Section 8

THE EFFECT OF FEEDING SPRING CHINOOK SALMON A LIVE FOOD SUPPLEMENTED DIET DURING ACCLIMATION, 1995

By

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Introduction

A central question to increasing the postrelease survival of hatchery reared fish is determining if prerelease forage training increases postrelease foraging success. Many successful captive rearing programs for endangered and threatened species of higher vertebrates have successfully trained the animals to forage naturally prior to releasing them back into their natural environment (Beck et al. 1994). For instance, after research showed that cage-raised Siberian ferrets killed mice and prairie dogs more efficiently when they had previous experience (Miller et al. 1992), the captive breeding program for endangered black footed ferrets began providing captive bred animals the opportunity to stalk and kill live prairie dog (*Cynomys ludovicanus*) in large outdoor enclosures to develop their natural hunting skills prior to release (Oakleaf et al. 1992). Successful prerelease foraging training has also been conducted with Iberian lynx (Lynx *pardinus*) (Rodrigues et al. 1995).

Prerelease forage training has also been successful with cold blooded carnivores. Nile crocodile (*Crocodylus niloticus*) were successfully taught to forage naturally by being presented live fish in prerelease holding pools (Morgan-Davies 1980). Cultured chinook salmon (*Oncorhynchus tshawytscha*) exposed to a live food supplemented diet ate more live prey in laboratory test arenas than fish reared only on pellets (Maynard et al. 1996). Hybrid pike (Essox *lucius*) fed live foods had higher postrelease survival than fish reared on pellets (Johnson 1978)

Foraging training has also been implemented in captive breeding programs for herbivores. Prior to release, captive bred Golden lion tamarin (*Leontopithecus rosalia*) that were allowed to move around on natural vegetation and forage for hidden food in their cages developed better natural foraging skills. (Beck et al. 1991). In the case of avians, thick billed parrots (*Rhynchopsitta* pachyrhyncha) have been provided experience with handling their primary food source, pine cones, prior to reintroduction to the wild (Wiley et al. 1992). A unique tutoring program, in which nonendangered Texas bobwhite quail (*Colinus* virginanus texanus) were grouped with endangered masked bobwhite quail (C.*virginanus* ridgewayi) in acclimatization cages, was successfully used to demonstrate food-finding and antipredator behavior to captive bred animals (Carpenter et al. 1991).

In the study reported here, we examined how exposing spring chinook salmon to live food supplemented diets and a more natural rearing habitat during acclimation affected postrelease foraging ability. Both foraging theory and the above cited studies suggested these factors should enhance spring chinook salmon foraging ability.

Material and Methods

A 2 x 2 factorial design was used to examine the effect of live food supplemented diets and rearing habitat complexity on postrelease foraging ability. The four treatments consisted of 1) a gravel covered bottom and live food supplemented diet, 2) a gravel covered bottom and a pellet only diet, 3) a barren bottom and a live food supplemented diet, and 4) a barren bottom and pellet only diet. Habitat complexity of the rearing tanks was increased by covering the bottom with 2-cm gravel, so that fish could learn to forage in this more complex environment.

The experiment was conducted with 1993-brood Yakima River spring chinook salmon. Fish rearing was conducted at the National Marine Fisheries Service (NMFS) Freshwater Fish Culture Laboratory at the University of Washington's Big Beef Creek Research Station near Seabeck, Washington. The fish were fed a commercial semimoist diet and reared in a common

circular tank following standard fish culture practices. The experiment was initiated in March 1995. The yearling fish were anesthetized in MS 222, their fork length measured to the nearest mm, and PIT tagged. PIT tagging was done with an automated injector following the procedures outlined in Prentice et al. (1990). The tagged fish were randomly distributed to 24 400-L rectangular acrylic aquarium tanks.

The two ends and sides of each tank were covered with grey colored material. Black plastic aquaria hoods covered much of each tank's surface. Each tank was supplied with 4 L/min of food-free well-water through a 10-cm diameter opening in one end of the tank Water exited the tank through a similar opening in the other end. Six tanks were assigned to each of the four treatments, and the bottom of half the tanks covered with l-cm diameter gravel.

The fish in all 24 tanks received an equal volume of feed pellets each day. Those fish on a live supplemented diet were also given a ration of brine shrimp or tubifex worms prior to being fed pellets. The fish were maintained on these diets until tested in the experimental enclosures.

