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ABSTRACT

Two feeds, Alaska Dry Pellet (ADP-2) and Oregon Moist Pellet (OMP), were fed to pink salmon, *Oncorhynchus gorbuscha*, for 2 to 4 weeks in 1982 and 1983 in marine net pens adjacent to the Tutka Hatchery. We found no significant growth differences between the diet groups in 1982. In 1983 fish fed ADP grew significantly faster than those fed OMP. We attribute some of the effects on growth to quality control problems in each of the feeds. Although recoveries of adult marked fish, resulting from releases of pink salmon fingerlings in both 1982 and 1983, showed that ADP-fed fish returned at a slightly higher rate, the experimental design was not sensitive enough to show significance of such subtle differences.

KEY WORDS: salmonid hatchery diets, ADP, *Oncorhynchus gorbuscha*, pink salmon, net pens.

INTRODUCTION

For more than two decades, Oregon Moist Pellet (OMP) diet has been the standard food fed to salmon in most Pacific coast hatcheries. The Alaska Department of Fish and Game also adopted this food for its salmonid hatcheries and used it almost exclusively until 1981. During the years of 1975-1981, one of the authors, Dr. Ken Leon, examined the rationale for feeding OMP to salmonids in Alaska. Yes, OMP had been used successfully in the propagation of salmonids to the stage of release from hatcheries, and, yes, adult fish had returned from these releases; but little or no data were available that compared both in-hatchery and marine survival of fish fed OMP to those fed other balanced, pelleted diets.

There were several points that argued against the feeding of OMP in Alaska. First, it was manufactured outside of Alaska and had to be shipped frozen via expensive commercial transport. If temperatures were not maintained sufficiently low, the nutritional quality of the food declined. Second, once at Alaskan hatcheries, OMP had to be kept in freezers that are costly to buy and maintain. Third, because of its high moisture content, OMP required about 1.3 times greater volume in transport and storage room than a dry pellet. Fourth, why should Alaska, which has more than enough of its own fishery byproducts that are suitable for a good commercial fish food, import fish food from Oregon or Washington? Last, OMP, as traditionally formulated, did not provide the general mix of ingredients that are natural in the diet of salmonids. In respect to this last point, one would expect salmonids to grow better and healthier on a food that simulates the nutrient profile contained in food naturally ingested by them in their wild state. Using such a diet formulation from research done in 1974 and described by Leon (1984), Kron (1985) obtained excellent results with ADP when it was compared to OMP, Biodiet, and an Abernathy dry diet in a laboratory study using chum salmon *Oncorhynchus keta*. The next step was to field test ADP in a production-sized comparison with OMP.

MATERIALS AND METHODS

1982 Study

ADP-2 (Table 1) was compared to OMP when fed to pink salmon *O. gorbuscha* fry in net pens moored in a saltwater lagoon at the Tutka Hatchery (across Kachemak Bay from Homer, Alaska).

Table 1. Ingredients and proximate analysis of Alaska Dry Pellet Number Two (ADP-2) in 1982 and 1983.

Ingredients	% in mix
	1982 and 1983
Herring Meal[a]	65.2
Salmon Meal[b]	16.3
Marine Oil[c]	8.2
Blood Flour	5
Added Water	4-5
Vitamins	0.12
Minerals	0.04
Ascorbic Acid[d]	0.2

	% (dry basis)	
	1982	1983
Protein	66.3	66.1
Fat	19.1	19.3
Carbohydrate	<1	<1
Ash	13.0	12.5
Salt	1.6	1.1

[a]Salt content low enough so that finished feed has less than 1.5%.

[b]Fish solubles are replaced in the fish meal before pelleting ADP-2.

[c]Extracted during manufacture of herring and salmon meals.

[d]Ascorbic acid is kept separate from vitamin pack until time of feed pelleting.

Pen Loading:

The production-sized pens, 3.6 X 3.6 X 1.8 m, were loaded with approximately 250,000 fry each. Eight pens, from the array of 38, were randomly selected to receive one or the other of the two diets; i.e., four replicates per diet. This part of the study was for comparison of growth and survival of the two diet groups while in captivity. In addition, each of two smaller pens was used to rear marked fish on ADP or OMP for eventual comparison of post-release survival to adult in the ocean.

