NOAA Technical Memorandum NMFS F/NWC-187

Status and Future of Spring Chinook Salmon in the Columbia River Basin--Conservation and Enhancement

Spring Chinook Salmon Workshop,
8-9 November 1989,
Sponsored by the
Coastal Zone and Estuarine Studies Division
Northwest Fisheries Center
National Marine Fisheries Service
Pasco, Washington

Donn L. Park, Convenor

August 1990

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

A REVIEW OF REARING DENSITY EXPERIMENTS: CAN HATCHERY EFFECTIVENESS BE IMPROVED?

J. L. Banks

U.S. Fish and Wildlife Service
Abernathy Salmon Culture Technology Center
1440 Abernathy Road
Longview, Washington 98632

Salmon hatcheries in the Columbia River Basin participate in a diversified program involving numerous government agencies, resource managers, citizen groups, and scientists to return today's valuable salmon runs to historic levels. In their efforts to maximize adult contributions from hatcheries, those involved with hatchery production have frequently assumed that maximum smolt liberations produce correspondingly large numbers of adults for fishery harvest. Hatchery production decisions, therefore, are often based on maximum fingerling carrying capacities. The effects of crowded rearing conditions on post-release survival of smolts is usually not given enough consideration.

Under the administration of separate governmental agencies, rearing density and post-release survival studies of chinook salmon (Oncorhynchus tshawytscha) have been conducted or are currently under way at five hatcheries on the west coast of Canada and the United States. Most of the evidence from these investigations suggests that high rearing densities are counter-productive in terms of hatchery contribution of adults. The subject of this paper is a review of the results from these studies.

Experiments have been conducted with spring chinook at Cowlitz Hatchery (Washington Department of Fisheries) (Hopley 1980). Spring chinook studies were also conducted by Fagerlund et al. (1987) at Capilano Hatchery (British Columbia Department of Fisheries and Oceans) and by Denton (1988) at Deer Mountain Hatchery (Alaska Department of Fish and Game). Tests are under way with coastal fall chinook at Elk River Hatchery (Oregon Department of Fish and Wildlife) (Downey et al. 1988) and with spring chinook (Banks 1989, unpubl. manuscr.) at Carson National Fish Hatchery (U.S. Fish and Wildlife Service).

Rearing conditions and ranges in pond loadings varied widely between studies (Table 1). Various sizes and modifications of rectangular circulating rearing ponds (Burrows and Chenoweth 1970) were used in tests at Cowlitz, Capilano, and Elk River. Swedish-type ponds were used at Deer Mountain Hatchery in Alaska and linear-flow, single-pass raceways were used at Carson National Fish Hatchery. Rearing unit volume varied from 22 to 566 m^3. Pond inflows ranged from approximately 700 to over 7,500 L/min. Fish size at release varied from approximately 6 to over 133 g.

Rearing density effects on survival and total estimated adult contribution for the completed studies at Cowlitz, Capilano, and Deer Mountain hatcheries are summarized in Figures 1-3. Results to date from the on-going studies at Elk River and Carson Hatcheries are shown in Figures 4 and 5.

Within each study, post-release survival rates decreased as rearing density increased. Although this response demonstrates the adverse effects of high rearing density on smolt quality, comparison of survival rates in rearing density studies can be

Table 1.--Summary of rearing conditions and ranges in pond loading parameters at five chinook salmon hatcheries where fingerling rearing density and post-release survival studies were conducted.