In April 1995, all fish were measured, photographed, and a subsample of three fish from each tank sacrificed for pathological analysis. The remaining fish were returned to their tanks and reared as previously described.

The foraging ability of a 'subsample of fish from each treatment was examined in test enclosures beginning in mid May 1995 for the marine tests and late May 1995 for the freshwater tests. Size classes were established based on length and a subsample of fish removed from each aquaria for testing in the in situ enclosures. Three fish from each tank were removed, placed in a common transport container, and transferred to a marine enclosure at the NMFS Manchester Marine Experimental Station. Another three fish from each tank were removed, assigned to a freshwater test cage, and transported in a common container to the Union River near Belfair, Washington, where they were released into their assigned test cage.

The marine enclosure was a 2-m wide by 3-m long fiberglass raceway. The bottom of the raceway was covered with several centimeters of pea gravel and the water level was maintained at 48 cm Unfiltered seawater flowed into the raceway at approximately 14 L/min The raceway was allowed to develop a natural flora and fauna over several months time before the test fish were added. A plankton bloom occurring in the surrounding waters enhanced productivity during the test period.

The six freshwater enclosures were 2.4-m long by 1.2-m wide by 1.2-m deep nylon net (1.9-cm stretch mesh) cages fitted around a PVC pipe frame. The top of each cage was covered with a l-cm thick sheet of plywood. The cages were anchored in place on the stream bottom by steel fence posts driven into the bottom and attached to each comer pipe. The six cages were dispersed along a 0.5-km section of the river.

After about 1 week of residence in the enclosures, the fish were netted, anesthetized in a lethal concentration of MS 222, length measured to the nearest mm, and scanned for PIT-tag code. The stomach contents of the fish were immediately preserved by formaldehyde injection of the stomach. After fixation, the stomach contents were transferred to a 70% ethanol solution for storage until analyzed. The stomach contents of each fish were sorted into digestible and indigestible material. The sorted material was then weighed to the nearest 0.001 g providing a measure of individual foraging success.

Contingency table analysis was used to statistically analyze the pathology data. A two way ANOVA was used to analyze the length and stomach content weight data.

Results

During the course of the study, in-culture mortality was relatively high ranging from 7.9 to 14.1% (Pig. 8-l). Although not statistically significant (P = 0.077), the in-culture survival of fish fed a live food supplemented diet was higher than that of fish fed pellets only. Additionally, fish whose diets were supplemented with live foods were significantly (P = 0.006) longer than fish fed a pellet only diet (Pig. 8-2). Rearing habitat complexity affected neither survival (P= 0.917) nor growth (P = 0.327).

Yersina ruckeri, the causative agent of enteric redmouth disease was not present in fish from either sample. The kidney tissue samples for determining the presence or absence of *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD), in fish from the rearing treatments have not been read at this time. However, gross autopsies of mortalities indicated that Renibacterium *salmoninarum* was the main cause of death for fish from all treatments.

In both test environments, most fish had little digestible material in their stomachs. In the marine enclosure, 85% of the fish had less than 0.1 g of digestible material (Pig. 8-3). In the freshwater enclosures, 49% of the fish had stomachs that were either empty or contained less than 0.1 g of food (Fig. 8-4). Less than 10% of the fish in either type of enclosure had more than 0.3 g of digestible material in their stomachs.

Rearing habitat complexity had no significant effect (P > 0.05) on foraging ability in either freshwater or marine enclosures (Pig. 8-5 and 8-6). In the marine enclosure, the fish from the live food supplemented diet had significantly less food in their stomach than pellet-fed fish (P = 0.035). Although not statistically significant (P = 0.095), the results were similar in the freshwater enclosures, with more digestible material in the stomach of fish from the pellet-fed acclimation treatments.

