The Ichthyogram

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Evaluation of Low Phosphorus Feeds

Public and private aquaculture facilities can be a high profile point source of pollutants, in particular phosphorus (P). Phosphorus is typically a limiting nutrient for algal growth. When supplemental P is introduced, it may result in algal blooms, reduction of oxygen levels due to a breakdown of detrital material, and ultimately to the eutrophication of a given body of water.

Because of this potential for eutrophication, hatcheries must reduce pollutant levels in effluents by either reducing production, managing feeding practices more efficiently, or adopting new technologies to reduce discharge of pollutants. Much current research is aimed at the possibility of manipulating the formulations of diets as a method of controlling phosphorus. Phosphorus in fish diets is derived from the bones present in fish meal, vegetable ingredients, and is also added as a supplement in mineral form. Total P content of a salmonid diet may range from 0.9-2.2%, but typically the whole body content of trout and salmon only averages 0.4%. This means that theoretically salmonids are only able to use from 18% to 44% of the P offered to them in the feeds, and in fact P retention for rainbow trout generally ranges from 13-27%. This means that a substantial amount of phosphorus is lost from fish hatcheries and degrades water quality in lakes and streams below.

Several state hatcheries in Utah are facing restrictions on how much P they can discharge. They are faced with either reducing fish production or reducing phosphorus discharge. The purpose of this study was to compare the concentration of phosphorus in raceway effluents, cost of production, and performance of fish fed either a standard grower diet or low phosphorus diet in three of Utah's state hatcheries.

At the Mantua, Loa, and Midway State Hatcheries rainbow trout of two different strains were fed either a Silver Cup grower diet (the control group) or a Silver Cup low phosphorus diet. Feed samples were regularly taken during the study and analyzed for total P content and proximate analysis.

Water samples were collected on a regular basis from a common source above the raceways and from the tails of each raceway. These were assayed for total P according to the persulfate digestion and ascorbic acid colorimetric methods. Because of concerns about daily fluctuations in the flow of phosphorus through the raceways, an assay was conducted for the final sample at Midway during which water was collected and analyzed every two hours during a 24 h period. Fish were inventoried monthly and necropsies were done at the beginning and end of the study according to the Health Condition Profile (HCP) system.

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At Mantua the low P diet reduced growth, but growth for the low P fish was better than the control fish at both Loa and Midway. Total weight gain, specific growth rate, and feed conversions were also relatively better for the low P group at both Loa and Midway, while weight gain and feed conversions were better for the control group at Mantua. At all three hatcheries there was some variability in the HCP indices, but nothing that would suggest feeding low P feeds had in some way compromised the health of the fish.

At Mantua total P discharge was significantly lower ($p = 0.03$) for the low P group, 40.5 mg P/day/kg fish, compared with 65.7 mg P/day/kg fish for the control group. At Loa there were no significant differences in P discharged from the treatment raceways for the first three sampling dates, but differences were evident for the final two. Total P (mg/L), daily P discharge on a g P/day basis and on a mg/day/kg fish basis were significantly lower for the low P group compared with the control group on the fourth sampling date. Daily P discharge on a mg/day/kg fish basis was also significantly lower for the low P group on the fifth sampling date. Comparisons of total P discharge within a given treatment between sampling dates revealed no significant differences over time, although as the study progressed there was a general increase in P discharge from the control group, 33.9 mg P/day/kg fish for the first sample to 47.0 mg P/day/kg fish for the final sample. Daily P discharge (mg P/day/kg fish) for the low group averaged 27.4 ± 3.5 over the study.

At Midway phosphorus concentrations were consistently lower throughout the study for fish fed the low P diet except for the initial sample. Analysis of data from the 24 h P assay at Midway revealed an interesting trend. Total P concentrations over the 24 h period were at their lowest points approximately 30 min after the twice daily feedings (9:30 and 15:30).

Results from the proximate analysis of the regular feed (control group) were (on dry weight basis): protein, 40%; fat, 20%; moisture, 7%; ash, 8%. Proximate analysis of the low P feed was: protein, 44%; fat, 11%; moisture, 7%; ash, 9%. Total P of the regular feed averaged 17.1 mg P/g feed with a low value of 13.9 mg and a high of 21.4 mg. The low P feed averaged 17.0 mg P/g feed (range, 16.1 - 17.7 mg P/g feed). A two-sample *t*-test revealed no significant differences in the total P content of either diet type.