Hatchery	Cowlitz[1]	Capilano[2]	Deer Mountain[3]	Elk River[4]	Carson[5]
Race	Spring chinook	Spring chinook	Spring chinook	Fall chinook	Spring chinook
Brood year(s)	1975-76	1979-80	1977	1981-85	1982-84
Pond type	Rectangular circulating	Rectangular circulating	Swedish	Rectangular circulating	Raceway
Pond volume (m^3)	556	124	22	86	34
Pond inflow (Lpm)	7,570	2,385	719	1,703	757-2,271
Temperature (°C)	U[6]	6.1	U	U	6.1
Fish/pond (Thousands)	30-90	185-447	11-45	27-48	20-60
At release:					
Average weight (g)	90.8-133.5	5.7-7.7	17.7-17.8	U	22.8-27.0
Kg/m^3 rearing volume	6.4-17.6	11.2-22.4	6.4-32.0	9.6-25.6	9.6-44.8
Kg/Lpm inflow	0.4-1.4	0.5-1.2	0.2-1.0	0.5-1.3	0.2-2.0
Density index[7]	0.03-0.13	0.18-0.40	0.09-0.44	U	0.13-0.51
Flow index[7]	0.4-1.3	1.4-2.8	0.4-2.0	U	0.5-1.9

[1]Washington Department of Fisheries. Data from Hopley (1980 unpublished report).
[2]British Columbia Department of Fisheries and Oceans. Data from Fagerlund et al. (1987).
[3]Alaska Department of Fish and Game. Data from Denton (1988).
[4]Oregon Department of Fish and Wildlife. Data from Downey et al. (1988).
[5]U.S. Fish and Wildlife Service. (Banks 1989 unpublished data).
[6]Data unavailable.
[7]Density index (W/(L x V)) and flow index (W/(L x I)) as defined by Piper (1972) where W = known permissible weight of fish in pounds, L = average fish length in inches, V = rearing unit volume in cubic feet, and I = rearing unit water inflow in gallons per minute.

