AMMONIA CONCENTRATIONS IN PINK SALMON, *ONCORHYNCHUS GORBUSCHA*, REDDS OF SASHIN CREEK, SOUTHEASTERN ALASKA

Although the toxic effects of ammonia have been observed in developing salmonids in hatcheries, few measurements of ammonia are available from the natural environment. In the fall of 1969, ammonia levels in the surface waters of Sashin Creek, southern Baranof Island, southeastern Alaska, were measured during and after the run of pink salmon, *Oncorhynchus gorbuscha*. Ammonia levels increased significantly after the run. This increase was attributed to the large number of decaying carcasses of spawned-out adult salmon (Brickell and Goering 1972). Low levels of ammoniacal nitrogen have been found in samples of intragravel waters of Sashin Creek taken in August, just before most fish spawned (McNeil et al. 1964). Ammonia concentrations have not been measured in intragravel water taken directly from salmon redds with known densities of eggs or alevins.

The transition period just before and during emergence of alevins from the gravel is critical for survival of young salmon. The young salmon have a higher rate of metabolism than eggs and early alevins (Bailey et al. 1980) and are undergoing physiological changes to enable them to actively swim and feed rather than reside quietly in the gravel. Salmonid alevins nearing the end of yolk absorption excrete ammonia at a higher rate than eggs or early alevins (Rice and Stokes 1975; Bailey et al. 1980) and are more sensitive to ammonia than earlier stages (Penaz 1965; Rice and Stokes 1975; Rice and Bailey 1980). At the same time (winter and spring), freezing weather usually causes surface and intragravel water flows to be low and thus reduces the removal rate of excreted ammonia. In 1972 we measured ammonia in samples of intragravel water taken from random sites in Sashin Creek, including pink salmon redds, and measured densities of live and dead alevins at each sample site. In this paper we report the concentrations of total ammonia (un-ionized and ionized) found in stream and intragravel water and discuss the effect of ammonia concentrations on developing alevins.

Methods

In late March we sampled 60 random intragravel sites and 4 typical surface sites. Water flow in Sashin Creek was low, which was normal for late March—the rainy season had not begun and the winter snow was not melting. The water temperature was 1.6° C and pH was 6.7. Samples of intragravel water were taken from standpipes (McNeil 1962; McNeil et al. 1964). Water samples were frozen in glass bottles within 2 h of sampling and kept frozen until analyzed within 3 d.

We determined concentrations of total ammonia (NH_3 + NH_4^+) using an automated method that quantitates the intensity of blue indophenol after reaction of ammonia with alkaline phenol hypochlorite (U.S. Environmental Protection Agency [EPA] 1974). The EPA method was modified by stabilizing the heat source during the reaction to increase sensitivity to a detection limit of 0.004 ppm ammonia. Analyses were made on freshly thawed water samples. Some samples and standards of known concentration were measured, frozen, and thawed a second time, and again measured. The ammonia levels did not change, indicating that our preserving technique was adequate. The slightly acid water of Sashin Creek aided in the retention of ammonia.

The density of eggs and alevins was measured at each site within 2 h of sampling for ammonia. We sampled an area of 0.1 m^2, centered on the standpipe site, with a hydraulic egg-pump (McNeil 1964), and counted dead eggs, live eggs, and alevins.

Concentrations of Ammonia in Intragravel Water and its Implications

Concentrations of ammonia and densities of eggs and alevins varied widely. Total ammonia in intragravel waters ranged from 0.008 to 0.240 ppm, and density of live eggs and alevins ranged from 0 to 352/0.1 m^2 (average 21.2) (Table 1). The densities of pink salmon eggs and alevins found in Sashin Creek were typical of many streams in southeastern Alaska[1].

The concentrations of ammonia were not correlated with location in the stream (r = −0.18, P>0.05 for ammonia concentrations measured in

[1]The average densities of pink salmon alevins for 96 pink salmon streams of southeastern Alaska, 1966-1974, varied from <1 to 30 alevins/0.1 m^2 (Kingsbury, A., P. Larson, and G. Downey. 1975. Forecast of the 1975 pink salmon returns to southeastern Alaska. Alaska Dep. Fish Game, Inform. Leafl. 168, 33 p., on file at Northwest and Alaska Fish. Cent., Auke Bay Lab., Natl. Mar. Fish. Serv., NOAA, P.O. Box 155, Auke Bay, AK 99821).

TABLE 1.—Density of salmon eggs and alevins, and concentration of ammonia in intragravel waters of Sashin Creek, southeastern Alaska. Pink salmon eggs or alevins predominated, although a few coho salmon, *Oncorhynchus kisutch*, eggs, <10%, were occasionally present at the sample sites and are included in the totals. Four surface samples were also measured, ranging from 0.005 to 0.019 ppm total ammonia (average 0.013 ppm).

Sample site number	Number of eggs and alevins/0.1 m^2			Total ammonia (ppm)
	Dead	Live	Total	
Sites with highest numbers of eggs and alevins				
8	12	352	364	0.018
189	138	107	245	0.010
190	232	0	232	0.010
10	6	213	219	0.015
97	193	11	204	0.035
Sites with highest concentrations of ammonia ($NH_3 + NH_4{}^+$)				
95	0	2	2	0.240
92	10	0	10	0.240
100	4	0	4	0.115
87	3	0	3	0.065
105	41	9	50	0.065
Combined values for all 60 sites				
Mean ±95% confidence interval	23.6±12.3	21.2±15.0		0.035±0.012
Range	0-232	0-352		0.005–0.240

upstream versus downstream locations) nor with the density of eggs and alevins ($r = -0.17, P > 0.10$) (Table 1). None of the five sample sites with the highest ammonia concentrations was among the five sites with the highest densities of eggs and alevins.

