LOG SLUICE PASSAGE SURVIVAL OF JUVENILE CLUPEIDS AT CABOT HYDROELECTRIC STATION CONNECTICUT RIVER, MASSACHUSETTS

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EXECUTIVE SUMMARY

The presently configured log sluice at the Cabot Hydroelectric Station should provide safe passage for almost all (>98%) juvenile clupeids. Previous studies indicated that most of the emigrating clupeids used this log sluice for passage by the Station.

Injury and mortality attributable to sluice passage were determined with the HI-Z Turb'N Tag recapture technique by releasing 150 tagged fish at the entrance of the sluice (treatment) and 150 tagged fish near the sluice exit (control). A total of 96% of both treatment and control fish was recaptured.

The estimated short term (1 h) and long term (48 h) mortality was less than 2% (adjusted for controls). Only one treatment and one control fish were recaptured dead and few additional mortalities (4 treatment and 4 control) occurred during the 48 h holding period.

Incidence of injury was similar for both treatment and control groups which indicated most observed injuries were due to tagging, introduction, and recapture procedures. Cuts (3 specimens) and major abrasions (1 specimen) on a few treatment fish may have been sluice induced. Patchy minor scale loss was about two times higher on treatment than control fish. Adjusting for scale loss on controls resulted in a 10% descalation rate (mostly minor) for sluice passed fish.

Injuries and scale loss appeared to be minor; 48 hours after passage almost all fish were swimming vigorously and appeared to be in good condition prior to release back to the river.

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1.0 INTRODUCTION

Because of the success of the log sluice in passing juvenile clupeids (Harza and RMC 1993), Northeast Utilities requested RMC Environmental Services, a division of Normandeau Associates, to determine the extent of injury and mortality to these fish bypassed through the log sluice located at the downstream end of the Cabot Hydroelectric Station. The HI-Z Turb'N Tag recapture technique (U.S. Patent No. 4,970,988) was selected to asses injury and mortality based on its past performance (Heisey et al. 1992; Mathur et al. 1994; RMC 1992).

Fisheries resource agency personnel were informed prior to initiation of the study and invited to witness the study, offer comments, and make recommendations. Several members and their associates witnessed the study.

1.1 Project Description

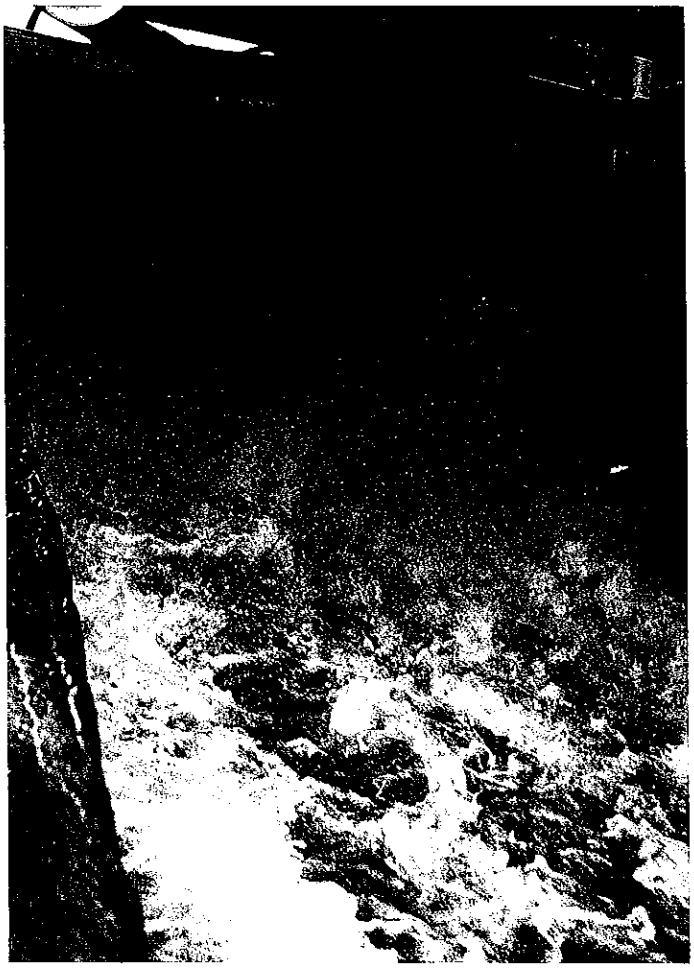
Cabot Station with its log sluice is part of the Turners Falls Project generation facilities built between 1905 and 1915. The Project consists of Turners Falls Dam, a canal gate house structure, a 2.1 mile long canal, Turners Falls No. 1 Station and Cabot Station. The dam is located at river mile 117 on the Connecticut River in Massachusetts and consists of the Montaque Spillway and Gill Dam. The Montaque Spillway has four 120 ft long by 13.5 ft high bascule gates for pond elevation control. The Gill Dam includes a non-overflow section and three tainter gates. Water is typically either stored or spilled over the dam when river flows exceed approximately 15,000 cfs, the combined hydraulic capacity of Turners Falls Station No. 1 and Cabot Station. Water is directed to the two hydro stations via a power canal. The canal gate house structure, situated on the east side of the river, regulates water flow, up to approximately 15,000 cfs, into the power canal.

Turners Falls No. 1 Station is located approximately 0.5 miles downstream from the gate house and houses five Francis turbines with a total nameplate rating of 5.6 MW at a head of 43 ft. The total hydraulic capacity of the units at Turners Falls No. 1 Station is 2,500 cfs. The station is operated primarily when daily river flows exceed 12,500 cfs.

Cabot Station is located at the downstream end of the power canal and has six Francis turbines with a total nameplate rating of 51 MW at a nominal head of 60 ft. The total hydraulic capacity of the Station is 12,500 cfs.

The log sluice, which is adjacent to the Cabot powerhouse, is constructed of smoothed concrete, is 16 ft wide and approximately 200 ft long with a slight curve (Figure 1-1). Water enters the sluice via a slidegate that is lowered 2.5 ft below the normal forebay elevation (around 173.3 ft). At this setting, water passes over the gate at approximately 225 cfs, drops about 10 ft to the sluice surface, and falls an additional 60 ft of vertical elevation down a gradually sloped

surface before entering the tailrace. The sluice exit is along the southeast shore of the tailrace approximately 100 ft downstream from the Unit 1 discharge. A 27.5 ft long stainless steel profile wire screen can be positioned to intercept the entire sluice discharge to monitor species and numbers of fish bypassed through the sluice. Fish are directed from the interceptor screen through a 31 ft long, 1 ft wide flume to a sorting area. Fish can be readily removed or passed by a pipe back to the sluice. Additional details about the flume sampler are presented in Harza and RMC (1993).



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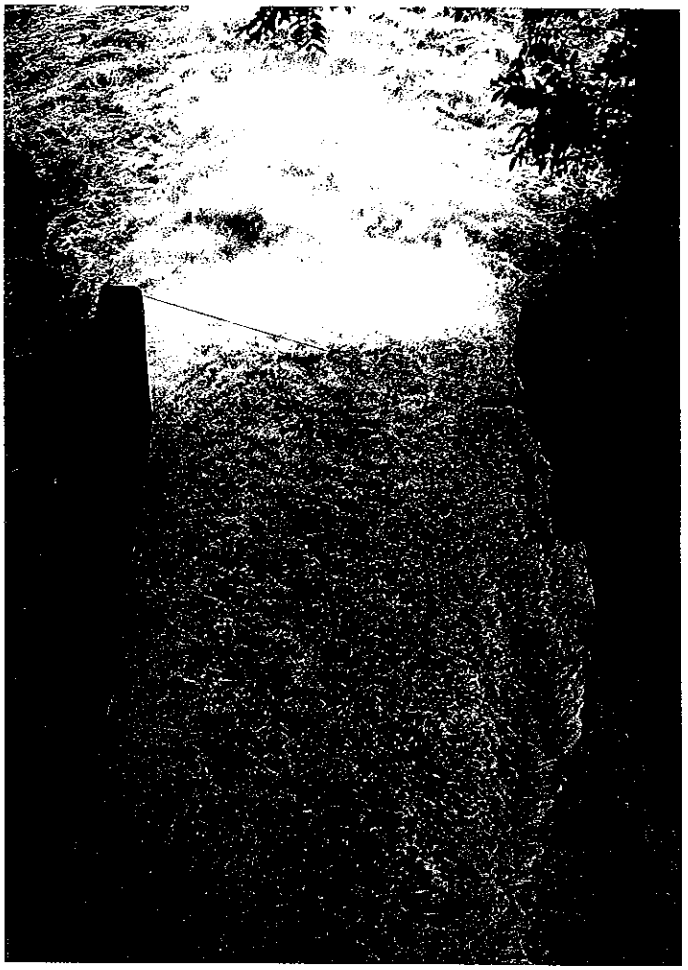

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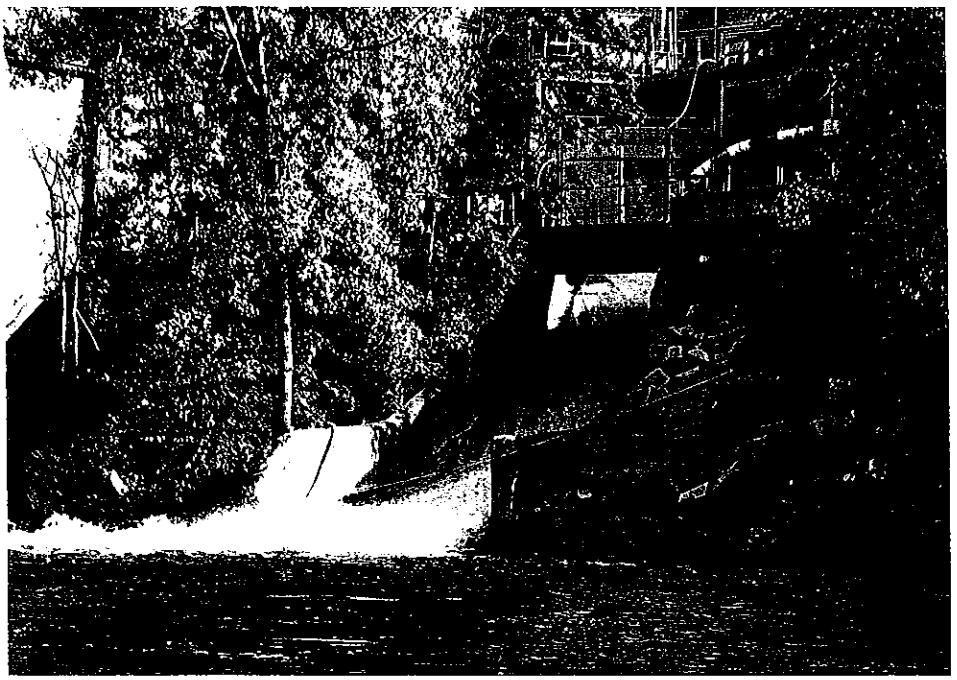


C

FIGURE 1-1

Log sluice bypass at Cabot Hydroelectric Station. A. 10 ft spill at beginning of sluice; treatment fish released above spill. B. Sluice exit; control release hose on right side. C. Overall configuration of sluice, note deflection spill.