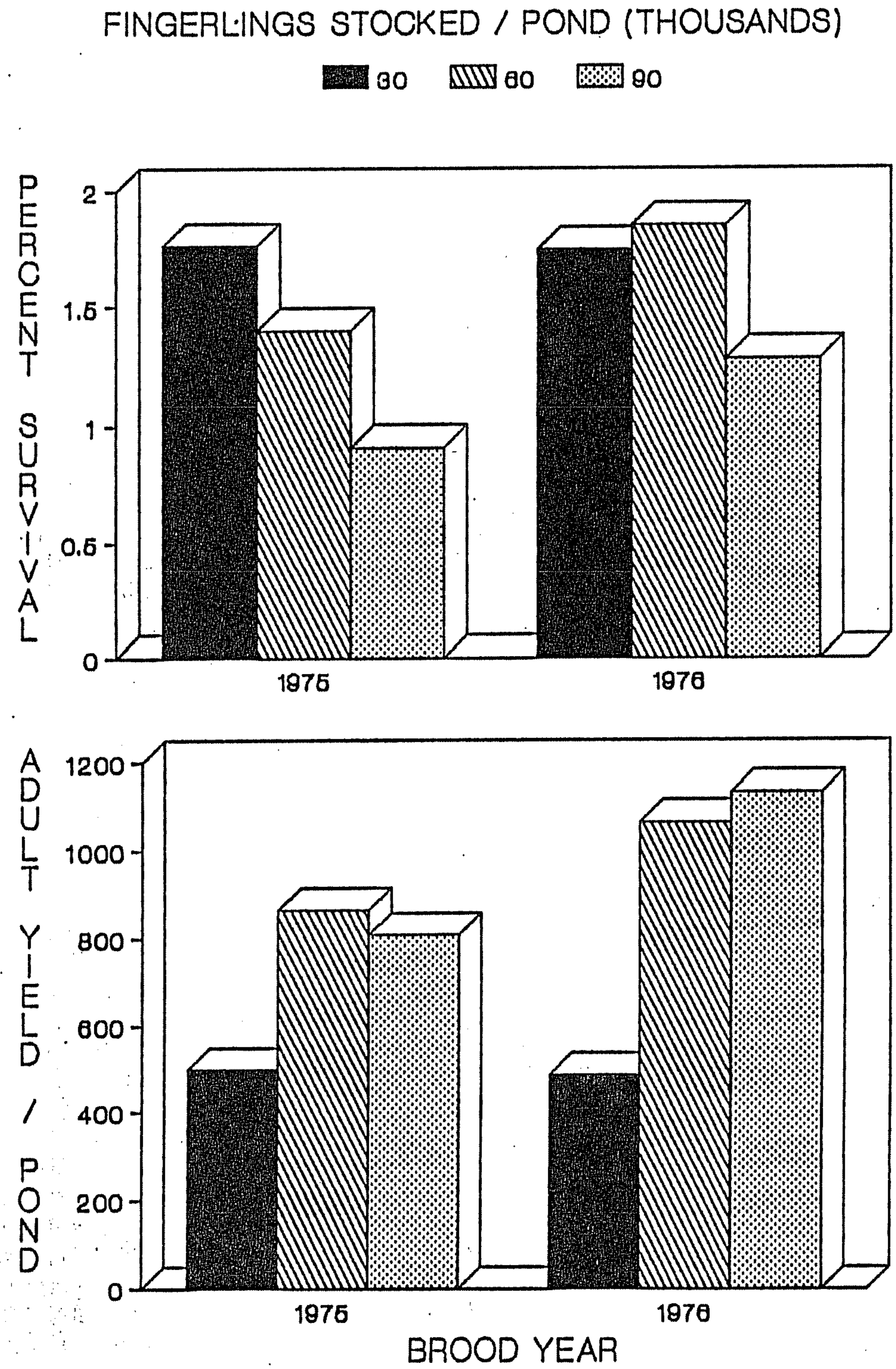

Figure 1.—Percent survival and adult yield per rearing pond in 1975- and 1976-brood spring chinook reared at three densities at Cowlitz Hatchery (Washington Department of Fisheries). Data from Hopley (1980 unpublished).