Feeding:

The OMP groups were fed to satiation, whereas the ADP groups were fed what we assumed was isocalorically to the fish on OMP. Proximate analyses performed on the two foods during the previous year were used to calculate the amount of ADP that should have been calorically equivalent to the amount of OMP fed. That amount was approximately 80% (by weight) of the OMP ration; however, as discussed later in this report, our assumption for the caloric value of OMP was incorrect.

Growth:

Initial weights of the emergent fry were measured from samples taken in the hatchery. We assumed no difference in mean weight among fish put into experimental pens on any particular day. Three weight samples of fry from each of the eight experimental pens were taken every 2 weeks. Each sample contained at least 75g of fish and was taken after first crowding the fish. Lengths were measured using 50 fish from each pen.

Marking Fingerlings and Recovery of Adults:

Under the experimental design, a minimum of 45,000 of each diet group were to be marked by excising either the right or left

pelvic fins. Assuming a 4% survival rate for the OMP control group, the design would permit the detection of a 25%-30% difference in survival between the two diet groups at an alpha level of .05 with a power of 0.95 (based on Fleiss 1981). We expected to sample about 200,000 adult pink salmon out of a return of 1 million fish.

Sampling was stratified throughout the run to detect any temporal differences in the recovery rate of each mark. Only fish from the seine fishery and those returning to the hatchery were sampled.

1983 Study

Methods in 1983 were essentially the same as in 1982. Each diet group was again replicated four times. Thus, ADP and OMP were each fed to about 1 million fish for comparison. However, this time, ADP mash and 1/32 crumbles were fed at 92% and 83%, respectively, of the OMP rate so that, theoretically, all fish received the same number of calories in relation to their mean weight.

RESULTS

1982 Study

Within Hatchery Performance:

Because of variations in fry emergence time, the experimental pens were loaded serially. However, for each day of pen loading, equal numbers of fish for each diet group were loaded on the same day to remove a variable of different lengths of rearing time between treatments. The experimental fish were fed for 22-27 days. Initial and final mean weights are shown in

Table 2. Unfortunately, the attempt to feed each group isocalorically was nullified by an unexpected change in the OMP formula, which we discovered after the feeding period ended. A substantially lower moisture content and changes in total lipid combined to raise the caloric density of OMP above that of previous specifications. Instead of feeding ADP at 80% of the OMP rate, we should have fed at 92% when using mash, and at 83% of the OMP rate when using 1/32-size. Consequently, the fish that were fed ADP were given only 87-96% of the calories given to fish fed OMP, according to the amount of mash or 1/32-sized feed eaten. To test for differences in growth between the two diet groups, two-way Analysis of Variance was used. The test showed that initial weights were not significantly different among all pens ($P>0.5$). Then we compared final weights to see if the diets caused a difference. Because of significant interaction ($P<.01$) between diet and pen location, we could not demonstrate a difference in final mean weights between the two diet groups. This was so even though the ADP groups were fed much fewer calories than OMP groups.

In respect to the physical appearance of the food used in this study, the ADP mash was much coarser than the OMP mash, but ADP in the 1/32 size was much finer than specifications called for. Possible consequences are discussed later in the paper.

The mean weights of the fish in the two smaller pens were initially 242mg and 241mg, and finally 447mg and 456mg for the ADP and OMP groups, respectively. From these two pens, 43,767 ADP-fed fish were released with a LV clip and 46,058 OMP-fed fish were released bearing a RV clip.

Marine Survival:

Table 3 shows harvest, number sampled, and the recoveries by week and by mark in 1983. No difference could be found in the relative rates of return in the two diet groups in 7 categories;

Table 2. Initial and final mean weights of pink salmon reared in Tutka Lagoon net pens in 1982.

Diet	Initial weight (mg)	Final[a] weight (mg)	Final[b] weight (mg)
ADP	236	375	447
OMP	236	382	456

[a]Mean weight of fish in four pens for each diet to compare growth in pens.