2.0 METHODS

2.1 Collection and Holding of Juvenile Clupeids

Emigrating juvenile clupeids were collected from the sluice sampling facility at Cabot Station on three evenings (27, 30 September, and 3 October). Fish were water brailed from the sampler and placed into circular tubs partially filled with approximately 5 ppt salt buffered river water. Fish were then placed into one of two 600 gal vinyl circular tanks located in the upper parking lot near the entrance of the log sluice. Both pools were supplied with a continuous flow of ambient river water. A 50 lb block of salt was added when fish were stocked and on subsequent days when fish were removed for testing. The salt block dissolved slowly over an 8-10 h period and maintained a concentration of near 5 ppt for most of the holding period. Fish were held for a minimum of 24 h prior to tagging to allow for acclimation. Fish were handled with extreme care, including water to water transfer, throughout the study; direct netting was avoided to minimize scale loss. These procedures were used to minimize the effects of handling, transporting, and transferring sensitive clupeids (Heisey et al. 1992; RMC 1994a).

2.2 Tagging of Juvenile Clupeids

Fish to be tagged were concentrated within a pool with a seine then water brailed into 5 gal circular pails filled with approximately 5 ppt NaCl-buffered river water. Fish (5-10 specimens at a time) were carried to the treatment or control tagging sites. Each fish was fitted with a miniature radio transmitter and a Turb'N Tag (Figure 2-1). Tagged fish were released by an induction system either near the entrance of the log sluice (treatment) or near its end (control). Just prior to release into the induction system the tag was activated by injecting 1-1.5 ml of catalyst.

Details of the tag and release technique are given in Heisey et al. (1992). Briefly, un-inflated Turb'N Tags were made of bright colored latex and were pear shaped with a maximum length and width of approximately 38 mm (1.5 in) and 13 mm (0.5 in), respectively. Each tag weighed about 1.5 g. Upon inflation, tags measured approximately 75 mm (3 in) long and 50 mm (2 in) in diameter. Each radio tag was approximately 10 x 31 mm, weighed 1.7 g, and propagated radio signals through a 27 cm thin wire antenna. Tags were attached by a single stainless steel pin through the dorsal musculature near the insertion of the dorsal fin. The pin was inserted with a modified ear-piercing gun and secured with a small plastic disc.

2.3 Induction of Juvenile Clupeids

Treatment fish were individually introduced just upstream of the submerged sluice gate. Control specimens were released a few feet from the end of the sluice (Figure 1-1). Both treatment and controls were directed to the release points by an induction apparatus consisting of a

small holding basin attached to a 3 inch supply/delivery line. A gasoline powered trash pump supplied water to the system to ensure that fish were transported quickly within a continuous flow of water through the reinforced plastic delivery line. Initially, control fish (lot 1) were released near mid-channel at the end of the sluice and at an angle (approximately 45°) to the flow; thereafter, controls were released near the end of the sluice but close to its upstream side wall and in the direction of the water flow.

2.4 Juvenile Clupeid Recapture

The Turb'N Tag inflated shortly after release, usually within 5 minutes, and buoyed the fish to the surface for retrieval. Fish were located by homing on the radio signal and/or visually spotting the inflated Turb'N Tag. Radio signals from tagged fish were received with a boat mounted 5-element Yagi antenna coupled to a programmable scanning receiver (Advanced Telemetry Systems, Inc., Isanti, MN). Fish which failed to surface were monitored via radio signals for at least 30 minutes.

Immediately upon retrieval, each fish was carefully examined for injury and tags were removed with modified pliers (Heisey et al. 1992). Within minutes of recapture, each fish was transferred via 5 gal buckets to a 600 gal holding pool to assess the long-term (48 h) effects of tagging, handling, and sluice passage. The treatment and control fish were held in separate pools initially containing about 5 ppt salt water. These pools were continuously supplied with ambient river water and covered to prevent escape and minimize external stressors. A 50 lb block of salt was placed in each pool approximately an hour prior to testing. Salt was added to the holding pools to minimize potential adverse effects of handling and transfer as juvenile clupeids are known to be extremely sensitive to handling stress (Backman and Ross 1990; Heisey et al. 1992; Ruggles 1993). Fish were measured (total length in mm) at the end of the 48 h assessment period or at time of mortality.

In addition to the Turb'N tagged fish, untagged fish (equal to the number tagged) were stocked into the treatment and control pool at the beginning of each day's testing. These additional controls were monitored to determine if factors other than tagging and passage through the induction system caused mortalities. Mortalities in the pools were examined at 24 and 48 h.

2.5 Classification of Recaptured Juvenile Clupeids

Recaptured fish were classified as follows to estimate the short-term (≤ 1 h) effects of passage through the sluice: (1) *recaptured alive* denotes *short-term (1 h) survival*; (2) *alive but not recovered, sighted swimming* denotes *live*; (3) *recaptured dead* denotes *immediate mortality*; (4) *tags only recaptured* were classified as *tag separation*; (5) *unrecovered fish with a transmitting radio tag* was assigned a status based on signal movement pattern. Fish were assigned *predation* if

movement patterns were typical of predator (i.e., rapid movements throughout the tailrace, movement into areas of strong current, and aerial signals from gulls); and (6) *unknown* - neither fish nor tag were recovered within 30 minutes after release and status could not be ascertained from the radio signal.

The status of non-recaptured fish was determined by characteristics of the radio signals or recovery of inflated detached tags. For the purpose of a conservative estimate of survival all fish classified as tag separation, predation or unknown were also categorized as mortalities (Heisey et al. 1992; Mathur et al. 1994). Survival of fish passed by the sluice was adjusted for only the control mortality of tagged fish because none of the tagged fish died. Survival and its variance were estimated with the formulas given by Burnham et al. (1987):

$$\hat{S} = \frac{(r_t/R_t)}{(r_c/R_c)}$$

where $\hat{S}$ = survival of fish after passage through sluice
r_t = number of live treatment fish recaptured
R_t = number of live treatment fish introduced into sluice
r_c = number of live control fish recaptured
R_c = number of live control fish released

$$Variance\ of\ \hat{S} = (\hat{S})^2[\frac{1}{r_t} - \frac{1}{R_t} + \frac{1}{r_c} - \frac{1}{R_c}]$$

$$Standard\ error\ (\hat{SE})\ of\ \hat{S} = \sqrt{Var(\hat{S})}.$$

The statistical significance in the differences in mortality and recapture rates of treatment and control groups was determined by a chi-square analysis as recommended by Burnham et al. (1987). Data were analyzed using the Statistical Analysis System (SAS Institute, Inc., Version 6.03). Appendix I gives the injury codes used and the data listing and Appendix II provides the statistical output.