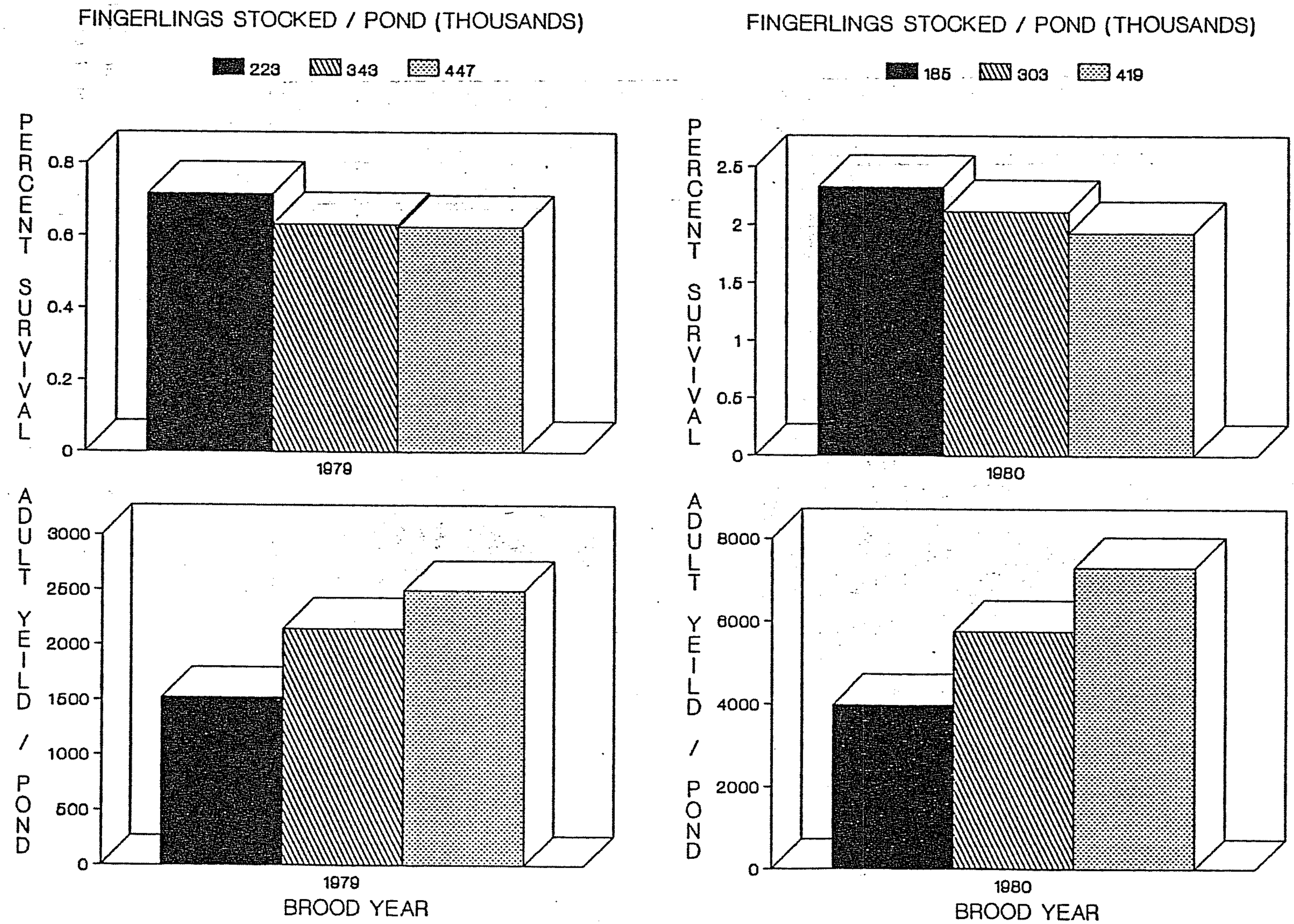

Figure 2.—Percent survival and adult yield per rearing pond in 1979- and 1980-brood spring chinook reared at three densities at Capilano Hatchery (British Columbia Department of Fisheries and Oceans). Data from Fagerlund et al. (1987).

