Section 4

THE EFFECTIVENESS OF LIVE FOOD SUPPLEMENTATION IN IMPROVING THE FORAGING ABILITY OF FALL CHINOOK SALMON, 1992[2]

By

Desmond J. Maynard, Gail C. McDowell,
Eugene P. Tezak, and Thomas A. Flagg

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Manchester Marine Experimental Station
P-0. Box 130
Manchester, Washington 98353

[2] Information from Section 4 has been published as:
Maynard, D. J., G. C. McDowell, E. P. Tezak, and T. A. Flagg. 1996. Effect of diets supplemented with live food on the foraging behavior of cultured fall chinook salmon. Prog. Fish-Cult. 58: 188-192.

Contents

Page

Introduction 43

Methods 43

Results and Discussion

Prey Behavior 44

Foraging 45

Morphology.. 45

Disease Analysis 50

Conclusions 50

References 51

Introduction

The low postrelease survival of cultured salmonids used in enhancement and supplementation may be partially due to their inability to forage on naturally available foods (Miller 1952, Hochachka 1961, Reimers 1963). It is generally recognized that during the first weeks after release, cultured salmonids eat less and forage on more inedible material than wild fish (Sosiak et al. 1979, Myers 1980, O'Grady 1983, Johnsen and Ugedal 1986).

This difference in foraging may result from the following causes: 1) stress associated with entering a new environment; 2) the inability of pellet-reared fish to recognize live food; 3) taste bias against live food developed in pellet-reared fish; or 4) the inability of pellet-reared fish to develop successful hunting tactics.

Stress associated with entering a new environment may be reduced by rearing fish under seminatural conditions. In addition, postrelease foraging may be improved by training fish to feed on live food in the hatchery. This study compared the foraging ability of fall chinook salmon reared on pelletized feed to that of fish reared on a combination of pellets and live food.

Methods

The research 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 facility is adjacent to the estuary of Big Beef Creek, a small coastal stream.

Age-O fall chinook salmon (*Oncorhynchus tshawytscha*) fry were obtained from the Washington State Department of Fisheries George Adams Salmon Hatchery and were acclimated to the NMFS laboratory for 2 months prior to the initiation of experimental rearing. These fish were fed commercially available pelletized diets from swimup (February 1992) until April 1992, when they were measured and randomly dispersed among six 2-m-diameter blue polyethylene tanks. Each tank received 150 fry and was supplied with clear 10°C well-water. Fish in three of the six tanks were fed commercially available pellets only (PO), while those in the other three tanks were fed a pellet diet supplemented with live food (LFS).

Fish were reared under these experimental conditions for 3 months. Every morning, fry in the three LFS tanks were presented with various combinations of live food (mysids, chironomid larvae, mosquito larvae, and daphnia that are referred to as "familiar" prey). After 1 hour, these fish were fed to satiation with a pelletized ration. Fry in the three PO-diet tanks were fed to satiation on pellets only. Both groups were fed to satiation in an attempt to equalize utilizable energy intake and growth between the two treatment groups. Except for their diets, both groups were cultured using the same general procedures outlined by Leitriz and Lewis (1980).

The live foods used in the study were either cultured on site, following the general methods outlined by Masters (1975), or harvested from an adjacent stream. The daphnia, chironomid larvae, and mosquito larvae were grown in fertilizer-enriched water in several 2-m-diameter by 0.3-m-deep polyethylene swimming pools. Burlap sacks were added to each pool to provide suitable substrate for the chimnomids. Daphnia were seeded into the pools from a stock population while the chironomid and mosquito larvae were naturally recruited to the pools from the local population. The mysids were harvested with an aquarium net from the Big Beef Creek estuary at high tide just below the stream weir. Mayfly larvae, which were subsequently used as

novel prey, were harvested from the stream by overturning submerged stones and collecting the disturbed larvae in a small, fine-mesh seine.

On 15 July 1992, all fish were anesthetized in tricainemethane sulfonate, weighed, measured, and visually examined for coloration and fin condition. A subsample was divided into three length classes and maintained separately in 400-L aquaria for use in foraging effectiveness evaluations. A second subsample of fish (PO n = 42, LFS n = 35) was sacrificed and examined for bacterial kidney disease (BKD) to determine if live food supplemented diets affected the incidence of this common chinook salmon pathogen.