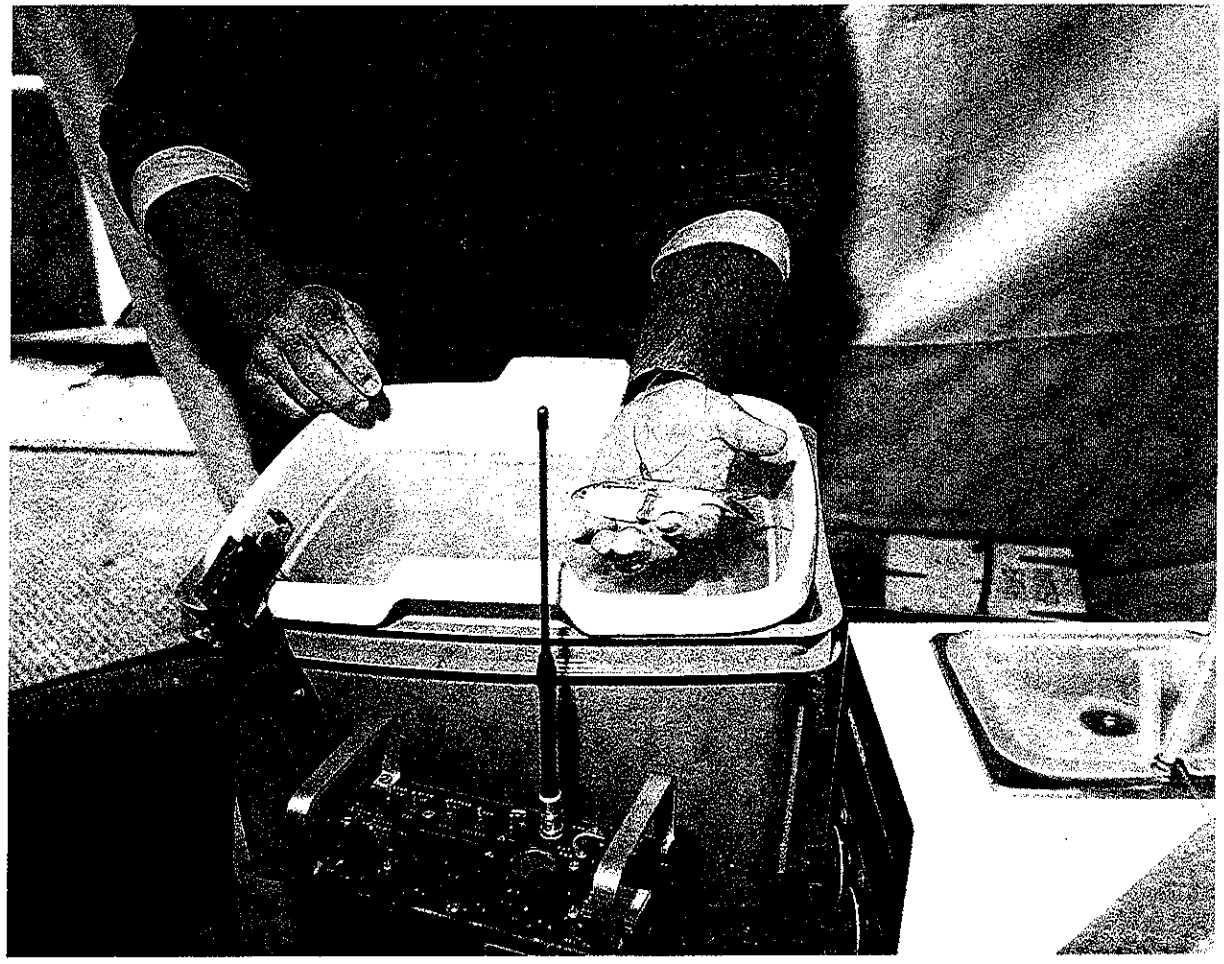


FIGURE 2-1

Example of typical Turb'N Tag and radio transmitter attachment on a juvenile American shad.

3.0 RESULTS

An estimated 980 juvenile clupeids were collected from the sampler and held in the pools over the course of the study. Only four fish died prior to testing (Table 3-1). All specimens not used for the study were released to the forebay or the log sluice bypass. All specimens used in the tests were released to the tailrace. Only fish in control and treatment lot 3 were sacrificed to ascertain the portion of the catch that was American shad or blueback herring. All 111 of these fish sub-sampled for species composition were American shad. This subsample represented 18.5% of all fish tested which consisted of 300 tagged fish and 300 untagged fish. Although almost all of the fish tested were American shad, the similarity of American shad and blueback herring warrant the transfer of findings to blueback herrings as well. The length of tagged treatment fish and control fish ranged from 80-121 mm (mean 92 mm) and 80-116 mm (mean 91 mm), respectively. Untagged fish ranged from 72-105 mm with a mean of 88 mm (Table 3-3).

Water temperature and dissolved oxygen in the holding pools were similar to ambient River conditions and ranged from 15.0 to 18.5°C and 8.5 to 9.4 mg/l, respectively (Table 3-1).

Water quality parameters in the delayed assessment pools was also similar to ambient conditions (Table 3-2). Water temperatures decreased during the course of the study with a high of 18.0°C on 30 September and low of 13.0°C on 7 October. Dissolved oxygen in the pools ranged from 7.7 to 9.6 mg/l. Ambient conditions ranged from 17.5 to 14.5°C and 8.9 to 9.2 mg/l, respectively. Salinity in the delayed assessment pools was near 5.0 ppt (high values ranged from 4.2 to 6.8 ppt) when fish were initially stocked into pools but was near zero the following morning.

Forebay water level fluctuated between 172.5 and 173.8 ft during the tests and averaged within two tenths a foot of 173.3 ft (typical level) most of the time (Table 3-4). Although the forebay fluctuated, most fish were introduced to the log sluice at a discharge near 225 cfs.

3.1 Recapture Rates

A total of 150 treatment and 150 control juvenile clupeids was released in test lots of 25 to 35 fish on 5 days (Table 3-4). Recapture and survival results were homogenous for the test and control lots, thus the five treatment and five control lots were pooled (Appendix II). Recapture rates of both groups were high and identical (96.0%). Only one each of the 144 treatment and 144 control fish recaptured was dead. The non-recaptured fish consisted of three treatment fish with tags only and three with nothing recaptured. Control fish had four and two fish in these respective categories. Because juvenile clupeids have relatively soft flesh some of the "tags only" fish were likely separated from their tag in turbulent areas without any passage related injury to the fish. There was no evidence of predation on any of the unrecaptured fish even though this has

been observed in other studies; a fisherman was catching smallmouth bass in an eddy just downstream of the sluice exit.

The recapture times of both treatment and control fish were short and almost identical (Table 3-5). Most specimens were recaptured in about two minutes; average was 2.9 minutes for treatment and 3.0 minutes for controls. Thus, both groups were exposed to tailrace conditions for similar times.

3.2 Survival Rates

The survival of juvenile clupeids was high (Table 3-6). The short-term (1 h) survival was estimated at 100% (95% CI=95.0-100%). The 48 h survival was also estimated at 100% (95% CI=93.6-100%). If data from the first treatment and control trial (T1 and C1) is excluded because of a possibly more turbulent flow at the control release site, short term and long term survivals are 98.3% and 99.1%, respectively (Table 3-6). Little mortality occurred after passage; only four each of the 139 treatment and 139 control fish (all trials) held died over the 48 h period; all latent mortality occurred during the first 24 h (Table 3-4). Additionally, almost all fish surviving at 48 h appeared in excellent condition and swam away with vigor when released to the tailrace. Differences in survival of treatment and control fish were not significant ($P > 0.05$) at 1 h or 48 h.

3.3 Injury

All recaptured fish (live and dead) were carefully examined for type and location of injury, scale loss, and unusual behavior (Table 3-7). Fish with obvious injuries and most that died were also photographed (Figure 3-1). A total of seven treatment and seven control specimens were noted with some type of physical injury (cuts, hemorrhage, abrasion). These injuries were observed solely or in combination with other injuries and scale loss. Physical injuries observed included hemorrhaging around the snout of three treatment and six control specimens. Three treatment fish also had cuts and one was scraped along both sides (Figure 3-1). One control fish was scraped on its side. Some of the fish (both treatment and controls) may have received the snout injury while in transit through the induction system, but obstructions within the sluice also likely accounted for a few injuries, especially the severe abrasion on one specimen and cuts on three treatment fish. Minor scale loss, generally patchy covering less than 20% of fish's body was observed for both treatment (22) and control (11) specimens. This was not surprising since juvenile clupeids readily slough off scales. However, the two times higher incident rate for treatment fish indicates some scale loss is attributable to sluice passage. Major scale loss, characterized by swaths of scales removed from greater than 20% of the fish's body was noted on five treatment and three controls.

A total of five treatment and seven control fish were also noted as being stressed. This usually consisted of the specimens swimming poorly or lying on the bottom of the recapture bucket. Many of the fish assigned a stressed condition righted themselves and resumed normal swimming behavior when released into the long term assessment holding pools. Fish which displayed a greater degree of stress and did not resume normal behavior often had other injuries (hemorrhaging, cut).

Generally, cuts, hemorrhaging, and major scale loss were injuries most often associated with short-term or long-term mortalities; however, one treatment fish with a noticeable cut on its head was quite vigorous at the end of the long-term assessment period. Although not individually examined, hemorrhage areas were less obvious when the fish were released after 48 h.

If injuries (laceration, hemorrhage, and abrasion) observed on controls are taken into account, none of the sluice passed fish would be assigned an injured status; both groups had the same number of injured fish (7). Adjusting scale loss rates of treatment fish (27 of 144) by that for controls (14 of 144) would attribute 10% descalation (mostly minor) to sluice passage (Table 3-7).

Table 3-1 Water quality parameters for the Connecticut River and supply tanks stocked with juvenile clupeids for the log sluice passage survival study conducted at Cabot Hydroelectric Station, September-October 1994.

		Holding Pool Water Quality			River Water Quality		Fish Status	
Holding Period	Holding Site	Temp (°C)	DO (mg/l)	Salinity (ppt)	Temp (°C)	DO (mg/l)	Number Held	Number Died
9/27-10/1	Pool 6	16.5-18.5	9.0-9.1	0.0-4.9	17.0-18.5	-	≈300	0
9/30-10/4	Pool 7	15.0-16.8	8.5-9.4	0.0-3.6	15.0-17.0	9.2-8.9	≈300	0
10/3-10/5	Pool 6	15.0-16.0	8.9-9.2	0.0-5.0	15.0-16.0	8.9-9.0	≈380	4

Table 3-2 **Water quality parameters of the Connecticut River and long-term monitoring pools used for the juvenile clupeid log sluice survival study conducted at Cabot Hydroelectric Station, September-October 1994.**

				Holding Pool Water Quality			River Water Quality		Fish Status	
Test Lot No.	Test Date	Long-term Holding Site	Holding Dates	Temp (°C)	DO (mg/l)	Salinity (ppt)	Temp (°C)	DO (mg/l)	Number Held*	Number Died**
T-1	9/30	Pool 5	9/30-10/2	17.5-15.2	9.5-7.7	4.2-0.0	17.5-16.0	9.2	44	1
C-1	"	Pool 4	"	18.0-14.8	9.4-8.4	4.8-0.0	"	"	42	0
T-2	10/1	Pool 13	10/1-10/3	16.5-13.0	8.5-9.4	4.8-0.0	17.0-15.0	9.0-9.2	59	0
C-2	"	Pool 3	"	16.5-13.5	8.7-9.6	"	"	"	60	2
T-3	10/3	Pool 8	10/3-10/5	16.5-14.0	9.0-9.7	6.8-0.0	16.0-15.0	9.0-8.9	58	2
C-3	"	Pool 12	"	16.5-14.5	9.1-9.3	5.6-0.0	"	"	57	2
T-4	10/4	Pool 5	10/4-10/6	16.5-13.5	9.2-9.4	6.4-0.0	16.0-15.0	8.9-9.8	67	0
C-4	"	Pool 13	"	16.0-13.0	8.9-9.4	"	"	"	68	0
T-5	10/5	Pool 3	10/5-10/7	15.0-13.0	9.0-9.2	≈5.0-0.0	15.0-14.5	9.1-9.8	60	1
C-5	"	Pool 4	"	"	"	"	"	"	60	0

* Includes recaptured live tagged fish and untagged controls.

