Evaluation Of Migrational Delays On The Reproductive Success Of Adult Hatchery Spring Chinook Salmon In The Columbia And Snake Rivers (Objective 2 Only)

Evaluation of the Use of the Torry Fish Fatmeter to Non-Lethally Estimate Lipid in Adult Salmon

by

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EXECUTIVE SUMMARY

The metabolic energy available for migrating adult salmon is fixed when they enter fresh water. During the migration, salmon tend to primarily use lipid or fat as an energy source. Excessive energy demands resulting from migrational delay below dams or due to fallback (an adult fish passing downstream over the dam) may adversely impact their ability to successfully reproduce.

Previous research on bioenergetics of salmon migration was complicated by the facts that it was a) generally necessary to kill the fish to determine energy reserves, b) not possible to clearly identify the origin of the fish sampled, and c) necessary to base conclusions on population means rather than individuals. The development and implementation of PIT tags and receivers in the Columbia River basin have solved the identification problems. Furthermore, number of techniques have been developed to non-lethally estimate body composition. This research evaluated the use of the Torry Fish Fatmeter to non-lethally estimate whole body lipid reserves in adult salmon. This machine has been used to measure lipid content in ground meats and fillets, but has not been applied for use in whole fish. In this study, the efficacy of the Torry Meter for whole lipid measurements was examined. In conjunction with PIT-tagged fish, this method would allow correlation between energy reserves and migrational times for individual fish.

The Torry Fish Fatmeter uses a low power microwave source to estimate lipid content. There was a significant relationship between the Torry readings and the conventionally determined lipids (r^2 = 0.913). The Torry Meter did not affect the operation of the PIT or radio tags. The PIT or radio tags did not impact the accuracy of

the Torry Meter. Although the statistical power of the experiment was low, there was no statistically significant impact on the green-egg to eyed-egg survival of captive rainbow trout broodstock exposed to either 0, 1, or 4 sets of Torry meter readings.

Based on an assumed 60:40 percent distribution of lipids between migration and spawning, the Torry Meter could detect a 38% increase in migrational energy demand. The Torry Meter may give a better estimate of remaining lipid reserves during the latter stages of migration or spawning when visceral fat reserves have been depleted and therefore could be a better predictors of migrational and reproductive success than the whole body lipid value. This question can not be answered without in-river research.

INTRODUCTION

Adult salmon (*Oncorhynchus* spp.) and steelhead (*O. mykiss*) migrating to their natal streams in tributaries of the Columbia River must pass eight or nine dams and reservoirs, four each in the lower Columbia and Snake Rivers, and five in the mid-Columbia River. Compilation of past radio telemetry data show passage times often averaged from 1 to 5 days/project (Bjornn and Peery 1992). When compounded over eight to nine dams, these time delays could substantially impact salmonid populations if reproductive success is compromised. Significant modifications to passage facilities and hydro operations have been made to try to reduce adult delays at Columbia Basin dams.

Successful reproduction in anadromous salmonids requires migration of both sexes to the spawning grounds, appropriate reproductive behavior (nest building and spawning), high gamete quality, proper embryonic development, and survival of offspring for downstream migration of juvenile fish. Because salmon do not feed during the migration, the amount of energy available is fixed when they enter fresh water.

During the migration, salmon tend to primarily use lipid or fat as an energy source (Thurston and Newman 1962). Preferential use of fat early in maturation conserves the structure of muscles needed for swimming (Hendry 1998). The development of secondary sexual characteristics and actual spawning activities are fueled largely by metabolism of protein (Hendry 1998).

The impact of hydropower-induced delays on energy reserves and reproductive success of Pacific salmon migrating up the Columbia and Snake Rivers is largely

unknown. The standard analysis for measurement of energy, lipid, and protein reserves requires that the fish be killed. Because of ESA constraints and potential impacts on wild fish, opportunities to conduct this type of sampling in the Columbia River Basin are extremely limited. However, non-lethal techniques may be allowed. A number of non-destructive methods for lipid and protein analysis have been developed for use in fish farming and processing (Sigurgisladottir et al. 1997).