Foraging effectiveness was evaluated by comparing the foraging behavior of fish subsampled from the LFS and PO treatments under controlled laboratory conditions. Foraging behavior was observed in a barren, 200-L, acrylic aquarium 91cm long by 38-cm wide by 51-cm deep, with an opaque background on all but the front side. A total of 40 trials were conducted in this test aquarium. For each trial, a single fish from one of the two treatments was allowed a minimum of 60 min to acclimate to the new aquarium Fish were then allowed to forage on mosquito, chironomid, and mayfly larvae by introducing all prey simuhaneously into the test arena. Each trial lasted 30 min. Fish from the two treatment groups were alternated between trials until a minimum of 20 fish from each treatment had been examined in the test aquarium.

An observer used event recorder software on a personal computer to record the species of prey interacted with as well as the time of approach (swimming in general direction of prey), attack (burst swimming toward prey), capture, ingestion, or loss or rejection of each prey item. Temporal foraging efficiency was calculated from the average prey handling time (from attack to ingestion) of fish from each treatment. Foraging success was determined by the average number of prey of each type approached, attacked, captured, and ingested by each fish.

The prevalence of BKD was determined with standard fluorescent antibody technique (Bullock and Stockey 1975). The differences in length, weight, and temporal aspects of foraging efficiency between treatments were analyzed with Student's t-tests. The approach, attack, capture, and ingestion data were analyzed with Mann-Whitney U tests (Zar 1974).

Results and Discussion

Prey Behavior

The interaction between predator and prey differed markedly betweenprey type. Mosquito larvae appeared to avoid predation by remaining motionless at the surface. Those few that swam down from the surface usually attracted the attention of the fish and were readily attacked and ingested whole. In contrast, the wriggling bright red chironomid larvae were usually attacked by any fish that spied them on the bottom. In many cases, the fish would ingest several of these worm-shaped insects in a single attack. In the test aquarium, chironomid larvae did not appear to have any antipredator strategy.

The relatively large, heavily armored, and dorso-ventrally flattened mayfly larvae were the most difficult prey for the fish to handle. The fish had to tear each mayfly larva into pieces and ingest the smaller portions. Interestingly, after ingesting one mayfly larva, fish were usually. reluctant to ingest another, even though they continued to approach and attack these insects. This high rate of rejection after the initial mayfly larva was eaten suggests this particular mayfly species may have been unpalatable. A second antipredator strategy observed in mayflies was to remain

motionless whenever any mayfly in the tank was attacked. This strategy was successful against visually-hunting predators like salmonids, for which the primary cue that releases prey-attack behavior is movement within their visual field

Foraging

The fish from the LFS tanks ingested twice as many and significantly (P = 0.032) more chironomid and nonsignificantly (P = 0.3%) more mayfly larvae as fish from the PO tanks, whereas fish from both treatment groups ate similar numbers of mosquito larvae (P = 0.796) (Fig. 4-l). In general, all other major classes of foraging behavior (approach, attack, and capture) on chironomids and mayfly larvae were higher for LPS-treatment fish than PO-treatment fish (Pig. 4-2). However, the differences were only statistically significant ($P \leq 0.05$) in number of prey attacked, captured, and ingested for chironomid larvae. Since LFS fish were noticeably more bottom oriented than PO fish, it is not surprising that they attacked and ingested more chironomids. This orientation may have been conditioned by their foraging on the bottom for chironomids during the live-food supplementation phase of the experiment.

Twenty-five percent of the LFS-treatment fish and 40% of the PO-treatment fish failed to attack prey. This is similar to Paszkowski and Olla's (1985) findings that many hatchery coho salmon (0. *kisutch*) would not feed in test arenas. They attributed this to handling stress, rather than a rejection of live prey. However, the difference observed between treatments in the present study suggests fish reared on pellets may not have developed the ability to recognize live prey as food. Bryan and Larkin (1972), Ringler (1985), and Merna (1986) reported that juvenile salmonids can develop initial food preferences that are maintained throughout life. Therefore, to be fully effective, live-food supplementation training may need to be initiated at the swimup stage.

More effective foraging on both familiar and unfamiliar prey by experienced fish suggests that fish can generalize their experience with live food, however novel the prey. This is crucial if live-food supplementation is to enhance the postrelease foraging ability of migratory species, which will encounter a wide variety of prey species in nature. Furthermore, it suggests that even if individual fish develop early and narrow preferences, they can switch to other forms of live prey once they are weaned off pellets.

Prior exposure to live food appeared not to enhance foraging efficiency (Fig. 4-3). To increase the foraging efficiency of cultured fish, we may need to train them to forage on more complex prey and in more structurally complex environments.