Discussion

In the wild, spring chinook salmon stomach contents usually weigh more than 1% of total body weight. With few exceptions, the stomach contents of chinook salmon captured in the intertidal area of the Nanaimo River estuary weighed 1-4% of the fish's body weight (Healey 1979). By the time the fish were tested in the enclosures, they were about 145 mm long, and at that size, we would expect digestible material in their stomach to weigh from 250 to 1,000 mg. As most of our in situ enclosure fish had less than 100 mg of digestible material in their stomachs, we . believe they were not feeding as well as they should

In both types of enclosures, more food items generally preyed on by salmonids appeared to be available than were eaten during the test period. In the marine enclosure, plankton was so abundant that there was insufficient visibility for videotaping fish foraging behavior and amphipods were observed in the enclosure at the end of the test. In the freshwater tests, uneaten aquatic insect prey (such as stoneflies, *Plecoptera*) were observed within the enclosures when the fish were being removed at the end of the week. These observations suggest that it was failure of

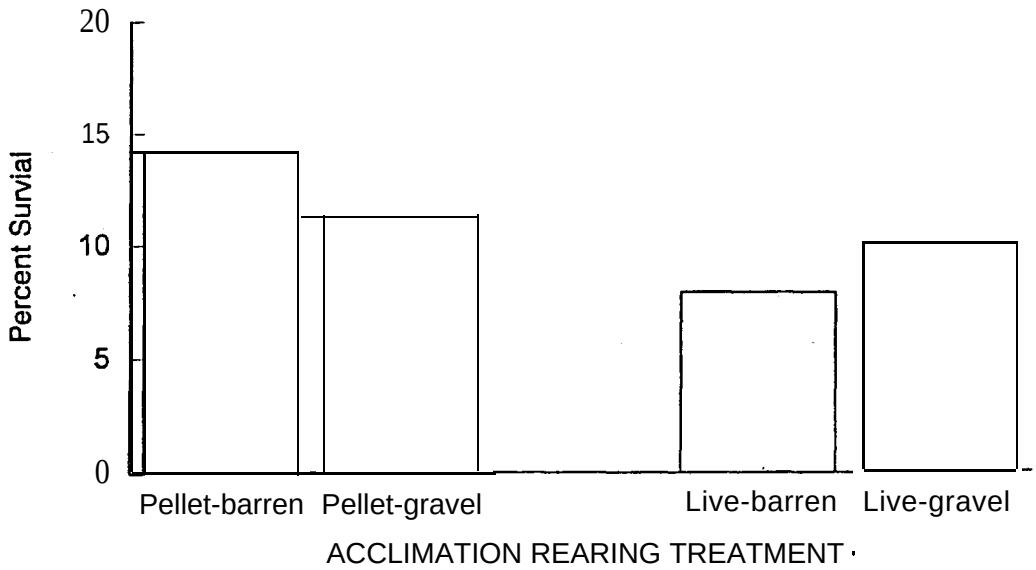

Figure 8-l. Percent in-culture mortality of 1993-brood Yakima River spring chinook salmon acclimated on pellet or live-food diets and structured or unstructured habitats.

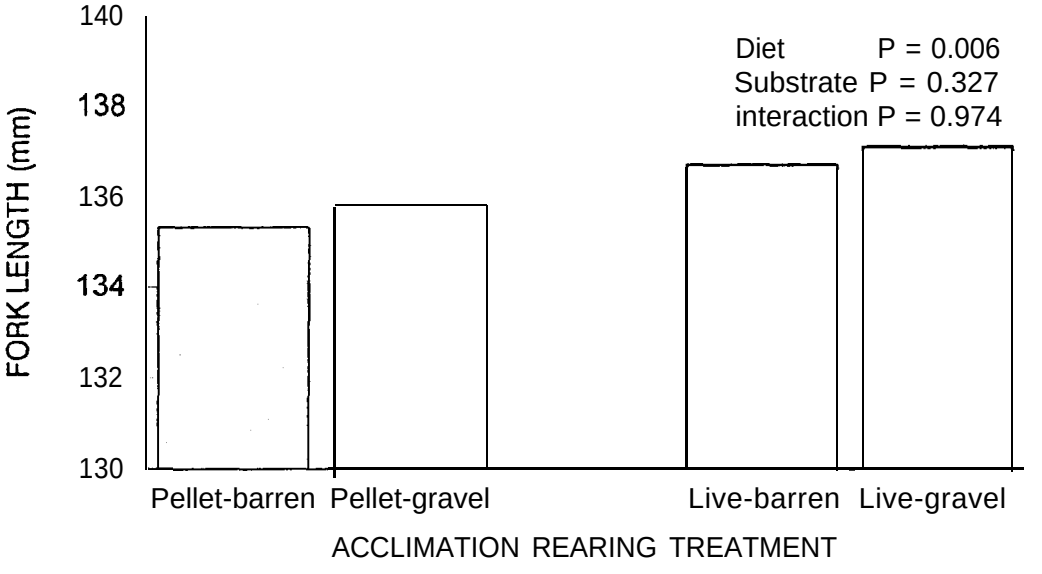

Figure 8-2. Fork length of 1993-brood Yakima River spring chinook salmon acclimated on pellet or live-food diets and structured or unstructured habitats.