[b]Mean weight of fish in one pen for each diet from which fish were marked to compare survival to adult after release. These fish were heavier because of 1-2 weeks longer rearing period in the pens.

Table 3. 1983 recoveries of ADP-fed and OMP-fed pink salmon including estimates of all pink salmon harvested by the seine fishery in Tutka Bay with the numbers sampled for mark recovery by statistical week in the fishery and at the hatchery.

Week	ADP-fed	OMP-fed	Estimated harvest	Sampled
27	7	4	19,700	2,294
28	58	55	102,800	17,258
29	132	132	236,600	59,335
30	75	64	157,300	38,645
31	19	25	61,400	25,611
32	13	12	26,000	12,446
hatchery	64	77	51,500	38,000
Total	368	369	655,300	193,609

i.e., 6 weeks in the fishery and samples taken at the hatchery (chi-square = 3.8, d.f.= 6, P>0.5). Therefore, all mark recoveries were combined into a single analysis (Table 4). Given the observed recovery rates and the marks originally applied, there is a 95% probability that a 15% difference in survival rates between the two diet groups would have been detected at P<.05 (based on Fleiss 1981). Our analysis showing no difference (P>0.5) in recovery rates supports a conclusion that the survival rates of ADP and OMP-fed fish are within 15% of each other.

Another way to compare survival rates is to determine the confidence intervals for these estimates. These are computed from a simple expansion of the mark recovery by statistical week assuming that the mark recoveries follow a Poisson distribution. Since the marked fish did not represent unmarked fish released (they were released at different sizes), the confidence intervals are for the survival of marked fish only. The 95% confidence interval for ADP-fed fish is [2.84, 3.54%], and for OMP-fed fish it is [2.58, 3.23%].

1983 Study

Within Hatchery Performance:

In 1983 more up-to-date information allowed us to feed the two groups on an isocaloric basis. We also found that better quality control in ADP manufacture had produced a more uniform particle size that complied with specifications. As in 1982, the pens were loaded serially, and equal numbers of each diet group were loaded on the same day. Table 5 shows the initial and final weight in addition to survival in the pens. The final mean weight of the fish in four pens receiving ADP was 13% greater than that of the fish in the corresponding four pens receiving OMP. This difference was statistically significant (P<.01).

Table 4. Chi-square analysis of pooled 1983 recovery data of ADP-fed and OMP-fed pink salmon.

Treatment	No. released	No. recovered	X^2	d.f.	% survival 95% confidence interval
ADP	43,767	368	0.26[a]	1	2.84, 3.54
OMP	45,689	369			2.58, 3.23

[a]corrected for continuity

Table 5. Initial and final mean weights of pink salmon reared in Tutka Lagoon net pens in 1983.

Diet	Initial weight (mg)	Final[a] weight (mg)	Final[b] weight (mg)
ADP	229.7	398.6	350
OMP	229.0	349.7	291

[a]Mean weight of fish in four pens for each diet to compare growth in pens.

[b]Mean weight of fish that were marked for subsequent comparison of survival from release to adult. Values given are the mean weights calculated from weights on two release dates one week apart.

The final mean weight of the marked fish released to compare marine survival was 7% greater for those fed ADP than for those fed OMP.

Marine Survival:

Table 6 shows harvest, number sampled, and the recoveries by week and by mark in 1984. No difference was found in the relative rates of return of the two diet groups in five categories -- 4 weeks in the fishery and samples taken at the hatchery (chi-square = 4.4, d.f. = 4, $P>0.25$). Therefore, all mark recoveries were combined into a single analysis (Table 7). Given the observed recovery rates and the marks originally applied, there is a 95% probability that a 40% difference in the survival rates between the two diet groups would have been detected at $P<.05$ (based on Fleiss 1981). Our analysis, showing no difference ($P>0.5$) in recovery rates, supports a conclusion that the survival rates of ADP- and OMP-fed fish are within 40% of each other. As we did with the 1983 data, we estimated 95% confidence intervals for the survival rates of the marked ADP- and OMP-fed fish. They are [0.84, 1.60%] and [0.70, 1.01%], respectively.