Although there were some conflicting results, it appears that low P feeds may be a good choice for reducing phosphorus discharges from Utah state hatcheries while maintaining production. In this study growth was 19% and 16% better for fish fed low P diets at Loa and Midway respectively, while at Mantua growth of fish fed the low P diet was only 88% that of the control group. Phosphorus output (mg P/day/kg fish) was reduced by 38% at Mantua, 27% at Loa, and by 25% at Midway.

Analysis of both test diets revealed no differences in total phosphorus content, however because of proprietary reasons exact formulations are unknown. It is possible that the low P diet used for this study simply manipulated the protein to fat ratio as a method of increasing P retention or digestibility and thereby lowered P discharges. In a study conducted by Heinen et al. (Applied Aquaculture 5:78-83), rainbow trout fed diets with a higher fat content (13% vs. 17%) and lower P content (1.0% vs. 1.6%) experienced better P retention and less phosphorus loss per unit wt. gain (g P/kg fish/gain). Analysis of our test diets showed the regular diet was 40% protein and 20% fat and the low P feed was 44% protein and 11% fat. This may in fact be the case because the assay of total P conducted by an independent laboratory revealed the low phosphorus feed had an average content of 17.0 mg P/g feed and the regular feed had an average content of 17.1 mg P/g feed.

The protein to fat ratio may also have influenced the growth results from Mantua. Fish at Mantua were in much colder water, 9° C, compared with those at Loa and Midway, 16° C and 15° C respectively. The

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thermal optimum for rainbow trout is generally considered from 10-16° C. It is possible at the lower temperatures the metabolism of the fish was such that they were not able to utilize the protein fraction of the low P diet as efficiently and therefore had to rely on the lipid fraction for energy requirements as well as growth. It is also possible that the positioning of test fish below the control group within a single raceway contributed to the differences in fish growth compared with Loa and Midway.

Low P diet formulations in past studies have contained ingredients whose cost may make their use prohibitive on a production scale. In this study commercially available diets were contrasted and the cost of feed per pound of fish produced compared favorably. The average pounds of fish produced from the three hatcheries that participated in this study is 113,000 lbs./year. At a feed cost of $ 0.35/ lb. fish produced (Table 1 average of Loa and Midway figures) for the low P feed, the annual feed bill would be $ 39,550, and the bill for the regular feed, at $ 0.34/lb fish produced, would be $ 38,420. This would be a 3% increase in feed expenses, but with the potential for decreasing phosphorus discharges and possibly increasing production through better growth, the added expense of low P diets may be advantageous.

With the exception of the poorer growth of low P fed fish at Mantua, the low P diet performed equally well if not better than the regular grower diet. For the low P fish growth was superior at Loa and Midway, feed conversions were better at Loa, and phosphorus discharges were reduced. Indices of fish health recorded from the HCP's revealed no clear trend of dietary effects on fish health. In general fish from both groups were very healthy and no difficulties resulted in the hatcheries' ability to meet their production needs as a result of feeding low phosphorus feeds.

A special thanks goes to the hatchery staffs at Mantua, Loa, and Midway. I was especially thankful for the practical jokes at Midway. Also, thanks to Bob Koby at the Bozeman Fish Technology Center for doing proximate analysis on the feed samples.
Ronney Arndt

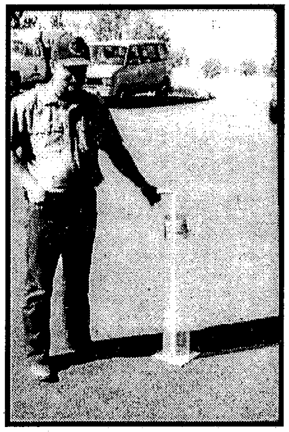
Table 1. Comparison of hatchery performance and phosphorus output of rainbow trout fed either a low phosphorus diet or regular trout diet at Mantua, Loa, and Midway state hatcheries. An asterisk indicates a significant difference from the control within a hatchery.