The ability to non-destructively estimate lipid reserves of an individual fish during migration up the Columbia River would greatly increase our ability to study the impact of hydrosystem delay or fallback. In addition, existing PIT tagging of smolts will allow identification of the origin of large numbers of individual fish and the ability to monitor their upstream passage. The use of these two techniques would allow us to determine bioengergetics in relationship to migration time, migration distance, or number of fallbacks. In the absence of non-destructive lipid techniques, it is impossible to study the impact of specific hydropower impacts (delay or fallback) on the energy reserves of individual fish and conclusions must be based on populations means of groups of migrating fish. In this report we present the results of the evaluation of the use of the Torry Fish Fatmeter to non-destructively estimate whole body lipid in salmon.

The objectives of this project were to 1) evaluate the use of the Torry Fish Fatmeter to estimate the whole body lipid content of Pacific salmon; 2) evaluate the impact of the Torry Meter on PIT- and radio-tag operation; 3) evaluate the impact of PIT- and radio-tags on the Torry Meter; and 4) assess the potential impact of the Torry Meter on the reproductive success of salmon. This work comprises Objective 2 of the Revised

Final Research Proposal dated February 2000. The other research objectives contained in the original proposal were not funded.

METHODS

Torry Fish Fatmeter

A 692-CDF Torry Fish Fatmeter (Serial No. 2270) was purchased from Distell Industries in West Lothian, Scotland, United Kingdom and used in all work. The meter has four channels that can be calibrated at the factory for different fish species. All readings were made on the Chinook #2 calibration on Channel 4. The operation of the meter was checked daily using the Distell Industries check pad. The test values on the check pad were 6.1and15.0%.

The Torry Fish Fatmeter uses a low-powered microwave sensor (2 mW output at 2,000 MHz) to measure the water content of biological tissues. In fish, the lipid content is strongly correlated with water content. This meter is field-portable and a series of measurements can be completed within 2-3 minutes.

Radio Tags and Radio Receiver

Two MCFT Series Coded Microprocessor Transmitters Tags were obtained from Lotek Wireless, Inc., New Market, Ontario, Canada. These tags are about 75 mm long by 15 mm in diameter and are identical to those used in adult salmon research in the Columbia River. These tags send a coded signal about every 15 seconds (Tag #1: Channel 21, Code 18 and Tag #2: Channel 21, Code 20). A portable Lotek receiver was

used to check the audible code transmission of the tags during the tag interaction work. After the completion of the tag interaction work, a separate Lotek receiver with code reading capability was used to verify that the codes were being accurately transmitted.

PIT Tag and PIT Tag Detector

The PIT tags used in this work were 133 MHz tags. The PIT tags were read using a Destron Fearing Portable Transceiver System, Model FS2001F.

Source of Test Fish

Six different batches of fish were used in the experimental work. The source and general characteristics of the different batches of fish are in Table 1; detailed data for each

Table 1. General information for the six batches of fish used in Torry Fish Fatmeter experiments. Batches 1, 2, 4, and 5 had completed their migration. Batch 3 were immature fish. Batch 6 was used in an exercise experiment at the Manchester Marine Experimental Station.

Batch	Source of fish	Species	Type	Additional comments	Date killed	Detailed data in:
1	Carson NFH[1]	Spring chinook	Pre-spawning adults	Fish arrived at Carson between 6/26/00 and 7/6/00	7/6/00	Appendix A, Table A-1
2	Little White Salmon NFH	Spring chinook	Pre-spawning adults	Used by USGS for energetic research	7/6/00	Appendix A, Table A-2
3	Minter Creek Hatchery	Coho	Immature		8/24/00	Appendix A, Table A-3
4	Carson NFH	Spring chinook	Post-spawning adults		8/23/00	Appendix A, Table A-4
5	Dworshak NFH	Spring chinook	Post-spawning adults		8/30/00	Appendix A, Table A-5
6	Dungeness Hatchery	Spring chinook	Post-spawning adults		8/01-9/01	Appendix A, Table A-6

[1] NFH = National Fish Hatchery

batch of fish is presented in Appendix A. At the hatchery, the fish were killed by a blow to the head or by severing the spinal column. The fish were placed on ice and transported to the Northwest Fisheries Science Center in Seattle, individually wrapped in plastic bags, and frozen until processed.

Preliminary Protocol Development

To gain experience with the Torry Meter, a number of preliminary experiments were conducted. These experiments specifically looked at the impact of surface moisture and temperature on the Torry reading.

Measuring Convention

As recommended by the manufacturer, a series of eight readings were made on each fish. Each fish was positioned ventral side facing the observer and head facing to the left. Reading 1 was closest to the head and reading 4 was closest to the tail (Fig. 1). After the first four readings were completed, the fish was turned over and a second set of four readings was made from the head to the tail. For some smaller fish (< 30 cm fork length), it was only possible to obtain three readings on each side. All eight readings were recorded and the means were computed from these readings.