** None of the untagged controls died.

Table 3-3 Total length (mm) distribution of juvenile clupeids used for the log sluice bypass survival study at the Cabot Hydroelectric Station, September-October 1994.

	Tagged			
Length	Control	Treatment	Untagged	Total
≤ 80	2	1	31	34
81-90	71	64	152	287
91-100	59	63	96	218
101-110	9	7	5	21
111-120	1	2	-	3
121-130	-	1	-	1
TOTAL	142	138	284	564
Minimum	80	80	72	72
Maximum	116	121	105	121
Mean	91	92	88	90
Standard Deviation	6.5	6.6	6.5	6.8

Table 3-4 **Tag-recapture data on juvenile clupeids passed through the log sluice (treatment) or released near the sluice exit (control) at the Cabot Station, September-October 1994. Approximately 225 cfs spilled through the sluice during tests.**

	Trials					
	1	2	3	4	5	Total
			Treatment			
Range of forebay elevation (ft)	172.9-173.6	172.8-173.4	172.7-173.5	173.3	173.0-173.8	172.7-173.8
Mean forebay elevation (ft)	173.3	173.1	173.2	173.3	173.4	173.2
Number released	25	30	30	35	30	150
Number recaptured alive	24	29	28	32	30	143
Number recaptured dead	0	0	1	0	0	1
Tags only	0	1	0	2	0	3
Unknowns/nothing recaptured	1	0	1	1	0	3
Number alive at 24 h	23	29	26	32	29	139
Number alive at 48 h	23	29	26	32	29	139
			Control			
Range of forebay elevation (ft)	172.9-173.6	172.5-173.8	173.2-173.6	173.2-173.7	173.0-173.5	172.5-173.8
Mean forebay elevation (ft)	173.4	173.2	173.5	173.4	173.3	173.3
Number released	25*	30	30	35	30	150
Number recaptured alive	22	30	27	34	30	143
Number recaptured dead	1	0	0	0	0	1
Tags only	2	0	1	1	0	4
Unknowns/nothing recaptured	0	0	2	0	0	2
Number alive at 24 h	22	28	25	34	30	139
Number alive at 48 h	22	28	25	34	30	139

* Control release point in area of greater turbulence for trial 1 than subsequent trials.

Table 3-5 Recapture times in minutes (time from release until recapture of fish or inflated tags) of juvenile clupeids passed through the log sluice (treatment) or released near the sluice exit (control) at Cabot Station, September-October 1994.

	N	Mean	Standard Deviation	Minimum	Maximum
Treatment	150	2.9	4.0	1	43
Control	150	3.0	3.0	1	20

Table 3-6 Recapture and survival rate of juvenile clupeids passed through the log sluice (treatment) or released near the sluice exit (control) at the Cabot Station, September-October 1994.

	Treatment	Control
Number released	150	150
Number recaptured live	143	143
Number dead or lost		
Recaptured dead	1	1
Tags only	3	4
Unknown/nothing recaptured	3	2
Estimated short-term (1 h) survival = $\frac{143/150}{143/150}$ = 100%		
95% CI	95.0-100%**	
Estimated long-term (48 h) survival = $\frac{139/150}{139/150}$ = 100%		
95% CI	93.6-100%**	

* Upper limit truncated at 100%.

** Excluding trial 1, short term = $\frac{119/125}{121/125}$ = 98.3% (95% CI=93.4-100%) and long term = $\frac{116/125}{117/125}$ = 99.1% (95% CI=92.5-100%).

Table 3-7 **Matrix of injury types and injury/descalation rate on juvenile clupeids passed through the log sluice (treatment) or released near the sluice exit (control) at the Cabot Hydroelectric Station, September-October 1994. A total of 144 treatment and 144 control specimens were examined.**

	Treatment					Control		
Injuries	Single Injury	Bruises/ Hemorrhaging	Major Scale Loss	Minor Scale Loss	Stress	Single Injury	Minor Scale Loss	Stress
Lacerations	0	1	1	1	0	0	0	0
Bruises/hemorrhaging	2	0	0	0	1	4	2	0
Abrasion/scrape	0	0	1	0	0	1	0	0
Major scale loss	0	0	0	0	3	1	0	2
Minor scale loss	21	0	0	0	0	8	0	1
Stressed	1	0	0	0	0	4	0	0
TOTALS	24	1	2	1	4	18	2	3

Estimated injury rate =

$$1 - \frac{\#\ Treatment\ examined - \#\ injured\ (laceration,\ bruise,\ abrasion)}{\#\ Treatment\ examined} \div \frac{\#\ Control\ examined - \#\ injured\ (laceration,\ bruise,\ abrasion)}{\#\ Control\ examined} =$$

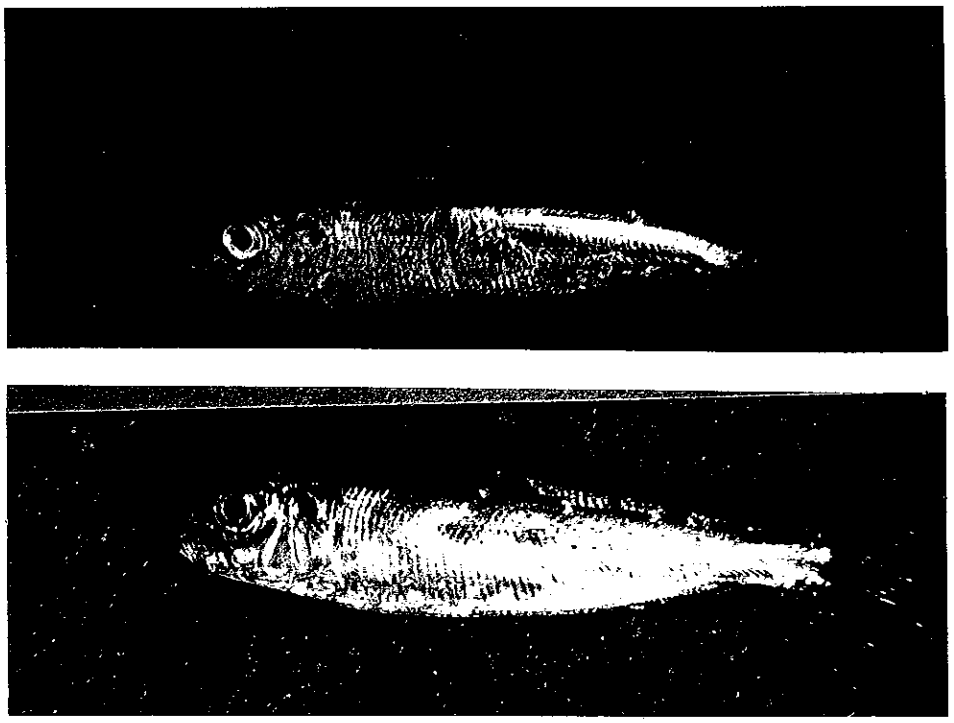
$$1 - \frac{144 - 7}{144} \div \frac{144 - 7}{144} = 0\%$$

Estimated descalation rate =

$$1 - \frac{\#\ Treatment\ examined - \#\ descaled}{\#\ Treatment\ examined} \div \frac{\#\ Control\ examined - \#\ descaled}{\#\ Control\ examined} =$$

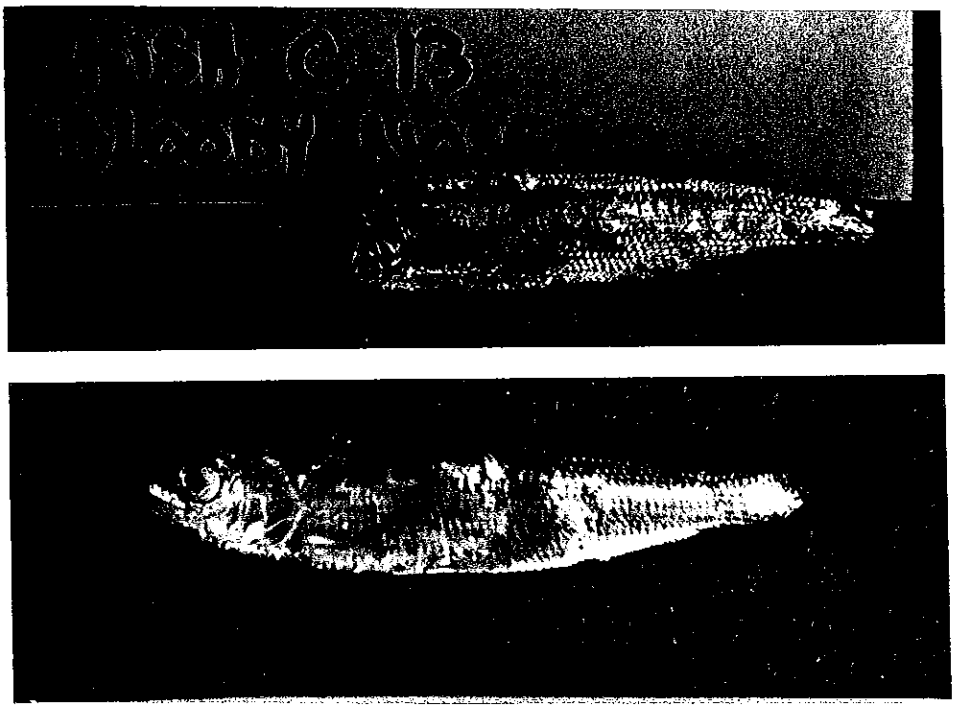
$$1 - \frac{144 - 27}{144} \div \frac{144 - 14}{144} = 10\%$$

$$95\%\ CI = 1.4\ to\ 18.6\%$$



TREATMENT SPECIMENS

Top - Fish T-11, 3 October, abrasion on side, dead ≤1 h
Bottom - Fish T-29, 5 October, cut near jaw and hemorrhage at nose, alive 48 h



CONTROL SPECIMENS

Top - Fish C-13, 3 October, hemorrhage at nose, dead 24 h
Bottom - Fish C-10, 1 October, scale loss, dead 24 h

FIGURE 3-1

Examples of injury types observed on fish released for the log sluice fish passage injury/mortality study at Cabot Hydroelectric Station.