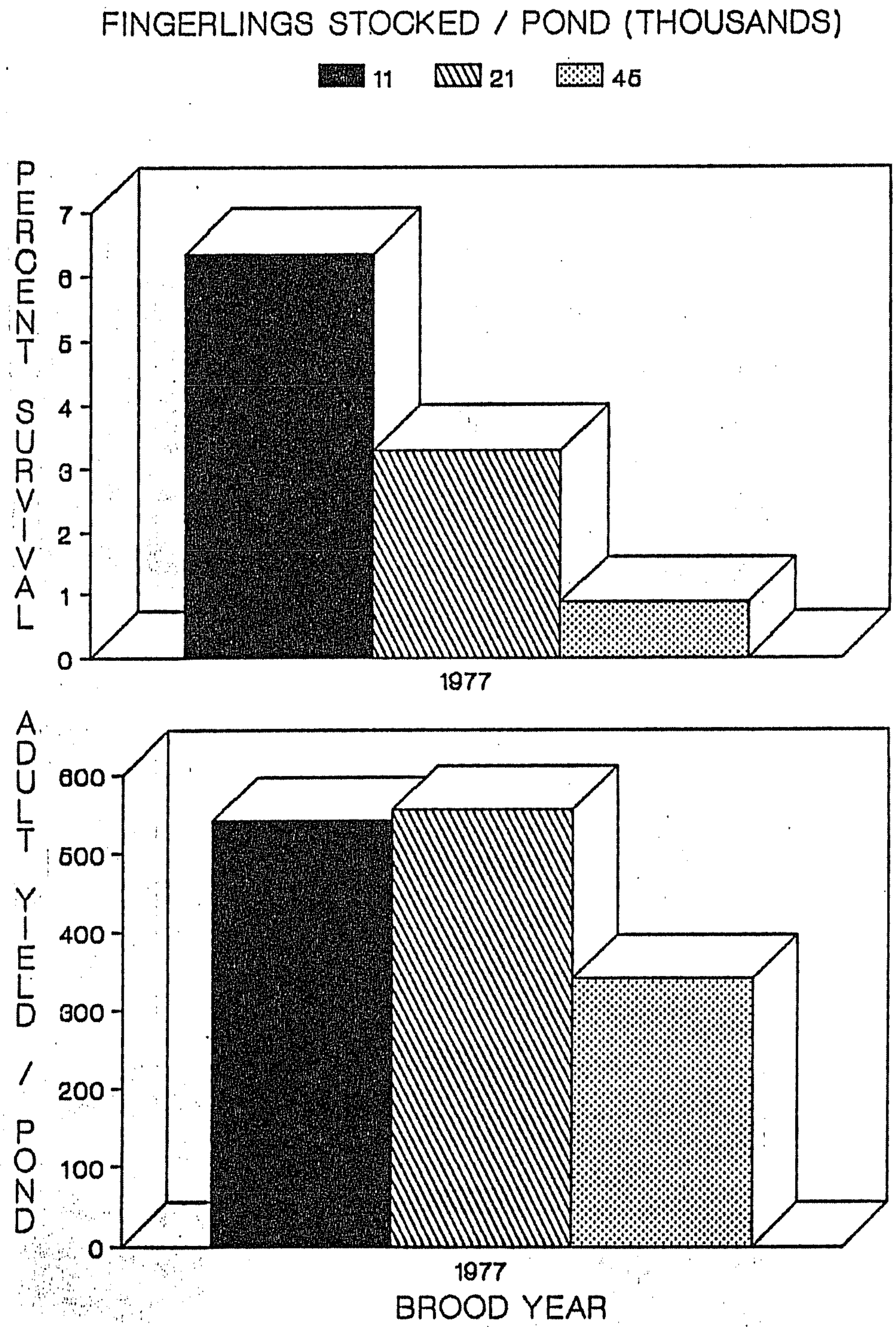

Figure 3.—Percent survival and adult yield per rearing pond in 1977-brood spring chinook reared at three densities at Deer Mountain Hatchery (Alaska Department of Fish and Game). Data from Denton (1988).