Experiment 1 - Effects of Surface Drying

In the first experiment, two previously frozen adult spring chinook (3,812 g, 5,456 g) were used. The fish were removed from their bags and allowed to defrost in a coldroom (3 - 4°C) in water. Each fish was removed from the coldroom and placed on a

wooden surface and four equally spaced readings were made on each side (total of eight readings). After the readings were completed, the fish was returned to the coldroom and the other fish was removed from the coldroom and measured. Thirty sets of eight Torry readings were made on each fish over a 3-hour interval.

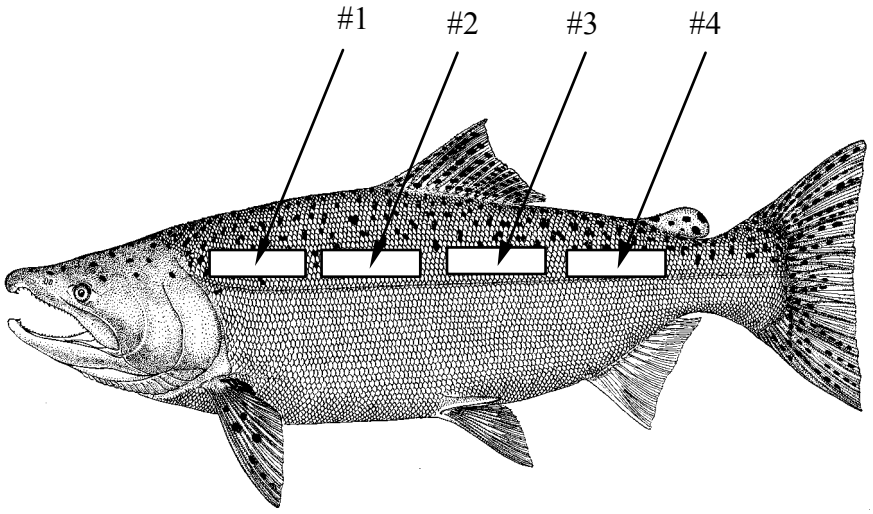
#1
#2
#3
#4

Figure 1. Location of Torry reading for adult salmon. Locations 5 - 8 are on the otherside of the fish.

Experiment 2 - Effects of Moisture Levels

In the second experiment, four adult chinook salmon (average weight = 5,053 g; range = 4,518 - 5,697 g) were exposed to three levels of moisture. The fish were removed from their bags and allowed to defrost in a coldroom (3 - 4°C) in water. Each fish was removed from the coldroom and placed on a wooden surface. Four series of readings were made on each fish for the three following moisture levels:

Moisture Level	Treatment
"wet"	splashed with cold water prior to each measurement
"dry"	dried with a single paper towel prior to each measurement
"very dry"	left uncovered in cold room for 1 hour before measurement

Four equally spaced Torry readings were made on only one side of the fish. This was done to avoid potential removal of slime and surface moisture that may have occurred if the fish was turned over to allow Torry readings on the other side.

Experiment 3 - Impact Of Tissue Temperature On Torry Reading

In the third experiment, the Torry readings on 14 spring chinook (average body weight = 4,202 g; range = 3,196 - 4,786 g) were measured at two different temperatures. The fish were removed from their bags and allowed to defrost in the coldroom (3 - 4°C) in water. Each fish was removed from the coldroom and placed on a surface and four

equally spaced readings were made on each side (total of eight readings). The fish were placed in a large sink with running "warm" water. The fish were allowed to equilibrate in the "warm" water for at least two hours before they were remeasured. The water temperatures in the coldroom and "warm" water were 3.1 ± 0.1°C and 18.6 ± 0.1°C, respectively.

Experiment 4 - Impact of Eggs on Torry Readings

In this experiment, Torry readings on five adult female chinook salmon (average weight = 4,595 g; range = 4,233 - 5,234 g) were measured before and after removal of all eggs. The fish were removed from their bags and allowed to defrost in the coldroom (3 - 4°C) in water. Each fish was then removed from the coldroom and placed on a wooden surface and four equally spaced readings were made on each side (total of eight readings). Torry readings were made on the intact fish, eggs were removed and the readings repeated. The weight of eggs removed from each female was determined.