4.0 DISCUSSION

The survival of fishes in passage through turbines, spillways, or bypasses can be reliably estimated with the fulfillment of assumptions associated with the procedures used in a study. To obtain a valid survival and injury estimate for the Cabot log sluice bypass study, the following explicit assumptions were made: handling, tagging, and release do not differentially affect the survival rates of treatment and control groups; recapture probabilities for the treatment and control groups are the same; and recapture crews do not differentially retrieve either group of fish. The assumptions were considered fulfilled as follows. Although insertion of the tag, fish induction, and tag removal requires handling and may result in some injury or mortality, the results indicated that these processes had limited effects over the 48 h assessment period. The 48 h survival of live recaptured treatment and control fish was identical (97.2%) and nearly all held fish (>98%) appeared to be in good condition 48 h after passage.

The assumption that treatment and control fish were equally vulnerable to recapture was not violated. Chi-square tests indicated homogeneity ($P > 0.05$) in recapture and survival probabilities of control and treatment fish between trials. The two recapture crews did not selectively retrieve control or treatment fish; the fish were recaptured by the available crew. The average recapture times for the treatment and control groups were virtually identical. Thus, the recapture crew bias was minimized. High recapture rates of both treatment and control fish minimized bias due to recapture. Because recapture rates were 96% for both treatment and controls the status of only 4% of the fish was open to some speculation.

Although configuration and discharge volumes differ among sites, survival rate of clupeids passed through the Cabot log sluice was better than observed for juvenile blueback herring spilled (40 cfs discharge) over a 12 ft high dam on the lower Mohawk River (RMC 1992). The estimated short-term (1 h) survival at the Mohawk site was 100% but dropped to 88.3% at 48 h. These fish were similar in size (74-105 mm total length) to those tested at the Cabot Station and were also equipped with a Turb'N Tag. Recapture rates (96.3% treatment, 95.2% control) were almost identical to the 96% found at Cabot. Although the hydraulic forces of the Mohawk site appeared to be more benign than the Cabot sluice, lower spillage and a rougher spillway surface at the Mohawk spill site may have contributed to some of the delayed mortalities (though non-significant). Another difference observed between the Mohawk and Cabot sites was the incidence of predation. Although some detached tags and stationary radio signals were observed at Cabot, no predation was confirmed or suspected. Predators, primarily smallmouth bass, took about 3 and 5% of the treatment and control fish at the Mohawk site, respectively. Several of the predators were buoyed to the surface after ingesting the tagged herring. Although an angler was catching

smallmouth bass near the Cabot sluice discharge, the high velocity discharge from the sluice carried almost all tagged fish rapidly toward the center of the tailrace and away from the boulder and eddy areas along shore, likely preferred by the smallmouth bass. A high velocity, mid river discharge was not present at the Mohawk site. The fish passage exit site and discharge characteristics appear to be important factors influencing the extent of predation (Ledgerwood et al. 1991; RMC 1994b).

Although juvenile clupeids are very sensitive and readily shed scales the presently configured log sluice at the Cabot station appears to provide at least a 98% safe passage rate. Some descalation (mostly minor) attributed to sluice passage did not appear to be severe enough to warrant concern; however, spillage rates considerably less than the approximately 225 cfs tested could increase incidences of contact with the concrete sluice. Heisey et al. (1993) reported major scale loss (>25% descalation) of 20% for Atlantic salmon smolts bypassed with a 200 cfs spillage at the Wilder Dam but only 0 and 4% at higher discharges of 300 and 500 cfs, respectively.

Survival estimates reported for salmonids bypassed by some type of spillage have generally been high. Schoeneman et al. (1961) estimated the survival of fingerling and yearling chinook salmon smolts (*Oncorhynchus tshawytscha*) at the McNary Dam on the Columbia River at 98%. These fish plunged from a height of approximately 92 ft. Atlantic salmon smolts (5.7 to 14.1 inch fork length) passed through an ice-log sluice at Bellows Falls (height 60 ft) and Wilder Dam (height 52 ft) on the Connecticut River had an estimated survival of 96% (Heisey et al. 1993). Although the log sluice bypassed Atlantic salmon had identical survival rates, injury and scale loss were considerably higher (42 versus 3%) at the site which had obstructions in the path of the spillage. Heisey et al. (1993) concluded that injuries and mortalities to salmon smolts should be minimal when bypassed fish encounter minor obstructions and are discharged into a deep plunge pool. Based on the relatively unobstructed flow and deep discharge area at the Cabot log sluice and the high survival of the delicate juvenile clupeids, survival of Atlantic salmon smolts using this facility should also be high. However, some injuries (though likely non-lethal) could possibly be inflicted in the presently configured sluice where water initially drops about 10 ft to the sloping flume.

5.0 LITERATURE CITED

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APPENDIX I - Injury codes and Data listing

APPENDIX I TABLE 1 Condition codes assigned to fish and Turb'N Tags during fish passage survival studies.

Codes	Description
FISH CODES	
A	No visible marks on fish
B	Flesh tear at tagging site(s)
C	Minor scale loss, 3 to 20%
D	Major scale loss, >20%
E	Laceration(s); tear(s)
F	Severed body parts
G	Hemorrhaging, bruised
H	Stressed (lethargic, swimming poorly or sporadically)
I	Spasmodic movement of body
J	Very weak, barely gilling, died within 15 minutes of recovery
K	Fish failed to enter system
L	Fish likely preyed on based on telemetry, and/or circumstances relative to Turb'N recapture
M	Substantial bleeding at tag site
N	Bulging or missing eye(s)
Q	Other information
R	Necropsied, no obvious injuries
S	Necropsied, internal injuries observed
T	Trapped inside tunnel/gate well
V	Not recaptured, no Turb'N tags(s) recaptured, radio signal stationary, assign status dead
W	Not recaptured, sighted swimming in tailrace, assign status alive
FISH RECOVERY CODES	
1	Alive when recaptured or not recaptured - assigned alive
2	Dead when recaptured or not recaptured - assigned dead
3	Live/Dead status unknown
TURB'N TAG CODES	
A	Fully inflated
B	Partially inflated
C	Pinhole, leaking
D	Burst
E	Not inflated at all
X	Detached from fish