Morphology

Although fish in both treatments were fed to satiation, fish in the LFS tanks were significantly ($P \leq 0.05$) longer and heavier than those in the PO group (Table 1). This may have resulted from their having more opportunities to feed during the day, more total nourishment available, or live food containing essential trace elements or vitamins not present in sufficient quantity in the pellet diets. Withii the confines of this study there is no conclusive way to isolate these factors.

There were no obvious differences in coloration or fin condition between fall chinook salmon in either treatment. In contrast, in a previous study cutthroat trout (0. *clarki*) reared exclusively on live food had noticeably better coloration and fin condition than those reared on pellet-only diets (personal observations). While preliminary, this suggests that live-food supplementation does not provide the enhanced coloration and better fin condition associated with

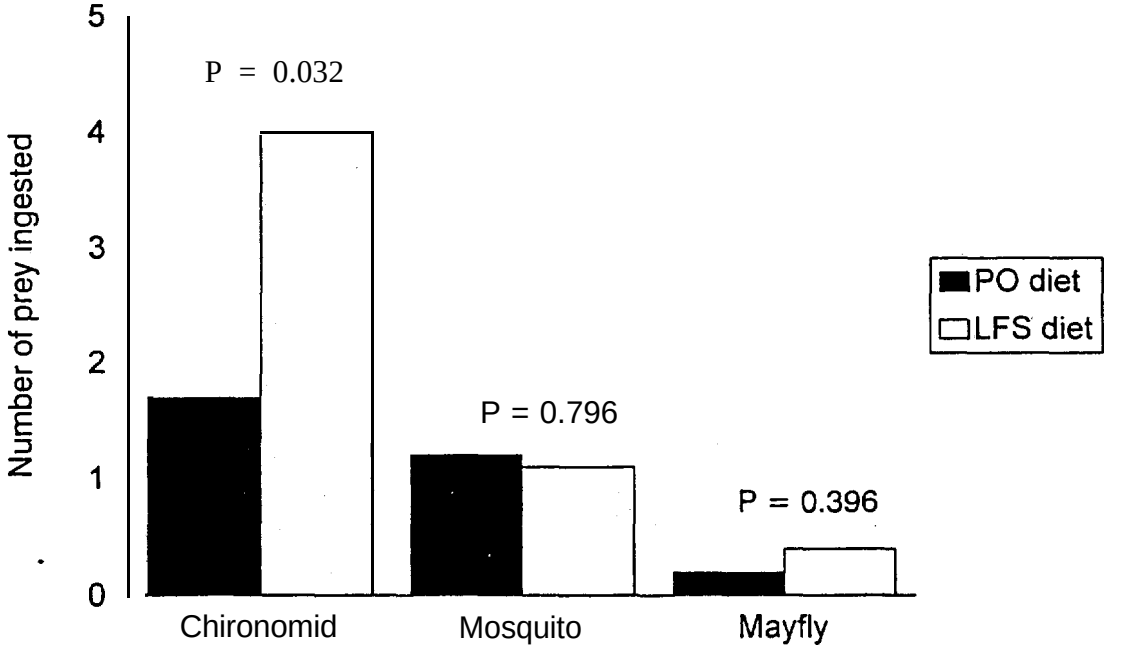

Figure 4-l. Average number of test prey ingested by fall chinook salmon reared on pellet-only (PO; n = 20) or live-food-supplemented (LFS; n = 20) diets. Probability values based on Mann-Whitney U tests.