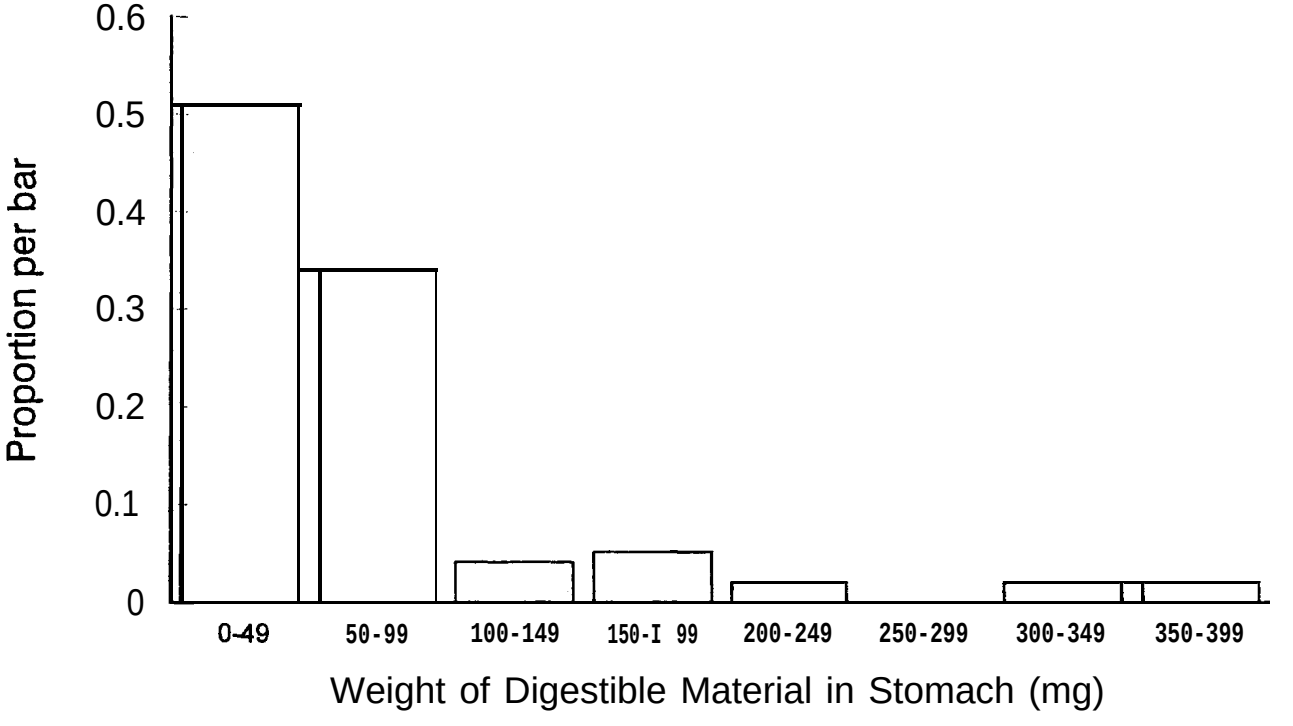

Figure 8-3. Weight (mg) of digestible material in stomachs of 1993-brood Ynkima River spring chinook salmon acclimated on pellet or live-food diets and structured or unstructured habitats and challenged to forage in a marine enclosure.