	Hatchery					
	Mantua		Loa		Midway	
	low P	control	low P	control	low P	control
Final fish weight (g/fish)	191.4	219.1	300.4*	242.6	170.5*	158.6
Total weight gain (g/fish)	183.4	210.2	264.7	206.9	153.9	142.5
Specific growth rate (%/day)	1.34	1.25	1.15	1.04	0.97	0.95
Total amount fed (g/day)	188.0	207.9	280.0	265.6	225.0	214
Feed conversion ratio	1.03	0.99	1.06*	1.28	1.49	1.57
Daily total P output (mg P/day/kg fish)	40.5	65.7	27.4*	37.7	17.7	23.7
Feed cost per pound of fish produced			$ 0.31	$ 0.30	$ 0.38	$ 0.37

The Morrill Egg Jar

Ron Morrill, Hatchery Superintendent of the Whiterocks State Fish Hatchery in Whiterocks, Utah, has recently developed a simple but innovative hatching jar. The jar has been used instead of hatching trays successfully to hatch brook, brown, cutthroat, and rainbow trout eggs **after eye-up**. Impetus for the jar arose from problems with fungus in standard tray stacks. The jar has proven better for dealing with the fungus. The fungus floats just above the eggs in the jar when flows are adjusted just enough to get the eyed eggs rolling (about 3 gal/min or 11.35 L/min). The rolling action may help keep the fungus from attaching to the eggs. Fungus clumps are easier to pick out this way also. At Whiterocks, green eggs are keep in egg jars and treated with formalin daily to prevent fungal growth. After "bumping" the eggs at eye-up, the eggs are transferred to the Morrill jars to hatch without any further chemical treatments.

The jar design is relatively simple. A section of PVC pipe about 2 ½ ft long is glued to a plexiglass plate that serves as the base for the jar. Ron uses 6" diameter clear PVC, but standard opaque PVC of other dimensions should also work. A section of 3/4" PVC, taller than the jar, is suspended in the center of the jar about 3/4" above the plexiglass bottom. Water is delivered to the jar through this pipe and up wells through the eggs. No screen or other parts are used to keep eggs off the bottom. Screening material is used to keep hatched fry from escaping the overflow which just flows over the top of the jar and onto the floor. Stiff window screen is cut about 3 - 4" wide, wrapped around the top of the jar, and held in place with a hose clamp. That is it!



The jar costs about $25 - $30 to make and requires about 15 - 20 minutes to build. Kamas and Springville state hatcheries have starting using them. Perhaps you may be interested in building one yourself. If you have any questions about the jar, call Ron Morrill at 801-353-4855.

Eric Wagner

Kamloops Rainbow Trout Destroyed at Jones Hole NFH

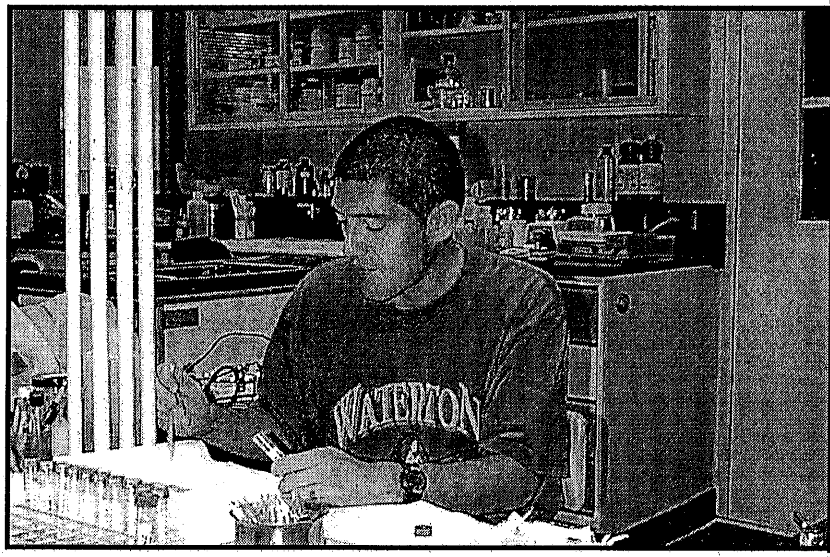
Earlier this year, a lot of large Kamloops rainbow trout at the Jones Hole National Fish Hatchery near Vernal were destroyed after testing positive for *Renibacterium salmoninarum*, the bacteria which causes bacterial kidney disease. These fish were tested as part of the annual fish health inspection by the U.S. Fish & Wildlife Service. Laboratory testing was done at the regional fish health center at Ft. Morgan, Colorado, using the fluorescent antibody method. Although the fish showed no symptoms of the disease, the bacteria is a prohibited pathogen in Utah and many other states.