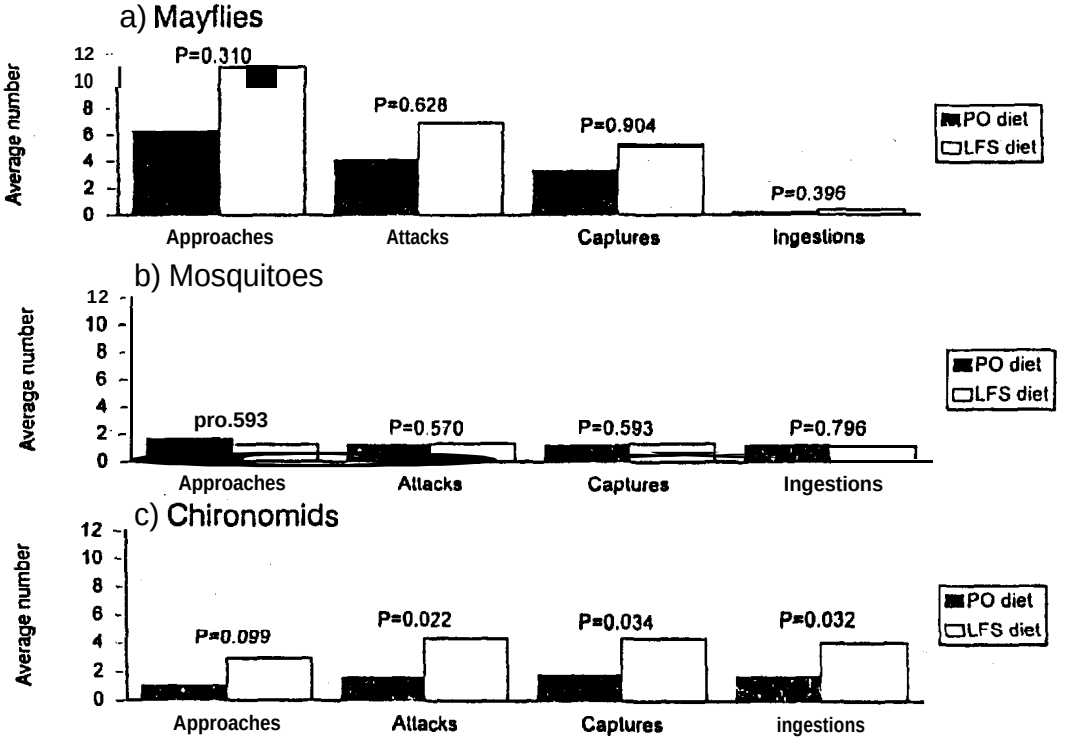

Figure 4-2. Foraging behavior on a) mayflies, b) mosquitoes, c) chironomids by fall chinook salmon reared on pellet-only (PO; n = 20) or live-food-supplemented (LFS; n = 20) diets. Probability values based on Mann-Whitney U tests.

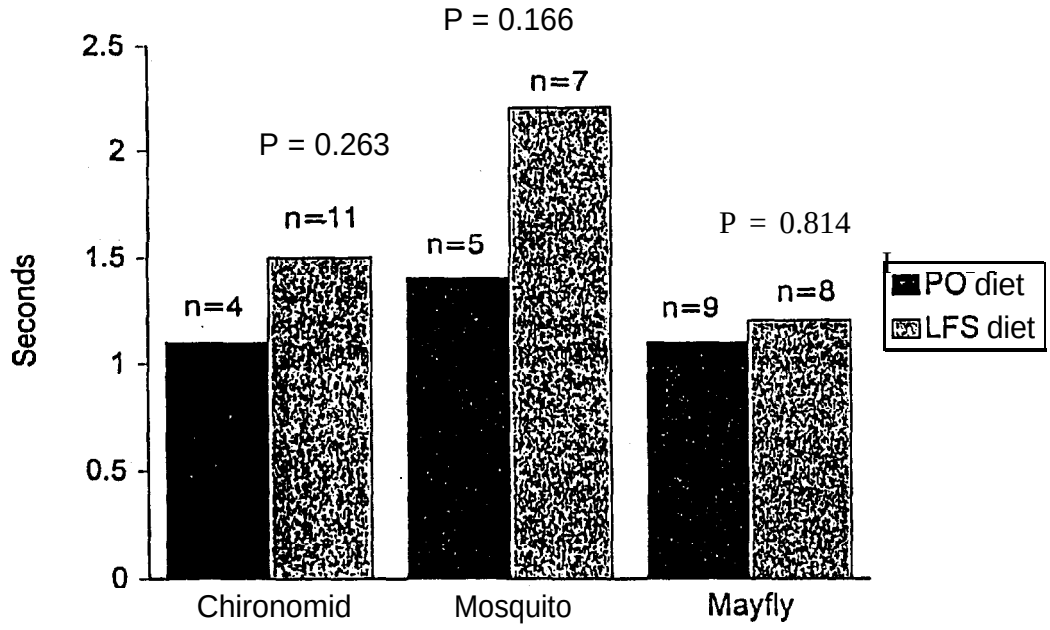

Figure 4-3. Foraging efficiency (average handling time) of fall chinook salmon reared on pellet -only (PO) or live-food-supplemented (LFS) diets. Probability values based on t-tests with n being determined by the number of fish that ate at least one of the prey.

Table 4-l. Comparison of length and weight of fall chinook salmon reared on commercially pelletized diets with and without live food supplements.