DISCUSSION

Because of previous diet tests, we expected the ADP-fed fish in 1982 to grow faster than those fed OMP. That this did not happen might be explained by the following:

1. We fed fewer calories of ADP as compared to OMP.
2. ADP starter mash was much coarser than OMP starter.
3. ADP in 1/32 size had broken down into particles smaller than called for in the specifications and certainly smaller than OMP 1/32 size.

Table 6. 1984 recoveries of ADP-fed and OMP-fed pink salmon including estimates of all pink salmon harvested by the seine fishery in Tutka Bay with the numbers sampled for mark recovery by statistical week in the fishery and at the hatchery.

Week	ADP-fed	OMP-fed	Estimated[a] harvest	Sampled
27	7	5	40,700	6,528
28	59	51	91,800	35,175
29	51	41	76,600	19,541
30	2	0	14,600	270
hatchery	37	46	41,000	41,000
Total	156	143	264,700	102,514

[a]Final estimates were not available when preparing this report, but any changes are expected to be slight.

Table 7. Chi-square analysis of pooled 1984 recovery data of ADP-fed and OMP-fed pink salmon.

Treatment	No. released	No. recovered	X^2	d.f.	% survival 95% confidence interval
ADP	44,515	156			0.84, 1.60
			0.25[a]	1	
OMP	43,534	143			0.70, 1.01

[a]corrected for continuity

It is impossible to definitively say which of these factors or what combination might have caused the less than expected growth. If we knew that we had fed fewer metabolizable calories, rather than only being able to document fewer total calories fed to the ADP group, we would have a probable cause and effect. Unfortunately, it is impossible to accurately measure the metabolizable calories without conducting rigorous laboratory tests on individual fish fed from the same batches of feed used in this study. Furthermore, we do not know how much of the food was wasted in each pen. Therefore, we only know that, because of the lower than expected water content in the OMP, we gave the ADP fish an opportunity to eat only 87-96% of the calories fed to the OMP group. On the other hand, hatchery personnel did observe that the finer OMP starter mash was more readily consumed during the initial feeding of fish in each pen. Apparently, the coarser ADP starter was rejected more often so that more drifted out of the pens and was wasted. When this happened, the OMP-fed fish initially grew faster. As the mean size of the fish increased, at least a substantial portion of the fish on ADP were able to consume the 1/32-size feed. This was apparent because many of these fish caught up to or surpassed the size of OMP-fed fish. However, because of the initial problem in the ADP-fed fish, there was more variation in size such that the "pin heads" kept the mean weight below the OMP-fed fish.

In 1983 with most of the experimental problems eliminated, we observed a much different result. ADP-fed fish clearly grew at a faster rate. We attribute this to better quality control in the manufacture of ADP, feeding groups isocalorically, and to the possible poor quality control in the OMP manufacture as evidenced by the overly fine particle size received in 1983.

Although the estimated survival of marked ADP-fed fish was greater than that of OMP-fed fish in both 1983 and 1984, the differences were not enough to demonstrate an effect of the

diets. This differs from preliminary data from a previous study (Kron and Geiger, unpublished data) in which chum salmon, *O. keta*, that were fed either ADP or AMP (Alaska Moist Pellet) were recovered as adults at a significantly greater rate than fish fed other commercial diets including OMP. However, one should realize that the chum salmon were fed the various diets for 12 weeks before release as compared to the 2 to 4 weeks in these pink salmon studies. Consequently there was much less time for the diets to affect the health of the pink salmon as compared to the chum salmon.

Nevertheless, we started out with the goal of developing a dry fish feed, made in Alaska, that would perform at least as well as the traditional moist diet. The results from these two studies certainly indicate the attainment of our goals (assuming at least equal feed quality is obtained from the manufacturer in the future). With fish fed for a longer duration before release, such as chum salmon or chinook salmon, *O. tshawytscha*, we expect to exceed this goal in respect to fish growth in the hatchery and survival to adult after release.

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