In response, the Utah Division of Wildlife Resources (UDWR) presented a variance proposal to the Fish Health Board to allow remaining fish at the hatchery to be stocked out in certain waters in Utah (where no significant populations of reproducing wild fish were found) only after another testing for *R. salmoninarum* confirmed their negative status. The Fish Health Board unanimously approved the variance. Since then, UDWR has decided not to accept any further shipments of eggs from the federal hatchery in Montana where the Kamloops originated until the issue is resolved.

Chris Wilson

Utah Whirling Disease Survey Enters New Segment, New Biologist Hired

The statewide survey to determine the extent of the whirling disease parasite, *Myxobolus cerebralis*, has entered a new phase. Although several hundred sites have already been tested since the parasite was first discovered in Utah in 1991, fish pathologists want to obtain samples from fish from every U.S. Geologic Survey hydrologic unit throughout the state which contains salmonids. Regional aquatic biologists have already collected many samples throughout the year. Earlier in 1996, they were asked to provide a list of "priority waters" within each hydrologic unit where trout were found. These waters represent sites of valuable fisheries, often where significant natural reproduction occurs. Initial sampling will occur low in the drainage, possibly extending higher in the drainage in subsequent years.



Wildlife biologist Art Butts prepares laboratory samples as part of the statewide survey for *Myxobolus cerebralis*.

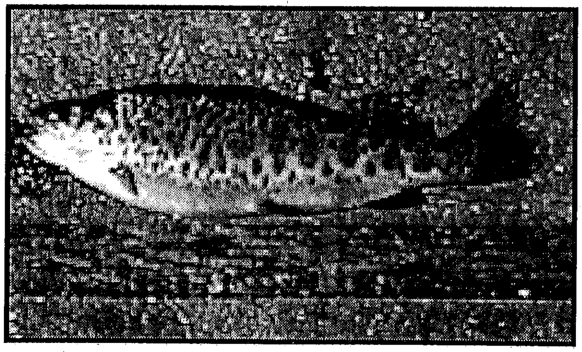
Another change in the project will include processing of the samples at the Fisheries Experiment Station. In previous years, the samples were sent to independent contracting laboratories. It is anticipated that performing the work "in house" will allow for more extensive testing and rapid processing and reporting . To assist in this effort, a recent graduate of Utah State University has been hired as a seasonal biologist to assist in the collection and processing of laboratory samples.

Other parts of the project planned for this year include continued entry of the results into an existing database and transferring that data into a mapping program (*ARCVIEW*). This will better show the extent of the parasite while allowing biologists to determine which waters may in jeopardy in the future. Other factors, such as land use and siltation, may be examined as cofactors where the parasite is found and fish are significantly impacted. In addition, surveys of oligochaete worms in the sampled waters will be performed next year prior to snowmelt runoff. For more information on the project, contact Chris Wilson or Ron Goede at the Fisheries Experiment Station.

Chris Wilson

AND YET ANOTHER HYBRID--BROWNBOWS

The brown trout is somewhat resistant to whirling disease, so the Utah Division of Wildlife Resources has been crossing browns with other species in the hopes these hybrids will also be resistant and retain some feeding behaviors of their parents. Most everyone now has heard of the brake (brown ♀ X lake trout ♂) and the tiger trout (brown ♂ X brook ♀). The newest addition is the brownbow (brown ♂ X rainbow trout ♀).



Egan SFH personnel fertilized 104,260 Ten Sleep rainbow eggs with milt from brown trout on November 27, 1995. These underwent the heatshock process shortly after fertilization to induce triploidy in the hopes this would improve eye-up. The Loa SFH received 79,398 brownbow eggs from Egan on Dec. 26, 1995, 76.15 % of total eggs taken. Notes on the record of eggs shipped however, showed a large percentage of "blanks", eggs undeveloped but not turned white by the bumping process.

During incubation the eggs had to be treated with formalin to control fungus due to the large number of dead eggs. The number of temperature units required to hatch the brownbow closely resembled those of rainbow trout. A total of 26,419 dead eggs were removed before hatch and another 15,847 dead fish removed after hatch resulting in a 66.73% hatch and a 19.96% loss from cripples. Though worse than rainbows at Loa (95% and 2% respectively), this hatch was much more successful than either the tiger or brake trout.