Variable	Treatment diet	
	Pelletized ration	Pelletized ration plus live-food supplement
Number	446	449
Length (mm)		
mean	109.5*	111.2*
SD	6.9	7.1
Weight (g)		
mean	16.4*	17.4*
SD	3.4	3.6

* Significantly different at $P \leq 0.05$.

total live food diets, or that them are species-specific differences in how diet interacts with coloration and fin condition.

Disease Analysis

There was no significant difference in the incidence of BKD in fish from either treatment. At subsampling, no evidence of BKD was found in either treatment group.

Conclusions

The findings of this and other studies (Johnson 1978, Hesthagen and Johnsen 1989) suggest diets supplemented with live food may enhance the postrelease foraging ability and survival of cultured fish used in enhancement and supplementation. Future work should concentrate on exposing fish to difficult to handle prey in semi-natural structured habitats. Implementation of this technique, along with other life-skill training approaches (Suboski and Templeton 1989), such as antipredator training (Thompson 1966, Olla and Davis 1989), offers the possibility for dramatically improved postrelease survival of cultured fish.

References

Bryan, J. E., and P. A. Larkin. 1972. Food specialization by individual trout. J. Fish. Res. Board Can. 29:1615-1624.

Bullock, G. L., and H. M. Stockey. 1975. Fluorescent antibody identification and detection of the *Corynebacterium* causing kidney disease of salmonids. J. Fish. Res. Board Can. 32:2229-2227.

Hesthagen, T., and B. 0. Johnsen. 1989. Lake survival of hatchery and pre-stocked pond brown trout, *Salmo trutta* L. Aquacult. Fish. Manage. 20:91-95.

Hochachka, P. W. 1961. Liver glycogen reserves of interacting resident and introduced trout populations. J. Fish. Res. Board Can. 18:125-135.

Johnsen, B. O., and 0. Ugedal. 1986. Feeding by hatchery-reared and wild brown trout, *Salmo* tmtta L., in a Norwegian steam. Aquacult. Fisher. Manage. 17:28 l-287.

Johnson, L. D. 1978. Evaluation of esocid stocking program in Wisconsin. Am. Fish. Soc. Spec. Publ. 11:298-301.

Leitritz, E., and R. C. Lewis. 1980. Trout and salmon culture (hatchery methods). Calif. Dep. Fish Game Bull: 164, 197 p.

Masters, C. 0. 1975. Encyclopedia of live foods. T. F. H. Publications, Neptune City, New York.

Merna, J. W. 1986. Contamination of stream fishes with chlorinated hydrocarbons from eggs of Great Lake salmon. Trans. Am. Fish. Soc. 115:69-74.

Miller, R. B. 1952. Survival of hatchery-reared cutthroat trout in an Alberta stream. Trans. Am. Fish. Soc. 81:35-42.

Myers, K. 1980. An investigation of the utilization of four study areas in Yaquina Bay, Oregon, by hatchery and wild juvenile salmonids. Master's Thesis, Oregon State Univ., Corvallis, 233 p.

O'Grady, M. F. 1983. Observations on the dietary habits of wild and stocked brown trout, *Salmo* trutta L., in Irish lakes. J. Fish Biol. 22:593-601.

Olla, B. L., and M. W. Davis. 1989. The role of learning and stress in predator avoidance of hatchery-reared coho salmon (*Oncorhynchus* kisutch) juveniles. Aquaculture 76:209-214.

Paszkowski, C. A., and B. L. Olla. 1985. Social interactions of coho salmon (*Oncorhynchus kisutch*) smolts in seawater. Can. J. Zool. 63:2401-2407.

Reimers, N. 1963. Body condition, water temperature, and over-winter survival of hatchery reared trout in Convict Creek, California. Trans. Am. Fish. Soc. 92:39-46.

Ringler, N. H. 1985. Individual and temporal variation in prey switching by brown trout, *Salmo trutta*. Copeia 1985:918-926.

Sosiak, A. J., R. G. Randall, and J. A. McKenzie. 1979. Feeding by hatchery-reared and wild Atlantic,salmon (*Salmo salar*) parr in streams. J. Fish. Res. Board Can. 36:1408-1412.

Suboski, M. D., and J. J. Templeton. 1989. Life shills training for hatchery fish: social learning and survival. Fish. Res. 7:343-352.

Thompson, R. 1966. Effects of predator avoidance conditioning on the post-release survival rate of artificially propagated salmon. Ph.D. Thesis, Univ. Washington, Seattle, 155 p.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey.