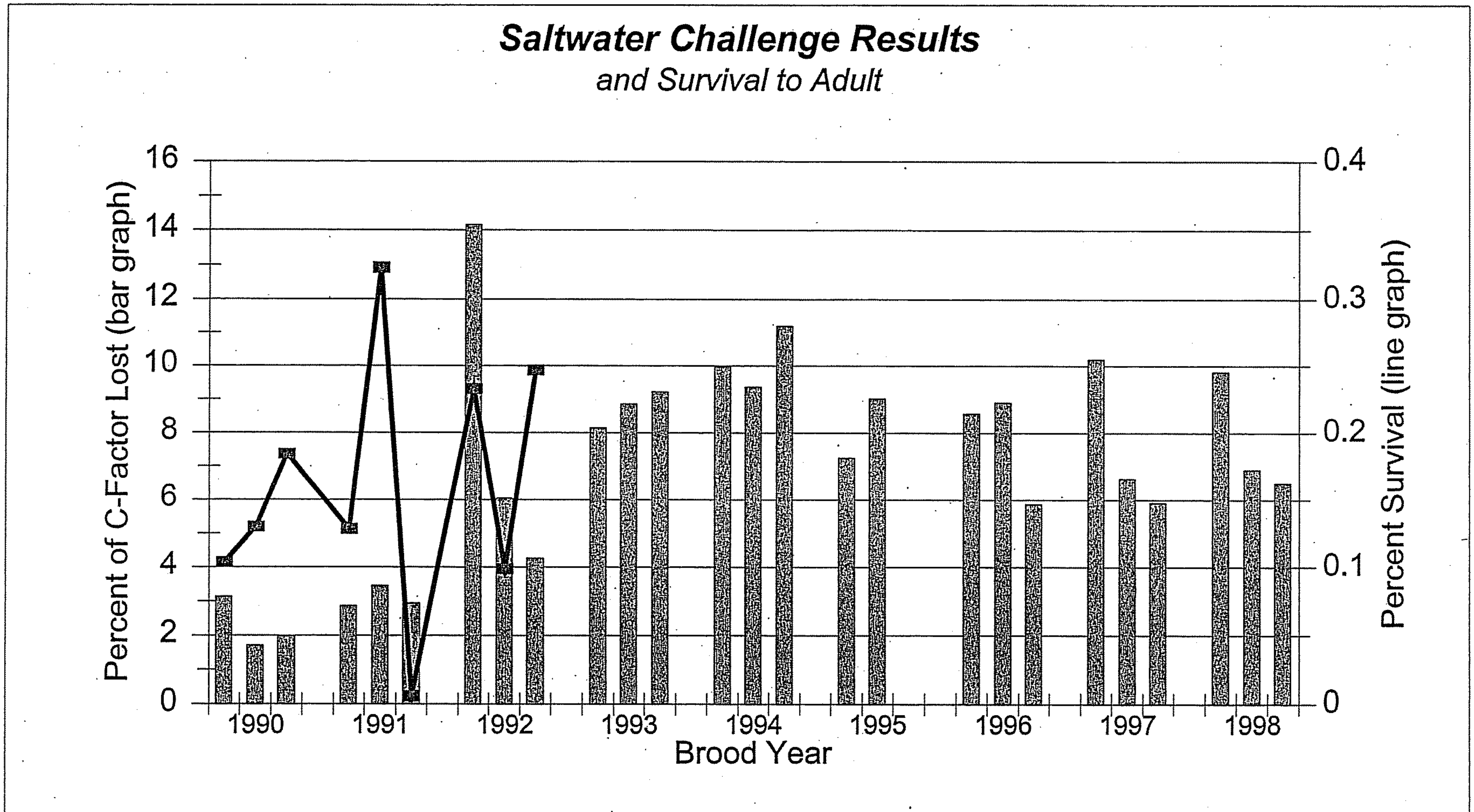
Data is from Table 1

Graph 4



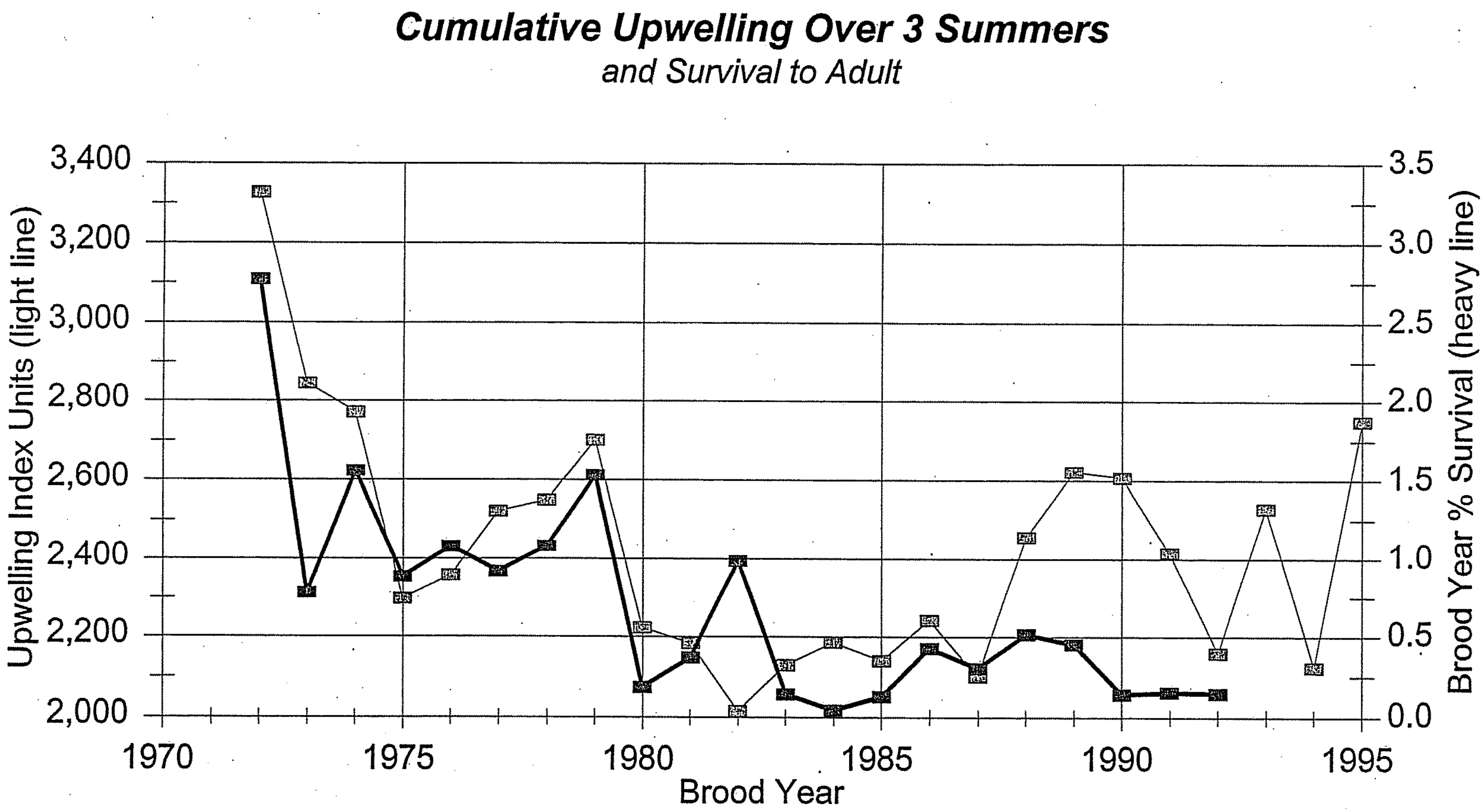
Each series of three represents the three releases of a brood year. The leftmost bar or point in each series represents the March release, the center bar or point represents the April release, and the rightmost bar or point represents the May release. Brood Year 1987 had no March release. Survival data was downloaded from PSMFC.