APPENDIX I TABLE 2

Short-term turbine passage survival data on individual juvenile clupeids released from an induction system into the log bypass sluice (treatment fish) or the end of the log bypass sluice (control fish) at the Cabot Hydroelectric Station.
Fish were tagged with RMC's HI-Z Turb-N tags.
Description of condition codes and status codes are presented in Appendix Table 1.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Released	Recovered	At Large (min.)			No. Tags	No. Recovered	Condition Codes	
	30 September 1994 - LOT C1 CONTROL - WATER TEMP 17.5 C											
C1	.	YES	11:14	11:15	11:16	1	ALIVE	A	1	1	A	
C2	.	YES	11:17	11:19	11:20	1	ALIVE	A	1	1	A	
C3	.	YES	11:22	11:23	11:25	2	ALIVE	A	1	1	A	
C4	.	YES	11:24	11:25	11:26	1	ALIVE	A	1	1	A	
C5	.	YES	11:28	11:29	11:30	1	ALIVE	A	1	1	A	
C6	.	YES	11:30	11:31	11:32	1	ALIVE	A	1	1	A	
C7	.	YES	11:41	11:42	11:43	1	ALIVE	A	1	1	A	
C8	.	YES	11:43	11:43	11:45	2	ALIVE	A	1	1	A	
C9	.	YES	11:45	11:46	11:47	1	ALIVE	B	1	1	A	
C10	.	YES	11:48	11:48	11:49	1	ALIVE	A	1	1	A	
C11	.	YES	11:49	11:50	11:52	2	ALIVE	A	1	1	C	
C12	.	YES	11:52	11:53	11:54	1	ALIVE	QG	1	1	A	small hemorrhage on nose
C13	.	YES	12:01	12:01	12:03	2	ALIVE	A	1	1	A	
C14	.	YES	12:03	12:03	12:06	3	ALIVE	A	1	1	B	
C15	.	YES	12:05	12:05	12:07	2	ALIVE	A	1	1	A	
C16	.	YES	12:10	12:11	12:12	1	DESIG. DEAD		1	1	AX	only Turb'n tag recovered
C17	.	YES	12:11	12:12	12:13	1	ALIVE	A	1	1	A	
C18	.	YES	12:20	12:20	12:22	2	ALIVE	A	1	1	A	
C19	.	YES	12:21	12:22	12:23	1	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condi-tion Codes	
C20	.	YES	12:24	12:25	12:28	3	ALIVE	H	1	1	B	
M10	.	YES	16:06	16:07	16:11	4	ALIVE	A	1	1	A	
M11	.	YES	16:07	16:08	16:14	6	DESIG. DEAD		1	1	AX	only Turb'n tag recovered
M12	.	YES	16:13	16:13	16:15	2	ALIVE	A	1	1	A	
M13	.	YES	16:16	16:16	16:18	2	ALIVE	DH	1	1	A	
M14	88	YES	16:18	16:18	16:20	2	DEAD	D	1	1	A	large area of scales missing from side of fish, photographed
30 September 1994 - LOT T1 TEST - WATER TEMP 17.5 C												
T1	.	YES	9:02	9:03	9:05	2	ALIVE	A	1	1	A	
T2	.	YES	9:07	9:08	9:09	1	ALIVE	A	1	1	A	
T3	.	YES	9:10	9:11	9:16	5	ALIVE	A	1	1	B	
T4	.	YES	9:13	9:14	9:18	4	ALIVE	A	1	1	A	
T5	.	YES	9:20	9:21	9:22	1	ALIVE	A	1	1	A	
T6	.	YES	9:26	9:27	9:28	1	ALIVE	A	1	1	A	
T7	.	YES	9:28	9:29	9:32	3	ALIVE	C	1	1	B	
T8	.	YES	9:31	9:32	9:33	1	ALIVE	A	1	1	A	
T9	.	YES	9:34	9:35	9:37	2	ALIVE	A	1	1	A	
T10	.	YES	9:38	9:38	9:39	1	ALIVE	A	1	1	A	
T11	.	YES	9:44	9:44	.	.	UNKNOWN	Q	1	0		stationary radio signal off flume
T12	.	YES	9:47	9:47	9:48	1	ALIVE	A	1	1	A	
T13	.	YES	9:56	9:57	9:58	1	ALIVE	A	1	1	A	
T14	.	YES	9:58	9:59	10:03	4	ALIVE	A	1	1	A	
T15	.	YES	10:01	10:01	10:03	2	ALIVE	B	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condi-tion Codes	
T16	.	YES	10:07	10:08	10:09	1	ALIVE	A	1	1	B	
T17	100	YES	10:09	10:10	10:12	2	ALIVE	G	1	1	A	hemorrhage at anal fin, photographed
T18	.	YES	10:12	10:12	10:15	3	ALIVE	A	1	1	A	
T19	.	YES	10:15	10:15	10:16	1	ALIVE	A	1	1	A	
T20	.	YES	10:17	10:18	10:19	1	ALIVE	A	1	1	A	
M1	.	YES	15:08	15:08	15:11	3	ALIVE	A	1	1	A	
M2	.	YES	15:10	15:11	15:12	1	ALIVE	A	1	1	A	
M3	.	YES	15:38	15:39	15:40	1	ALIVE	A	1	1	A	
M4	.	YES	15:40	15:41	15:42	1	ALIVE	A	1	1	A	
M5	.	YES	15:42	15:42	15:45	3	ALIVE	A	1	1	A	
	1 October 1994	-	LOT C2	CONTROL	-	WATER TEMP	17.0 C					
C1	.	YES	9:30	9:32	9:34	2	ALIVE	A	1	1	B	
C2	.	YES	9:34	9:35	9:36	1	ALIVE	A	1	1	A	
C3	.	YES	9:39	9:40	9:41	1	ALIVE	A	1	1	A	
C4	.	YES	9:40	9:41	9:43	2	ALIVE	A	1	1	A	
C5	.	YES	9:43	9:44	9:45	1	ALIVE	A	1	1	A	
C6	.	YES	9:45	9:45	10:03	18	ALIVE	A	1	1	A	
C7	.	YES	9:54	9:55	9:57	2	ALIVE	A	1	1	A	
C8	80	YES	9:58	9:59	10:01	2	ALIVE	H	1	1	B	photographed
C9	.	YES	10:02	10:03	10:08	5	ALIVE	A	1	1	A	
C10	94	YES	10:11	10:11	10:14	3	ALIVE	HC	1	1	A	photographed
C11	.	YES	10:12	10:13	10:14	1	ALIVE	H	1	1	B	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Released	Recovered	At Large (min.)			No. Tags	No. Recovered	Condition Codes	
C12	.	YES	10:16	10:17	10:20	3	ALIVE	A	1	1	A	
C13	.	YES	10:33	10:34	10:36	2	ALIVE	A	1	1	A	
C14	.	YES	10:34	10:35	10:37	2	ALIVE	A	1	1	A	
C15	.	YES	10:38	10:39	10:40	1	ALIVE	B	1	1	A	
C16	.	YES	10:39	10:40	10:44	4	ALIVE	A	1	1	A	
C17	.	YES	10:42	10:43	10:44	1	ALIVE	A	1	1	A	
C18	.	YES	10:45	10:46	10:47	1	ALIVE	A	1	1	A	
C19	.	YES	10:47	10:48	10:50	2	ALIVE	A	1	1	A	
C20	.	YES	10:58	10:59	11:00	1	ALIVE	CG	1	1	A	hemorrhage around nose
C21	.	YES	10:59	11:00	11:11	11	ALIVE	A	1	1	A	
C22	.	YES	11:02	11:03	11:12	9	ALIVE	G	1	1	A	hemorrhage around nose
C23	.	YES	11:15	11:15	11:20	5	ALIVE	A	1	1	A	
C24	.	YES	11:16	11:17	11:19	2	ALIVE	A	1	1	A	
C25	.	YES	11:21	11:21	11:23	2	ALIVE	A	1	1	A	
C26	.	YES	11:38	11:39	11:40	1	ALIVE	A	1	1	A	
C27	.	YES	11:40	11:40	11:42	2	ALIVE	A	1	1	A	
C28	.	YES	11:42	11:43	11:45	2	ALIVE	A	1	1	A	
C29	.	YES	11:44	11:44	11:47	3	ALIVE	A	1	1	A	
C30	.	YES	11:47	11:47	11:50	3	ALIVE	A	1	1	A	
1 October 1994 - LOT T2 TEST - WATER TEMP 17.0 C												
T1	.	YES	12:25	12:25	12:27	2	ALIVE	DH	1	1	A	
T2	.	YES	12:27	12:27	12:30	3	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condition Codes	
T3	.	YES	12:31	12:31	12:33	2	ALIVE	C	1	1	A	
T4	.	YES	12:33	12:33	12:35	2	ALIVE	B	1	1	A	
T5	.	YES	12:36	12:36	12:37	1	ALIVE	C	1	1	A	
T6	.	YES	12:38	12:38	12:47	9	ALIVE	A	1	1	A	
T7	.	YES	12:40	12:40	12:43	3	ALIVE	A	1	1	A	
T8	.	YES	12:45	12:46	12:47	1	ALIVE	A	1	1	A	
T9	.	YES	12:49	12:49	12:53	4	ALIVE	A	1	1	A	
T10	.	YES	12:50	12:50	12:53	3	ALIVE	A	1	1	A	
T11	.	YES	12:54	12:55	12:58	3	ALIVE	A	1	1	A	
T12	.	YES	12:57	12:57	13:00	3	ALIVE	A	1	1	A	
T13	.	YES	13:00	13:01	13:03	2	ALIVE	A	1	1	A	
T14	.	YES	13:02	13:02	13:03	1	ALIVE	A	1	1	A	
T15	.	YES	13:07	13:07	13:12	5	DESIG. DEAD		1	1	AX	only Turb'n tag recovered
T16	.	YES	13:08	13:08	13:10	2	ALIVE	A	1	1	A	
T17	.	YES	13:13	13:13	13:14	1	ALIVE	A	1	1	A	
T18	.	YES	13:14	13:14	13:16	2	ALIVE	A	1	1	A	
T19	.	YES	13:16	13:16	13:18	2	ALIVE	A	1	1	B	
T20	.	YES	13:18	13:19	13:20	1	ALIVE	A	1	1	C	
T21	.	YES	13:23	13:23	13:25	2	ALIVE	C	1	1	A	
T22	.	YES	13:25	13:25	13:27	2	ALIVE	A	1	1	A	
T23	.	YES	13:28	13:28	13:31	3	ALIVE	HG	1	1	A	hemorrhage around nose
T24	.	YES	13:30	13:30	13:33	3	ALIVE	B	1	1	A	
T25	.	YES	13:34	13:34	13:36	2	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condition Codes	
T26	.	YES	13:35	13:35	13:38	3	ALIVE	CB	1	1	A	
T27	.	YES	13:37	13:37	13:38	1	ALIVE	G	1	1	A	hemorrhage around nose
T28	.	YES	13:39	13:39	13:41	2	ALIVE	A	1	1	A	
T29	.	YES	13:42	13:42	14:25	43	ALIVE	A	1	1	E	
T30	.	YES	13:43	13:43	13:44	1	ALIVE	A	1	1	A	
	3 October 1994	-	LOT C3	CONTROL	-	WATER TEMP	15.0 C					
C1	.	YES	13:11	13:12	13:14	2	ALIVE	A	1	1	A	
C2	.	YES	13:13	13:14	13:15	1	ALIVE	A	1	1	B	
C3	.	YES	13:17	13:18	13:29	11	ALIVE	A	1	1	B	
C4	.	YES	13:18	13:19	13:23	4	ALIVE	A	1	1	A	
C5	.	YES	13:26	13:26	13:28	2	ALIVE	A	1	1	A	
C6	.	YES	13:27	13:28	.	. .	UNKNOWN		1	0		stationary radio signal off flume
C7	.	YES	13:33	13:34	13:38	4	ALIVE	A	1	1	A	
C8	.	YES	13:41	13:42	13:48	6	ALIVE	A	1	1	A	
C9	.	YES	13:44	13:45	13:47	2	ALIVE	A	1	1	B	
C10	.	YES	13:49	13:50	13:52	2	ALIVE	A	1	1	A	
C11	.	YES	13:51	13:52	14:01	9	ALIVE	A	1	1	A	
C12	.	YES	13:54	13:54	13:57	3	ALIVE	A	1	1	B	
C13	.	YES	14:01	14:01	14:03	2	ALIVE	QG	1	1	A	hemorrhage around nose
C14	.	YES	14:06	14:07	14:10	3	ALIVE	A	1	1	A	
C15	.	YES	14:11	14:12	14:15	3	ALIVE	A	1	1	A	
C16	.	YES	14:13	14:13	14:24	11	ALIVE	A	1	1	B	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME Tagged	TIME Re-leased	TIME Re-covered	TIME At Large (min.)	Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data No. Tags	Turb-N Tag Data No. Re-covered	Turb-N Tag Data Condition Codes	Comments
C17	.	YES	14:23	14:24	14:29	5	DESIG. DEAD		1	1	AX	only Turb'n tag recovered
C18	.	YES	14:26	14:27	14:29	2	ALIVE	A	1	1	B	
C19	.	YES	14:30	14:31	14:34	3	ALIVE	A	1	1	A	
C20	.	YES	14:32	14:32	14:35	3	ALIVE	A	1	1	A	
C21	.	YES	14:37	14:37	14:43	6	ALIVE	A	1	1	A	
C22	.	YES	14:45	14:46	14:47	1	ALIVE	A	1	1	A	
C23	.	YES	14:47	14:47	14:49	2	ALIVE	A	1	1	A	
C24	.	YES	14:51	14:52	14:54	2	ALIVE	A	1	1	A	
C25	.	YES	14:53	14:53	14:56	3	ALIVE	A	1	1	A	
C26	.	YES	14:56	14:57	15:17	20	ALIVE	CQ	1	1	E	
C27	.	YES	14:58	14:59	15:02	3	ALIVE	A	1	1	B	
C28	.	YES	15:04	15:05	.	.	UNKNOWN	Q	1	0		stationary radio signal off flume
C30	.	YES	15:23	15:24	15:38	14	ALIVE	A	1	1	B	
C29	.	YES	15:24	15:24	15:26	2	ALIVE	A	1	1	A	
	3 October 1994	-	LCT T3	TEST	-	WATER TEMP	15.0	C				
T1	.	YES	9:57	9:58	9:59	1	ALIVE	A	1	1	B	
T2	.	YES	9:59	10:00	10:01	1	ALIVE	A	1	1	A	
T3	.	YES	10:01	10:02	10:06	4	ALIVE	A	1	1	B	
T4	.	YES	10:07	10:08	10:10	2	ALIVE	H	1	1	A	
T5	.	YES	10:13	10:14	10:23	9	ALIVE	A	1	1	A	
T6	.	YES	10:15	10:16	10:27	11	ALIVE	HDB	1	1	B	
T7	.	YES	10:25	10:26	10:35	9	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condition Codes	
4 October 1994 - LOT C4 CONTROL - WATER TEMP 15.5 C												
C1	.	YES	9:21	9:21	9:23	2	ALIVE	A	1	1	A	
C2	.	YES	9:24	9:25	9:26	1	ALIVE	A	1	1	A	
C3	.	YES	9:27	9:27	9:29	2	ALIVE	A	1	1	A	
C4	.	YES	9:28	9:28	9:30	2	ALIVE	A	1	1	A	
C5	.	YES	9:30	9:31	9:35	4	ALIVE	B	1	1	A	
C6	.	YES	9:33	9:33	9:35	2	ALIVE	A	1	1	A	
C7	.	YES	9:37	9:37	9:39	2	ALIVE	B	1	1	A	
C8	.	YES	9:43	9:44	9:46	2	ALIVE	A	1	1	A	
C9	.	YES	9:45	9:46	9:48	2	ALIVE	A	1	1	A	
C10	.	YES	9:47	9:47	9:51	4	ALIVE	A	1	1	A	
C11	.	YES	9:50	9:51	10:00	9	ALIVE	A	1	1	B	
C12	.	YES	9:53	9:54	9:57	3	ALIVE	A	1	1	A	
C13	.	YES	9:59	10:00	10:03	3	ALIVE	A	1	1	A	
C14	.	YES	10:09	10:09	10:11	2	ALIVE	A	1	1	A	
C15	.	YES	10:13	10:14	10:15	1	ALIVE	A	1	1	A	
C16	.	YES	10:21	10:22	10:23	1	ALIVE	A	1	1	A	
C17	.	YES	10:22	10:23	10:27	4	ALIVE	G	1	1	A	hemorrhage around nose
C18	.	YES	10:26	10:26	10:33	7	DESIG. DEAD	Q	1	1	AX	only Turb'n tag recovered
C19	.	YES	10:30	10:31	10:32	1	ALIVE	A	1	1	A	
C20	.	YES	10:35	10:35	10:44	9	ALIVE	DH	1	1	B	
C21	.	YES	14:14	14:15	14:16	1	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Released	Recovered	At Large (min.)			No. Tags	No. Recovered	Condition Codes	
C22	.	YES	14:15	14:16	14:17	1	ALIVE	A	1	1	A	
C23	.	YES	14:17	14:18	14:19	1	ALIVE	A	1	1	A	
C24	.	YES	14:20	14:21	14:22	1	ALIVE	A	1	1	A	
C25	.	YES	14:22	14:22	14:29	7	ALIVE	A	1	1	A	
C26	.	YES	14:24	14:25	14:26	1	ALIVE	A	1	1	A	
C27	.	YES	14:32	14:32	14:34	2	ALIVE	A	1	1	A	
C28	.	YES	14:34	14:34	14:39	5	ALIVE	A	1	1	A	
C29	.	YES	14:37	14:37	14:39	2	ALIVE	A	1	1	A	
C30	.	YES	14:41	14:41	14:45	4	ALIVE	H	1	1	B	
C31	.	YES	14:48	14:48	14:49	1	ALIVE	A	1	1	A	
C32	.	YES	14:50	14:50	14:52	2	ALIVE	A	1	1	A	
C33	.	YES	14:52	14:52	15:01	9	ALIVE	A	1	1	A	
C34	.	YES	14:55	14:56	14:57	1	ALIVE	A	1	1	A	
C35	.	YES	15:02	15:03	15:05	2	ALIVE	A	1	1	A	
4 October 1994 - LOT T4 TEST - WATER TEMP 15.5 C												
T1	.	YES	11:00	11:00	11:02	2	ALIVE	B	1	1	B	
T2	.	YES	11:02	11:02	11:04	2	ALIVE	A	1	1	A	
T3	.	YES	11:18	11:19	11:23	4	ALIVE	A	1	1	B	
T4	.	YES	11:21	11:22	11:24	2	ALIVE	A	1	1	A	
T5	.	YES	11:25	11:26	11:29	3	ALIVE	A	1	1	B	
T6	.	YES	11:27	11:27	11:30	3	ALIVE	C	1	1	A	
T7	.	YES	11:33	11:33	11:38	5	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Released	Recovered	At Large (min.)			No. Tags	No. Recovered	Condition Codes	
T8	.	YES	10:32	10:33	10:39	6	ALIVE	A	1	1	A	
T9	.	YES	10:39	10:40	.	.	UNKNOWN		1	0		stationary radio signal off flume
T10	.	YES	10:43	10:43	10:49	6	ALIVE	A	1	1	A	
T11	.	YES	10:54	10:55	11:01	6	DEAD	QDG	1	1	B	major abrasion on both sides of body, photographed
T12	.	YES	10:56	10:56	10:58	2	ALIVE	A	1	1	A	
T13	.	YES	11:00	11:00	11:04	4	ALIVE	A	1	1	B	
T14	.	YES	11:05	11:05	11:07	2	ALIVE	C	1	1	A	
T15	.	YES	11:07	11:08	11:09	1	ALIVE	A	1	1	B	
T16	.	YES	11:10	11:10	11:16	6	ALIVE	HD	1	1	A	
T17	.	YES	11:11	11:12	11:15	3	ALIVE	A	1	1	A	
T18	.	YES	11:18	11:18	11:26	8	ALIVE	A	1	1	A	
T19	.	YES	11:22	11:23	11:24	1	ALIVE	A	1	1	A	
T20	.	YES	11:25	11:25	11:27	2	ALIVE	C	1	1	A	
T21	.	YES	11:29	11:30	11:31	1	ALIVE	A	1	1	A	
T22	.	YES	11:33	11:34	11:35	1	ALIVE	A	1	1	A	
T23	.	YES	11:34	11:35	11:36	1	ALIVE	A	1	1	A	
T24	.	YES	11:38	11:38	11:39	1	ALIVE	A	1	1	A	
T25	.	YES	11:39	11:39	11:40	1	ALIVE	A	1	1	A	
T26	.	YES	11:42	11:43	11:44	1	ALIVE	A	1	1	A	
T27	.	YES	11:46	11:47	11:48	1	ALIVE	A	1	1	A	
T28	.	YES	11:48	11:48	11:49	1	ALIVE	CB	1	1	A	
T29	.	YES	11:50	11:50	11:52	2	ALIVE	A	1	1	A	
T30	.	YES	11:53	11:53	11:55	2	ALIVE	HCE	1	1	A	cut on head