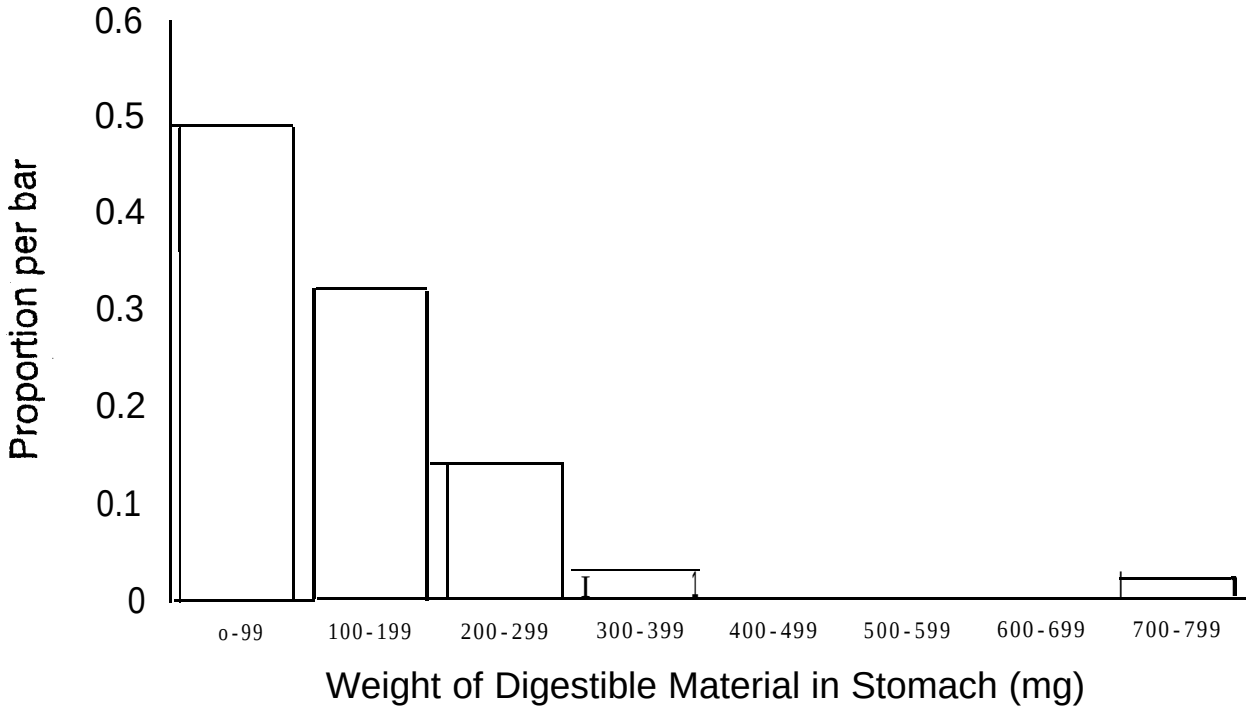

Figure 8-4. Weight (mg) of digestible material in stomachs of 1993-brood Yakima River spring chinook salmon acclimated on pellet or live-food diets and structured or unstructured habitats and challenged to forage in a riverine enclosure.

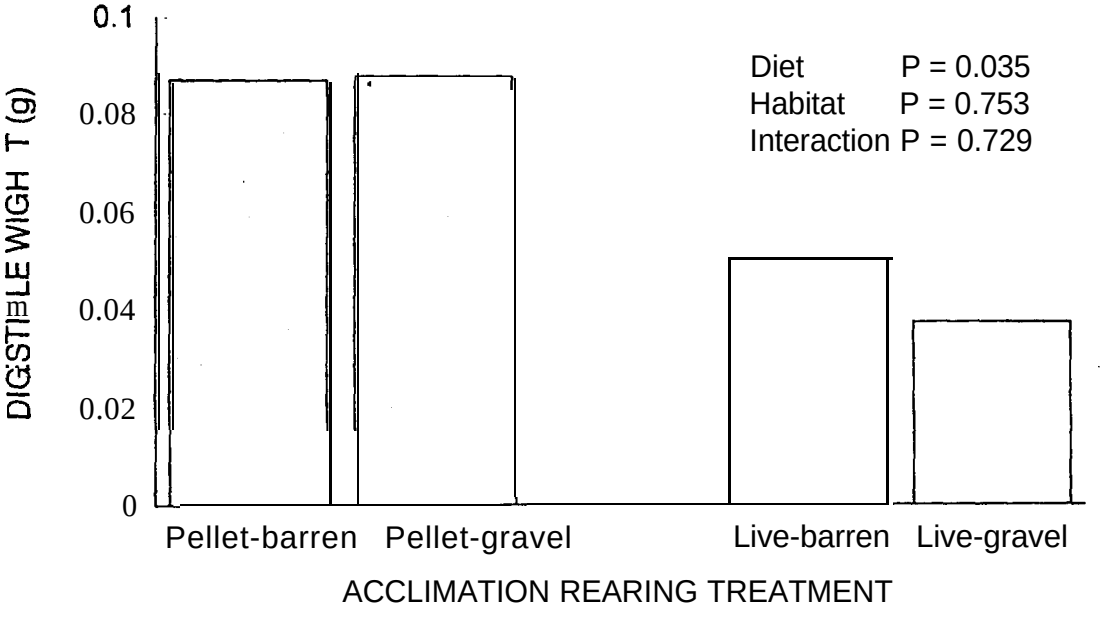

Figure 8-5.‘ Stomach content weight of 1993-brood Yakima River spring chinook salmon acclimated on different diets in different habitats and challenged to forage in a marine enclosure.

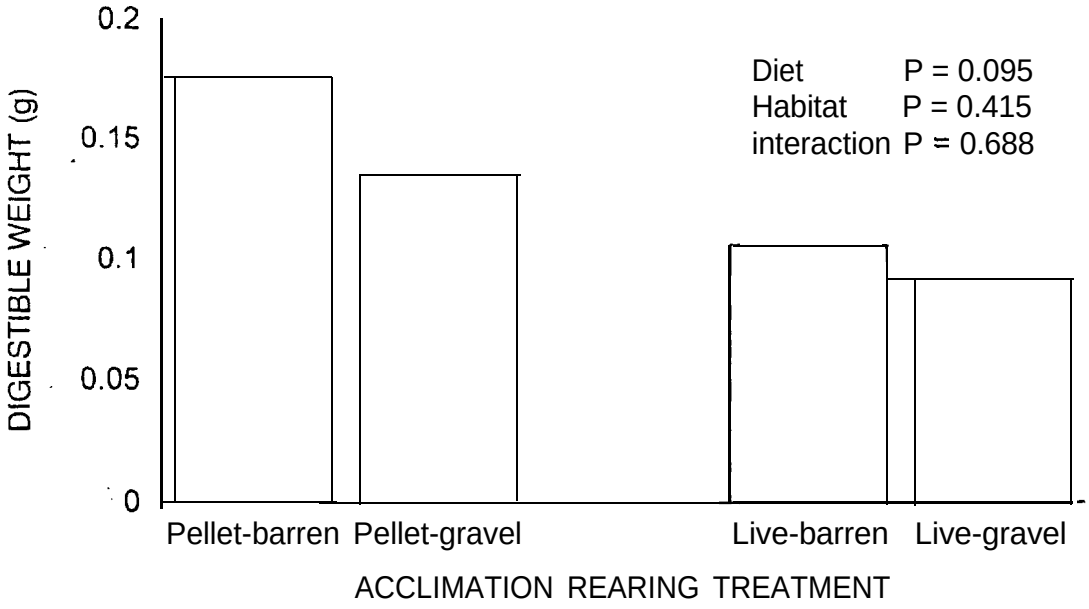

Figure 8-6. Stomach content weight of 1993-brood Yakima River spring chinook salmon acclimated on different diets in different habitats and challenged to forage in riverine enclosures.

fish to feed on the available prey in the enclosures rather than insufficient prey being available within the enclosures that resulted in so many fish with near empty stomachs.

In laboratory studies, more than a third of the hatchery-reared fish failed to feed even though food was plentiful (Paszkowski and Olla 1985, Maynard et al. 1996). In field studies, hatchery-mated fish are often found to be starving and have little or no food in their stomachs for the first few weeks after release (Miller 1952, Hochachka 1961, Reimers 1963, Sosiak et al. 1979, Myers 1980, O'Grady 1983, Johnsen and Ugedal 1986). The fact that a large number of hatchery-reared fish in many studies fail to feed demonstrates the need to develop culture techniques that improve the postrelease foraging ability of cultured fish.

Theoretically, the poor foraging ability of cultured fish may be attributed to 1) stress associated with entering a new environment, 2) disease, 3) inability to recognize live prey as food, 4) taste bias against live food, 5) inability develop successful hunting tactics, and 6) inability to switch to novel prey. In our study, the 1 week residence in the test enclosures should have provided sufficient time for the fish to recover from the effects of handling stress and begin feeding. Nevertheless, the fish in our study did not feed.