Graph 5



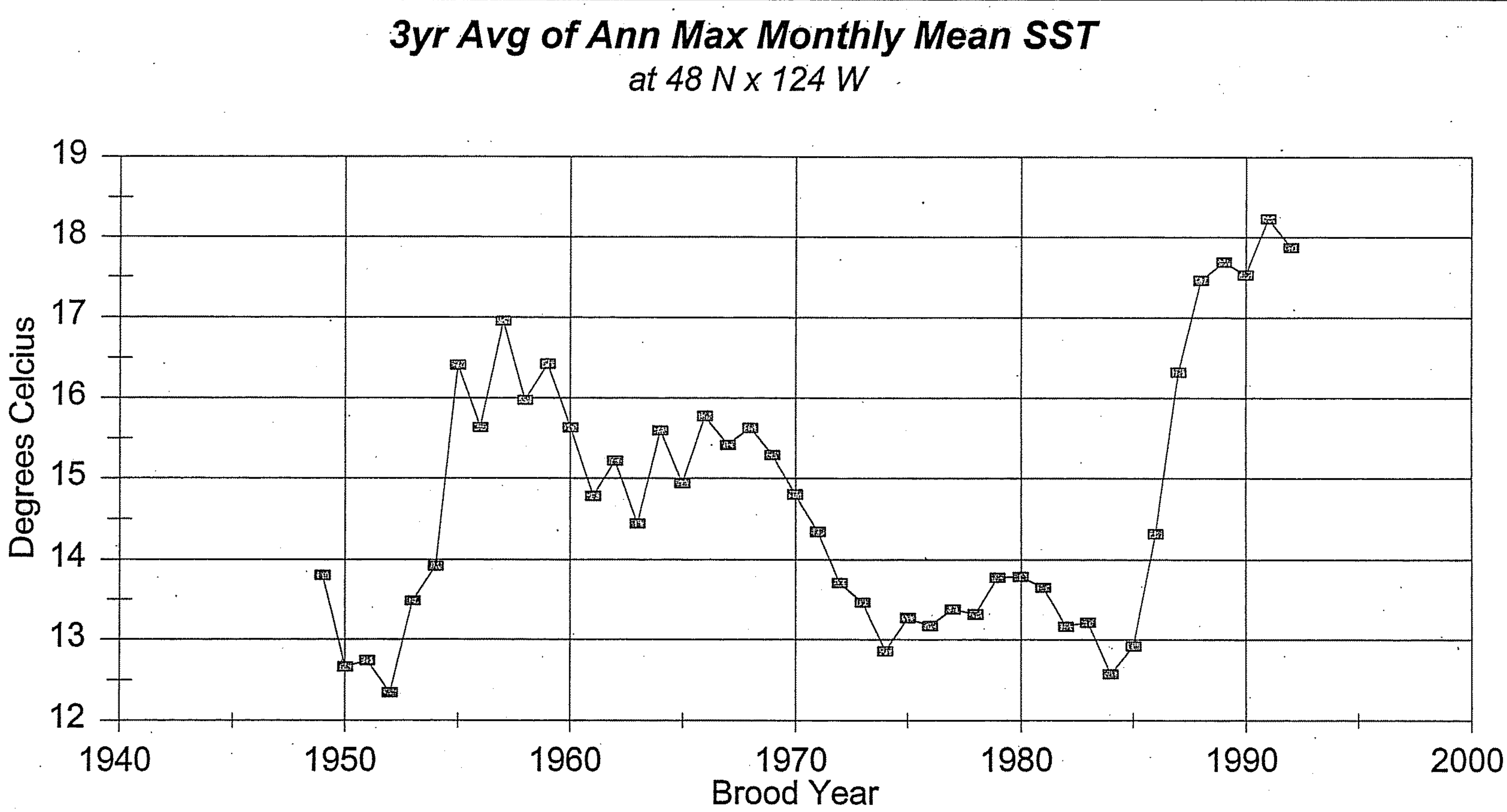
Each series of three represents the three releases of a brood year. The leftmost bar or point in each series represents the March release, the center bar or point represents the April release, and the rightmost bar or point represents the May release. A saltwater challenge was not done on the May release of BY95. Survival data was downloaded from PSMFC.

Graph 6



All upwelling index data was obtained from the National Marine Fisheries Service, Pacific Fishery Environmental Group's website (http://www.pfeg.noaa.gov/data_gate/pfeg_data_avenue.html). Upwelling indices at 42, 45, and 48 N x 125 W were summed for the months of April through September during the three year period after release of each brood year. For example, Brood Year 1972 as released in the spring of 1973. The upwelling data corresponding to Brood Year 1972 was caloulated by adding together the total upwelling units accumulated at each location during the "summer" months of 1973, 1974, and 1975.

Graph 7



All sea surface temperature (SST) data was accessed from the EarthInfo COADS Global Marine Database CD. This graph was produced by using a subset of the monthly mean SST data. The subset was compiled by selecting the maximum monthly mean SST value of each year. A running three year average was then graphed to represent the warmest conditions Spring Creek's three year old fish encountered during their ocean migrations.