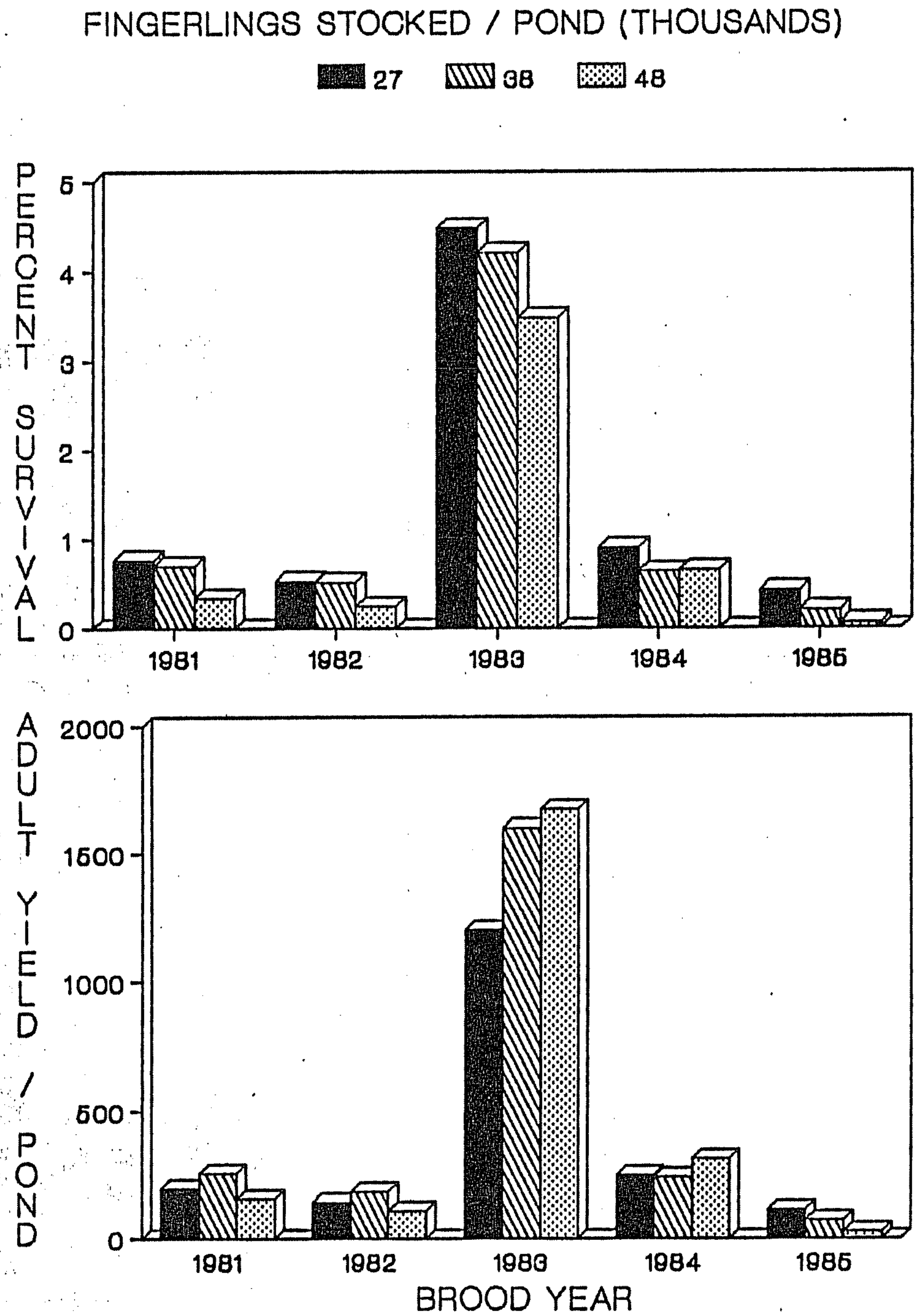

Figure 4.—Percent survival and adult yield per rearing pond in 1981-85-brood fall chinook reared at three densities at Elk River Hatchery (Oregon Department of Fish and Wildlife). Results are based on incomplete adult recoveries. Data from Downey et al. (1988).