After cripples were taken off and these fish were up on feed there was very little unexpected mortality. Only 3% were lost after moving them outside and rearing them to 8 inches. There was a big discrepancy in inventory when we moved them outside, a result possibly of an inaccurate count of dead eggs after hatch. It is suspected the percent hatch was not as good as earlier estimated. Overall success from eggs received to stocking was 25%.

The brownbows resembled brown trout in that they were a little harder to get on feed and resulted in slow growth while in the hatchery building. These fish remained quite "skittish" even after moving outside but we were able to obtain growth similar to rainbows once moved outside. Currently their overall growth rate is 0.027 in/day, but we have had mean growth as high as 0.037 in/day. Temperatures at the hatchery are 54° F for fish up to 2" and 59° F in the outdoor raceways. On the day before stocking, their condition factor was 3.838 x 10^4 (lb./in^3), resembling the brown trout in this respect.

These fish are not quite as unique looking as the tiger or brake trout, but are distinctive just the same. They are described as rainbow-looking from lateral line to dorsal and brown from lateral line to ventral. Dorsal fin erosion appears to be more severe for some reason. Other fin erosion seem to be comparable to rainbows.

On June 13th, 4000 of these fish were stocked into Mill Meadow Reservoir and 8000 into Forsyth Res. at 4.5". About 6750 were later stocked into Panguitch Lake at 6". Five hundred of these fish were kept to check for sterility at maturity.

Resistance to *Myxobolus cerebralis*, growth, survival, etc. in comparison to others species will be evaluated when gill nets are set in Mill Meadow and Forsyth in October. Plans are underway to produce another year class of these hybrids this fall and see if results can be improved. The results may determine if this hybrid merits inclusion in the regular fisheries program in Utah.

Pat Brown, Superintendant of Loa Hatchery

HYBRIDS: HOW DO THEY STACK UP?

Table 1 summarizes the hatchery survival of hybrid trout reared in Utah state hatcheries during the last few years. See Pat Brown's article in this issue for a discussion of the brownbows. Most of the survival of these hybrids is poor, relative to survival of normal crosses of their parents. Heat shocking the eggs to induce triploidy appears to improve the survival of the hybrids too. For example, diploid brake and reciprocal brake survival was only about 0.1% to stocking, compared to 3 - 4% for heat shocked fish. Heat shocked tiger trout also had higher survival this year than in years past. These results were not replicated, but do corroborate results from published reports.

Results also support the well known axiom that the more closely related the parents (e.g., same genus), the higher the survival of the hybrid progeny. The performance of reciprocal splake in the wild is still being evaluated, but in the hatchery the reciprocals do not appear to grow as quickly and survival is lower than splake. The reciprocal splake, like many of the hybrids tested, experienced the lion's share of the mortality in the early developmental stages prior to starting on feed. Once on feed, most hybrid mortality was similar to that of pure species. Therefore, a program relying on hybrids requires large numbers of eggs, but similar rearing requirements to other trout species.

Hatchery	Hybrid[b]	Year Class	Total eyed eggs shipped	Eye -up %	Hatch %	Cripple %	Survival Eyed Egg to Stock %
MC	Splake	95	100,687	~50	59	13.2	
MC	Splake	95	158,200	~50	43	15.4	41a
MC	Splake	95	49,910	~50	70.7	13.0	
MC	Rec. Splake	95	158,388	55	20.5	8.2	18.7
Loa	Brownbow-3N	95	79,398	72.6	66.7	20.0	25
MC	Splake	94	56,114		63	13.6	
MC	Spake	94	159,636	68.2[a]	76	15.1	54.4
MC	Splake	94	75,702		57	11.8	
MC	Rec. Splake	94	369,020		32	8.8	14.6
FG	Tiger	93	120,240	76.7	53.3	41.8	6.0
FG	Tiger	94	138,408	75.2	54.5	27.3	11.2
FG	Tiger	94	115,051	75.6	53	44.5	
FG	Tiger 3N	95	146,598	56.1	58.35	41.2	13.5
FE	Brake 3N	93	56,052		30	3.19	4.3
FE	Brake2N	94	96,938	64.4	3.56	4.2	.11
FE	Brake 3N	95	233,204	51.2	27.3		3.2
FE	Rec. Brake	94	74,561	41.69	17.39		.1

[a] average of the 3 lots [b] Hybrid parents: splake = lake ♀ x brook ♂; reciprocal splake = lake ♂ x brook ♀; tiger = brown ♀ x brook ♂; brake = lake ♀ x brown ♂; reciprocal brake = lake ♂ x brown ♀; brownbow = brown ♂ x rainbow ♀. 3N = heat shocked to induce riploidy.