The lack of correlation of ammonia concentrations with alevin densities may be due to the variability of intragravel water flow. Intragravel water flow varies considerably from site to site in all streams and is affected by surface water velocity, volume of water flow, stream gradient, gravel size, and obstructions such as trees or ice (Vaux 1968). Intragravel flow may differ in adjacent redds (cross-stream or upstream-downstream). Brickell and Goering (1972) found that ammonia concentrations in surface waters of Sashin Creek during the fall spawning were generally greater at the downstream sites than at the upstream sites. In contrast, we found no relation between concentrations of ammonia sampled in the spring from intragravel waters at upstream and downstream sites at Sashin Creek. Furthermore, the concentrations of ammonia in surface water in our study were much lower and more uniform than the concentrations in the intragravel water. We conclude that measurements of ammonia in surface water are poor estimates of ammonia concentrations of intragravel water.

Twice each year, in early spring and in fall, ammonia concentrations in salmon streams can be expected to reach levels potentially harmful to salmon eggs and alevins. In the fall, a large mass of decaying salmon carcasses may litter the stream. Brickell and Goering (1972) measured ammoniacal nitrogen in surface waters of Sashin Creek during and after a heavy run of salmon and found concentrations of ammonia to be greater than concentrations of ammonia that we found in surface waters in the spring. Brickell and Goering concluded that the ammonia was from the decaying carcasses and not from excretion by pre-eyed salmon eggs. Pre-eyed salmon eggs have low ammonia-excretion rates (Rice and Stokes 1975; Bailey et al. 1980). Unfortunately, no samples of intragravel water were measured in the study by Brickell and Goering, but the potential for harm to developing eggs is probably low because pink salmon eggs are quite tolerant of ammonia at this life stage (Rice and Bailey 1980). In early spring when water flows are low and excretion rates of developing alevins are maximum, high concentrations of ammonia could result. We found concentrations of ammonia in some of the salmon redds to be higher than the concentrations in concurrent samples of surface water and even higher than the concentrations reported by Brickell and Goering in the surface water in the fall.

Although the probability of exposure to high levels of ammonia in spawning grounds is greatest in the spring when alevins are most sensitive, the highest level we observed was below dangerous levels. The highest concentration of ammonia that we found in the intragravel samples was 0.24 ppm total ammonia, which is about 0.1 ppb of toxic un-ionized ammonia at the pH and temperature of Sashin Creek. This concentration is only about one-tenth of the lowest concentration that affected the size of fry resulting from alevins exposed to ammonia for 61 days (Rice and Bailey 1980) and about two-thirds of the maximum concentration found in hatchery incubators containing unusually high densities of eggs (Bailey et al. 1980). Our highest value for intragravel water exceeded the highest concentrations found in surface water of Sashin Creek (Brickell and Goering 1972) when many decaying salmon carcasses were present.

In subarctic and arctic streams where water temperature and pH are low, it seems unlikely that ammonia will accumulate in intragravel waters to concentrations that will significantly affect size or survival of salmon alevins. Ammonia toxicity may be significant at higher temperatures, especially in more alkaline streams.

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EGG CANNIBALISM IN THE NORTHERN ANCHOVY, *ENGRAULIS MORDAX*

Anchovies feed on their own eggs. Egg cannibalism has been reported for the Argentine anchovy, *Engraulis anchoita* (de Ciechomski 1967); Japanese anchovy, *E. japonicus* (Hayasi 1967); anchoveta, *E. ringens* (Rojas de Mendiola et al.[1]); and the northern anchovy, *E. mordax* (Loukashkin 1970). These studies give no indication whether this cannibalism was a significant part of natural mortality and incidence of cannibalism was included only as part of a general description of food habits. We provide evidence that egg cannibalism may account for a considerable proportion of natural egg mortality in the northern anchovy.

Northern anchovy feed by biting larger prey and by filtering smaller ones (Leong and O'Connell 1969). If both large and small prey are offered in the laboratory, northern anchovy in the front of the school bite the larger prey, whereas those at the end of the school feed by filtering the smaller prey (O'Connell 1972). Our laboratory observations indicate that adult northern anchovy feed on their eggs by filtering, whereas even the smallest anchovy larvae (ca. 3-4 mm long) are bitten. Such small larvae are digested beyond identification in 30 min, whereas the identifiable whole chorions and fragments may remain in northern anchovy stomachs up to 8 h although the contents of the egg (embryo and yolk) are digested after about 2 h. Northern anchovy eggs are prolate spheroids and can be easily distinguished from the spherical eggs of other pelagic spawners in the Southern California Bight.

Methods

The incidence of cannibalism in northern anchovy was estimated from an examination of 31 sets of stomach samples, usually of 10 adults each. Samples were taken at the peak of the spawning season, in the Southern California Bight, during March 1976 and 1977 (Table 1). Northern anchovy were collected in a midwater trawl or a commercial lampara net: 28 sets of collections were taken at night between sunset and sunrise and 3 sets during the day. Fish were frozen in liquid nitrogen

[1]Rojas de Mendiola, B., N. Ochoa, R. Calienes, and O. Gomez. 1969. Contenido estomacal de anchoveta en cuarto areas de la costa Peruana. Inst. Mar. Peru Inf. Espec. (IM-27), 29 p.