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condi-tion Codes	
T8	.	YES	11:34	11:34	11:35	1	ALIVE	A	1	1	A	
T9	.	YES	11:37	11:37	11:43	6	DESIG. DEAD	Q	1	1	EX	only Turb'n tags recovered
T10	.	YES	11:41	11:41	11:44	3	ALIVE	A	1	1	A	
T11	.	YES	11:45	11:45	11:47	2	ALIVE	C	1	1	A	
T12	.	YES	11:46	11:46	11:49	3	ALIVE	A	1	1	A	
T13	.	YES	11:49	11:50	11:53	3	ALIVE	A	1	1	A	
T14	.	YES	11:52	11:52	11:54	2	ALIVE	A	1	1	B	
T15	.	YES	11:56	11:56	11:58	2	ALIVE	A	1	1	A	
T16	.	YES	11:57	11:57	11:59	2	ALIVE	DHE	1	1	A	slight cut above left eye
T17	.	YES	12:01	12:01	12:13	12	ALIVE	A	1	1	A	
T18	.	YES	12:02	12:03	.	.	UNKNOWN		1	0		stationary radio signal off flume
T19	.	YES	12:14	12:14	12:15	1	ALIVE	A	1	1	A	
T20	.	YES	12:17	12:17	12:18	1	ALIVE	C	1	1	A	
T21	.	YES	12:21	12:22	12:26	4	ALIVE	C	1	1	A	
T22	.	YES	12:22	12:23	12:26	3	ALIVE	A	1	1	A	
T23	.	YES	12:28	12:28	12:30	2	ALIVE	A	1	1	A	
T24	.	YES	12:29	12:29	12:31	2	ALIVE	A	1	1	A	
T25	.	YES	12:31	12:32	12:33	1	DESIG. DEAD		1	1	BX	only Turb'n tag recovered
T26	.	YES	13:25	13:26	13:27	1	ALIVE	A	1	1	A	
T27	.	YES	13:28	13:29	13:33	4	ALIVE	A	1	1	A	
T28	.	YES	13:31	13:32	13:33	1	ALIVE	A	1	1	A	
T29	.	YES	13:35	13:35	13:38	3	ALIVE	A	1	1	B	
T30	.	YES	13:37	13:38	13:41	3	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Released	Recovered	At Large (min.)			No. Tags	No. Recovered	Condition Codes	
C17	.	YES	12:36	12:36	12:40	4	ALIVE	A	1	1	A	
C18	.	YES	12:38	12:38	12:41	3	ALIVE	A	1	1	A	
C19	.	YES	12:45	12:46	12:48	2	ALIVE	A	1	1	A	
C20	.	YES	12:47	12:47	12:49	2	ALIVE	C	1	1	A	
C21	.	YES	12:50	12:50	12:51	1	ALIVE	A	1	1	A	
C22	.	YES	12:52	12:52	12:54	2	ALIVE	A	1	1	A	
C23	.	YES	12:53	12:53	12:55	2	ALIVE	C	1	1	A	
C24	.	YES	12:56	12:56	12:59	3	ALIVE	BC	1	1	A	
C25	.	YES	12:58	12:58	12:59	1	ALIVE	A	1	1	A	
C26	.	YES	13:01	13:01	13:03	2	ALIVE	QG	1	1	A	abrasions on both sides of fish
C27	.	YES	13:03	13:03	13:05	2	ALIVE	C	1	1	A	
C28	.	YES	13:04	13:05	13:07	2	ALIVE	A	1	1	B	
C29	.	YES	13:07	13:08	13:09	1	ALIVE	A	1	1	A	
C30	.	YES	13:08	13:09	13:14	5	ALIVE	A	1	1	B	
5 October 1994 - LOT T5 TEST - WATER TEMP 15.0 C												
T1	.	YES	10:00	10:01	10:03	2	ALIVE	C	1	1	A	
T2	.	YES	10:02	10:02	10:05	3	ALIVE	C	1	1	B	
T3	.	YES	10:05	10:05	10:08	3	ALIVE	A	1	1	A	
T4	.	YES	10:09	10:09	10:10	1	ALIVE	A	1	1	A	
T5	.	YES	10:11	10:11	10:16	5	ALIVE	C	1	1	A	
T6	.	YES	10:13	10:14	10:15	1	ALIVE	A	1	1	A	
T7	.	YES	10:17	10:17	10:19	2	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Re-leased	Re-covered	At Large (min.)			No. Tags	No. Re-covered	Condition Codes	
T31	.	YES	13:40	13:41	13:42	1	ALIVE	A	1	1	A	
T32	.	YES	13:43	13:43	13:44	1	ALIVE	A	1	1	A	
T33	.	YES	13:44	13:45	13:46	1	ALIVE	C	1	1	B	
T34	.	YES	13:48	13:48	13:50	2	ALIVE	A	1	1	A	
T35	.	YES	13:49	13:50	13:52	2	ALIVE	A	1	1	B	
5 October 1994 - LOT C5 CONTROL - WATER TEMP 15.0 C												
C1	.	YES	11:52	11:53	11:54	1	ALIVE	A	1	1	B	
C2	.	YES	11:54	11:54	11:58	4	ALIVE	A	1	1	A	
C3	.	YES	11:56	11:56	12:01	5	ALIVE	A	1	1	A	
C4	.	YES	12:01	12:01	12:03	2	ALIVE	C	1	1	A	
C5	.	YES	12:03	12:03	12:06	3	ALIVE	HCG	1	1	A	hemorrhage around nose
C6	.	YES	12:05	12:05	12:07	2	ALIVE	A	1	1	A	
C7	.	YES	12:08	12:08	12:11	3	ALIVE	A	1	1	A	
C8	.	YES	12:10	12:10	12:12	2	ALIVE	A	1	1	A	
C9	.	YES	12:16	12:16	12:19	3	ALIVE	A	1	1	A	
C10	.	YES	12:17	12:17	12:19	2	ALIVE	A	1	1	A	
C11	.	YES	12:21	12:22	12:24	2	ALIVE	C	1	1	A	
C12	.	YES	12:22	12:23	12:24	1	ALIVE	C	1	1	A	
C13	.	YES	12:25	12:25	12:27	2	ALIVE	A	1	1	A	
C14	.	YES	12:27	12:27	12:31	4	ALIVE	C	1	1	B	
C15	.	YES	12:29	12:29	12:31	2	ALIVE	A	1	1	A	
C16	.	YES	12:32	12:32	12:34	2	ALIVE	A	1	1	A	