Effects of Rearing Density upon Cutthroat Trout Hematology, Hatchery Performance, Fin Erosion, and General Health and Condition

Cutthroat trout of the Bear Lake Bonneville strain *(Oncorhynchus clarki utah)* were compared in two separate density experiments. In the first, fish were reared for 212 d in outdoor raceways at four densities, allowing the fish to grow into their final rearing density without monthly adjustment of crowding screens and feeding seven d/ week. Final rearing densities averaged 768, 1597, 2073, and 2998 fish/m^3 (density index {DI; Piper 1972} = 0.40, 0.90, 1.10, and 1.46). In Experiment 2, crowding screens were adjusted monthly and fish were fed five d/week; final rearing densities were 338, 739, and 1,634 fish/m^3 (DI = 0.19, 0.39, 0.75). Also, aggressive behavior was compared between densities by observation of paired or five-fish groups in aquaria after four h of acclimation.

Feed conversion and mortality did not significantly differ among densities for either experiment. Final mean weight did not differ among the four densities of Experiment 1, but mean total length was significantly longer in fish at the lower densities. In Experiment 2, final mean weight was significantly reduced in the highest density and specific growth rates were lower than in Experiment 1. Frequencies of agonistic behaviors did not differ among densities in Experiment 2. Hemoglobin, total white blood cell (WBC) counts, differential WBC counts, and hepatosomatic indices did not differ among densities in either experiment. Red blood cell (RBC) counts and the splenosomatic index (SI=spleen weight/body weight x 100) did not differ among densities of Experiment 1. However, in Experiment 2 the RBC count was higher at the lowest density than at the highest and the SI was significantly higher at the highest density than the lowest. Condition factor, plasma protein, hematocrit, and relative dorsal fin length differences among densities were observed, but were inconsistent over time. Adverse effects of high density on mesenteric fat levels and pectoral fin condition were observed in Experiment 2. Saltwater challenge tests resulted in greater mortality for fish from high densities (Table 1). The data suggested that rearing cutthroat trout at DI > 0.40 (about 1000 fish/m^3) may compromise fish health when densities are adjusted monthly and fed five d/week, and even lower densities are needed for maximum growth.

Application of the results of this study depends on the objectives of the fish culturist. If maximum growth and a reduction in pectoral fin erosion are desired, the lowest densities tested are recommended since increasing density significantly reduced growth and increased pectoral fin damage. Data collected on aggressive behavior, feed conversion, most HCP variables, and hematological variables indicated that the highest densities of this study had little impact on general health and high numbers of fish were raised with little mortality. Raceway cleaning was also easier and less time consuming at the higher densities. However, the salt challenge results indicated that the higher densities can compromise the fish's ability to survive in extreme conditions. Fish from high densities may survive and perform well in the hatchery or when stocked into ideal conditions, but when seriously challenged may succumb rather than survive. For example, other researchers have shown that golden shiners *Notemigonus crysoleucas* or chinook salmon had higher levels of viral or bacterial infection at higher densities than counterparts at lower densities. Physiological changes caused by high densities such as reductions in the ability to adapt to saltwater (Na+, K+ ATPase activity) and hormonal changes can have impacts on the immune system and other organ systems essential for survival. Therefore, stocking conditions should guide decisions about rearing densities as well as economics. As experience with chinook salmon in Oregon has shown, more is not necessarily better.

Eric Wagner

Table 1. Survival of cutthroat trout reared at four densities and transferred to 15 g/L (Experiment 1) or 18 g/L (Experiment 2) salt solution for 24 h. Control fish were held in fresh water at the same temperature. An asterisk indicates survival that differed significantly from controls.

Density	Number surviving	Percent Survival
Experiment 1		
D1	2	33
D2	1	17*
D3	3	50
D4	0	0*
Experiment 2		
D1	57	98.3
D2	60	100
D3	51	89.5*
Control	179	99.4

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