The high proportion of *Renibacterium salmoninarum* in the population does not explain the low stomach content weight of the test fish. When the stomach weights of fish showing gross symptoms of BKD were compared to fish not showing those symptoms, the stomachs of the former fish had a greater weight of digestible material. Although it is possible that sick fish do not have as rapid a gastric evacuation rate as healthy ones, this suggests that fish undergoing a BKD infection forage as well as healthy ones.

Salmonid foraging is a multi-step process involving prey detection, capture, and ingestion. Simple visual cues are the primary behavior releaser. Our observations are that during the prey detection process, salmonids pursue any object moving in their visual field that is small enough to engulf, including bubbles and vegetable matter. Visual and acoustic cues are then used by the fish to capture the prey. No discrimination occurs up to this point, with both digestible and indigestible material being pursued and captured with equal vigor. However, once the prey can be tasted and felt within the oral cavity, discrimination occurs and the prey is either ingested or rejected This model is based on several hundred hours of observing coho salmon and chinook salmon feeding behavior (D. Maynard, personal observation), and is supported by our earlier observation that chinook salmon repeatedly attacked and captured mayflies until they breached the exoskeleton and rejected the prey based on its taste (Maynard et al. 1996).

Based on this foraging behavior model, prey texture and taste are probably the most important factors involved in developing techniques to successfully condition hatchery-reared salmonids to forage on natural prey. Bryan and Larkin (1972), Ringler (1985), and Merna (1986) suggested juvenile salmonids develop their tastes for food early in their life cycle and that these tastes are then maintained throughout their life. This leads us to suggest that most pellet-reared fish ate not ingesting live prey in laboratory and field studies because they do not develop that initial taste for natural live foods early in their rearing cycle.

However, when fish are reared primarily on pellets, but are given early experience with natural live foods, they may develop a taste for the feeds they must consume after release. This concept is supported by our observation that hatchery fall chinook salmon exposed to large amounts of natural prey entering their rearing vessel throughout their hatchery rearing cycle seemed to feed readily after release (E. Tezak and D. Maynard, personal observation). This suggests that

future research should determine if feeding live-food supplemented diets fed from swimup to release is a better approach for enhancing postrelease foraging success of hatchery reared fish.

It is unclear why fish in this study reared on a pellet-only diet contained mote digestible material in their stomach than fish reared on live food supplemented diets. Both theory and our earlier investigation with fall chinook salmon suggested the foraging experience provided by live food diets should improve the foraging skills of spring chinook salmon over that observed with fish reared on pellets alone.

One explanation is that the color and shape of feed pellets more closely resembled the natural prey available in the enclosures than the brine shrimp and blackworms used in the live food supplemented diets. However, since fish from both treatments had similar experience with pellets, they should have developed identical search images for pellet-like prey.

The difference between the two treatments might also be explained if the fish reared on live-food supplemented diets had more rapid gastric evacuation rates than fish reared on pellets alone. As reviewed in De Silva and Anderson (1995) both the type of food present in stomachs and the length of time since last feeding affects gastric evacuation rate. The gastric evacuation rate is faster for fish feeding on smaller particles than large particles, less fatty foods than more fatty food, and invertebrates with thinner exoskeltons than thicker exoskeltons.

If the live food supplemented fish were more prone to feed on smaller prey, prey without exoskeltons (worms), or less fatty prey, than their stomachs might contain less material at sampling because they were evacuated more rapidly. Similarly if it took the fish reared on pellets alone several days longer to learn to capture live prey, their stomachs might contain more food, as fish that have not fed for some time have gastric rates 50-68% slower than fish that have been continuously feeding (De Silva and Owoyemi 1983).

The live food dietary supplements did improve in-culture survival. Micronutrients or vitamins present in the live foods may have enhanced the performance of the immune system of fish teared on live food supplemented diets. Research has shown that higher dietary levels of Vitamin C than is found in standard prepared diets enhances the immune system of salmonids (Verlhac and Gabaudan 1994).

Given observations with other species, it is surprising that habitat enrichment in this study had no effect on postrelease foraging ability. However, this observation may be the result of very few fish in the study feeding. For habitat enrichment to enhance foraging ability, it may first be necessary to instill a preference for live food diets in salmonids. Once a dietary protocol is determined that results in most fish successfully foraging, then research should again be initiated to determine if habitat enrichment also enhances postrelease foraging ability.

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