APPENDIX I TABLE 2

Continued.

Fish No.	Length (mm)	Radio Tagged	TIME				Alive/ Dead (1h)	Condition Codes	Turb-N Tag Data			Comments
			Tagged	Released	Recovered	At Large (min.)			No. Tags	No. Recovered	Condition Codes	
T8	.	YES	10:19	10:19	10:23	4	ALIVE	A	1	1	A	
T9	.	YES	10:21	10:21	10:22	1	ALIVE	A	1	1	A	
T10	.	YES	10:25	10:25	10:27	2	ALIVE	A	1	1	A	
T11	.	YES	10:27	10:27	10:31	4	ALIVE	C	1	1	A	
T12	.	YES	10:29	10:29	10:32	3	ALIVE	A	1	1	B	
T13	.	YES	10:34	10:34	10:36	2	ALIVE	A	1	1	A	
T14	.	YES	10:35	10:35	10:37	2	ALIVE	A	1	1	A	
T15	.	YES	10:38	10:38	10:41	3	ALIVE	A	1	1	A	
T16	.	YES	10:40	10:40	10:50	10	ALIVE	A	1	1	A	
T17	.	YES	10:44	10:44	10:55	11	ALIVE	C	1	1	A	
T18	.	YES	10:55	10:55	10:57	2	ALIVE	A	1	1	A	
T19	.	YES	10:58	10:59	11:00	1	ALIVE	A	1	1	A	
T20	.	YES	11:00	11:00	11:03	3	ALIVE	B	1	1	A	
T21	.	YES	11:02	11:02	11:06	4	ALIVE	C	1	1	A	
T22	.	YES	11:06	11:06	11:07	1	ALIVE	A	1	1	A	
T23	.	YES	11:08	11:09	11:10	1	ALIVE	A	1	1	A	
T24	.	YES	11:10	11:10	11:11	1	ALIVE	A	1	1	A	
T25	.	YES	11:26	11:26	11:27	1	ALIVE	A	1	1	A	
T26	.	YES	11:27	11:27	11:30	3	ALIVE	A	1	1	B	
T27	.	YES	11:30	11:30	11:31	1	ALIVE	C	1	1	A	
T28	.	YES	11:32	11:32	11:33	1	ALIVE	C	1	1	A	
T29	.	YES	11:33	11:33	11:35	2	ALIVE	EHG	1	1	A	hemorrhage on nose and cut on head, photographed
T30	.	YES	11:35	11:35	11:39	4	ALIVE	A	1	1	B	

APPENDIX II - Statistical output

TESTYPE=CONTROL

TABLE OF CONDITN BY REP

CONDITN / Frequency / Expected / Cell Chi-Square	1	2	3	4	5	Total
ALIVE	22 23.833 0.141	30 28.6 0.0685	27 28.6 0.0895	34 33.367 0.012	30 28.6 0.0685	143
DEAD	3 1.1667 2.881	0 1.4 1.4	3 1.4 1.8286	1 1.6333 0.2456	0 1.4 1.4	7
Total	25	30	30	35	30	150

STATISTICS FOR TABLE OF CONDITN BY REP

Statistic	DF	Value	Prob
Chi-Square	4	8.135	0.087
Likelihood Ratio Chi-Square	4	9.641	0.047
Mantel-Haenszel Chi-Square	1	2.559	0.110
Fisher's Exact Test (2-Tail)			5.94E-02
Phi Coefficient		0.233	
Contingency Coefficient		0.227	
Cramer's V		0.233	

Sample Size = 150

WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

TESTYPE=TRTMENT

TABLE OF CONDITN BY REP

CONDITN / REP	1	2	3	4	5	Total
ALIVE	24	29	28	32	30	143
	23.833	28.6	28.6	33.367	28.6	
	0.0012	0.0056	0.0126	0.056	0.0685	
DEAD	1	1	2	3	0	7
	1.1667	1.4	1.4	1.6333	1.4	
	0.0238	0.1143	0.2571	1.1435	1.4	
Total	25	30	30	35	30	150

STATISTICS FOR TABLE OF CONDITN BY REP

Statistic	DF	Value	Prob
Chi-Square	4	3.083	0.544
Likelihood Ratio Chi-Square	4	4.237	0.375
Mantel-Haenszel Chi-Square	1	0.039	0.844
Fisher's Exact Test (2-Tail)			0.608
Phi Coefficient		0.143	
Contingency Coefficient		0.142	
Cramer's V		0.143	

Sample Size = 150
WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.