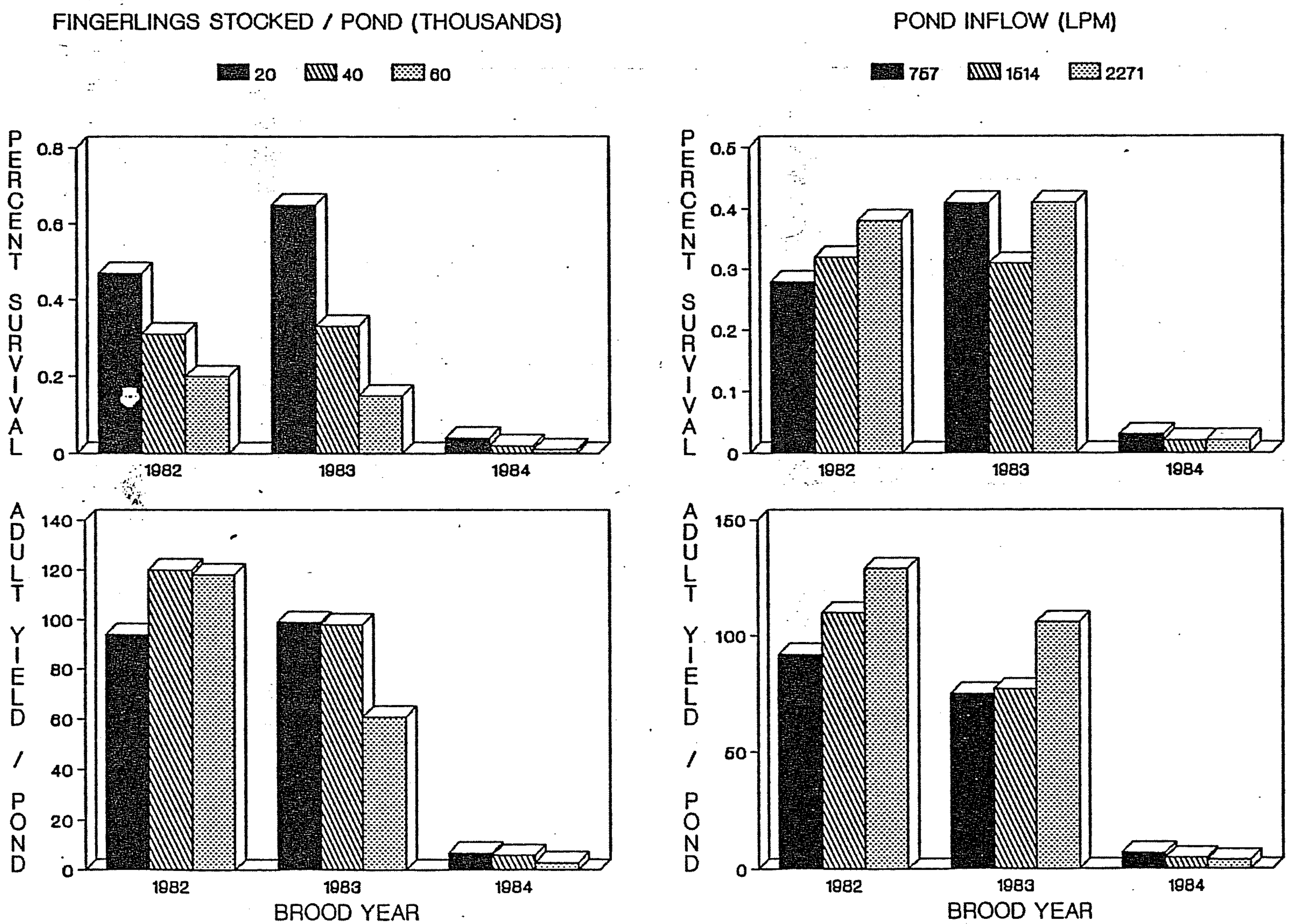

Figure 5.—Percent survival and adult yield per raceway in 1982-84-brood spring chinook reared at three densities and at three levels of water inflow per raceway at Carson Hatchery (U.S. Fish and Wildlife Service). Results are based on incomplete adult recoveries. Data from J. Banks (1989 unpublished).

misleading. Since different numbers of fish are reared within each test level, estimates of total adult yield (catch-release ratio x total fish released) are necessary before comparisons of production efficiency between rearing densities can be made.

At Cowlitz Hatchery, no increase in adult contribution was found when smolt production was increased from 60,000 to 88,000 fish per rearing pond with 1975- or 1976-brood fish (Fig. 1). Ponds with 28,000 smolts produced fewer adults than either of the two higher production levels.

Results from the spring chinook study at Capilano Hatchery are contrary to those observed at the other hatcheries. Increased rearing densities resulted in increased adult contribution levels in both 1979- and 1980-brood tests (Fig. 2). According to Fagerlund et al. (1987), the fish were reared for a period of 3 months prior to release at sizes ranging from 5.7 to 7.7 g. In contrast, fish at the other hatcheries were reared for time periods varying from 9.5 to 11 months and released at sizes of 16 g or larger. The difference in results at Capilano may be explained by the reduced period of rearing if adverse effects from crowded rearing environments accumulate over long periods.

Adult contributions of spring chinook at Deer Mountain Hatchery were nearly equal when spring chinook were reared at 8,500 or 16,800 fish per Swedish pond (Fig. 3). Total adult yield from each of these ponds exceeded that from the pond where 39,100 smolts were reared.

Through the 1987 return year, adult contributions of coastal fall chinook at Elk River have been higher in 3 of 5 years from rearing ponds with 38,000 fish than from ponds where 48,000 fish were reared (Fig. 4). Survival rates of 1983-brood fish were approximately four times higher than those of any other brood. Adult contribution levels from this brood also increased as rearing densities increased. This observation may suggest that, during high survival years, smolts of reduced quality from high rearing densities may be able to survive at higher rates and therefore out-produce smolts reared at reduced densities. To date, however, ponds with 38,000 smolts have produced more adults than ponds with 27,000 or 48,000 smolts (Downey et al. 1988).

Studies at Carson Hatchery were designed to test the effects of both rearing density and pond inflow on adult contribution. Although returns are incomplete, results indicate that adult contribution levels are related to both pond crowding and water inflow (Fig. 5). In 1982 brood-tests, contribution of adults from ponds with 20,000, 40,000 or 60,000 smolts were not statistically different (Banks 1989 unpubl. data). In 1983 brood-tests, ponds with 20,000 or 40,000 smolts produced significantly more adults than raceways with 60,000 smolts. Total adult recoveries from ponds with 2,271 L/min water inflow have exceeded those from ponds with 757 or 1,514 L/min inflow even though rearing temperatures were low (6.1°C) for most of the rearing period and dissolved oxygen levels in pond effluents were 7 mg/L or higher at smolt release. Reductions in contribution, therefore, were apparently due to factors other than low oxygen levels.

In conclusion, most of the evidence suggests that, for chinook salmon, high rearing densities do not result in increased levels of adult contribution. Conversely, there is also no evidence to suggest that strongly reduced rearing densities produce great increases in adult yield. In most cases the studies show that low or intermediate smolt production levels produce as many adults as high rearing densities. If these studies are indicative of smolt production and adult contribution limitations at other hatcheries, new criteria are needed for making production management decisions. Production levels in the past have been based primarily on maximum fingerling carrying capacities. Instead of accomplishing their intended goal, hatcheries operating at capacity may be merely contributing to their own fish cultural problems, such as disease outbreaks, and may be unnecessarily budgeting large sums of money on feed costs. Unfortunately, because of the unique rearing conditions at individual hatcheries (pond type, water quality, disease problems, species or race tolerance to crowding, etc.), optimum rearing levels are probably site-specific. If hatcheries are to operate at maximum efficiency, however, more studies of the hatchery crowding-adult yield relationship are needed.

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QUESTIONS AND ANSWERS

Q: Was oxygen supplementation used in any of the experiments?
A: No; the fish were in ponds with established flows. However, oxygen supplementation experiments are now under way. It will be interesting to see if increased oxygen will increase production. Maybe crowding has an adverse effect that overrides any oxygen advantages. It may turn out that we could use less water if oxygen is added to the same number of fish.
Comment: The Cowlitz Hatchery had 10-times the survival when 4 fish per pound were used instead of 20 fish per pound.
A: Most hatcheries have cold water and have a problem getting fish to that size. If there is fast growth, there are more precocious males. Getting larger fish is a good problem to work on.

Q: Did you look at growth rates or mean size in Carson fish?
A: There was no difference in mean size within brood years in the different treatments at release. This was surprising to see in so many raceways. The fish had the same feeding levels.

Q: If you lowered the flow but added more ponds, what would you see?
A: We didn't get into that because of variability with the different brood years. Flow is more significant at higher densities.

Q: What was the level of BKD?
A: In the Carson study, Brood-Year 1 had no mortalities from BKD, and only about 2-2.5% in Brood-Years 2-3, even though there was much higher BKD incidence. At present, we see different mortalities in different ponds. This is the first time we have noted interpond differences in mortality due to BKD. We would have to do studies with many brood years.

Q: In 100 years there is still no standard raceway, which makes it difficult to compare data--why are these still so different? Is it required because of species differences?
A: I don't know, but there may be a strong element of fashion and personal preference in this. It would be good to test various types of ponds. It is true that water supplies vary with siltation, etc., and perhaps different types work better than others in certain situations.

Q: Regarding your loading densities, High, Medium, and Low--is Medium the normal loading?
A: I understand that Medium was the normal loading for Cowlitz and Carson, and that at Carson this was 40,000 fish at 400 g/m.
Comment: This is the same as the loading at Elk River Hatchery.

Q: Was the diet the same for the whole year?
A: At Carson, the fish were started on OP4. Later, some BKD problems were suspected to be related to diet, so this was switched to OP3. The mortalities went down, so we stayed with OP3. I don't recall the diets in the other studies.