General Procedures for the Torry Measurements

The following general procedure for making Torry reading was derived from the preliminary experiments and used in all subsequent work. Prior to making the Torry readings, the fish were removed from their bags and allowed to defrost in the coldroom (3 - 4°C) in a water bath. Each fish was removed from the coldroom and placed on a PVC measuring board and a series of equally spaced readings were made on each side (total of eight readings). Just prior to the Torry measurements, any excess moisture on the fish was removed by a single swipe of the hand. Torry readings were obtained from fish from all six batches of fish.

Determination of Lipids and Protein Content

Fish were ground in a food processor and a subsample (approximately 150 g) was dried to constant weight at 105°C to determine moisture content. The dried sample was then ground in a coffee grinder. Lipids were determined from a subsample (approximately 2 g) by extraction with dimethyl chloride using the Soxlet method (AOAC 1990). Protein was determined by measuring nitrogen (N) using a LECO FP-2000 nitrogen analyzer and a conversion of N to protein of 6.25. Percent lipids, protein, and solids are expressed on a wet-weight basis:

$$\text{Percent Lipids} = \left[\frac{\text{weight of lipids in fish}}{\text{wet weight of fish}}\right]100$$

$$\text{Percent Protein} = \left[\frac{\text{weight of protein in fish}}{\text{wet weight of fish}}\right]100$$

$$\text{Percent Solids} = \left[\frac{\text{dry weight of fish}}{\text{wet weight of fish}}\right]100$$

Tag Interaction Work

Experiment 1 - Impact of Torry Meter on PIT-Tag Operation (prior to insertion in fish)

The first experiment evaluated the impact of the Torry Meter on PIT-tag operation before the tags were inserted into the fish. The PIT tags were place directly on the sensor head of the Torry Meter. Ten Torry Meter readings were made with the PIT

tag parallel and perpendicular to the long axis of the sensor. The measurements were repeated with the PIT tag 30 mm above the sensor head. These measurements were repeated for 10 different PIT tags. The operation of each PIT tag was checked at the start and finish of each series of readings.

Experiment 2 - Impact of Torry Meter on Radio Tag Operation (prior to insertion in fish

The second experiment evaluated the impact of the Torry Meter on radio tag operation before the tags were inserted into the fish. The radio tags were tested in the same way as the PIT tags. In addition, 10 readings were made with the Torry Meter touching the antenna wire. The operation of each radio tag was checked at the start and finish of each series of readings by listening to the coded transmission. The actual transmission of the code was not checked because this Lotek receiver did not have the ability to decode the transmission. At the end of the experiment, the operation of the coded transmission was checked with a second receiver at Bonneville Dam.

Experiment 3 - Interaction of Torry Meter on PIT and Radio Tag Operation (after insertion in fish)

The third experiment evaluated the impact of the Torry Meter on PIT and radio tag operation after the tags were inserted into the fish. Torry Meter readings on 10 adult spring chinook (average weight = 3,893 g; range = 2,179 - 5,086 g) fish with and without the PIT and radio tags were compared. Four sets of four readings were made on one side of each fish, then a PIT and radio tag was inserted and measurements repeated. The

operation of PIT and radio tags was checked at the start and finish of each series of readings.

Impact of Torry Meter on Egg Quality

Facility Information

The effects of Torry Meter readings on egg quality were tested on broodstock reared in spring water at Troutlodge's Orting facility located near Sumner, Washington. The rainbow trout (*O. mykiss*) used in this experiment were held separately in a single raceway. Over the period of time when the Torry readings were conducted, the water temperature ranged from 8.9 - 9.8°C.

Experimental Fish

The experimental fish were a domestic rainbow trout stock that typically spawned in February. At the start of the experiment, the fish were 2.5 years old and had been spawned the previous year. The fork length of the test fish ranged from 40 - 50 cm (46 ± 2.7 cm). The fish were fed a commercial Rangen trout broodstock feed 0.5% per day for five days per week.

Experimental Procedures

All the experimental fish were PIT tagged at the start of the experiment. The fish were randomly divided into three treatment groups: Group A - a single Torry reading at the start of the experiment, Group B - four Torry readings at 3 week intervals, and Group C - no Torry measurements. There were 11 fish in Groups A and C, and 12 in Group B. The fish were checked for mortalities daily.

During each Torry reading, the fish were crowded toward one end of the raceway and removed by nets in groups of 1 - 2 into a tank containing approximately 100 mg/L MS-222. When the fish were adequately anesthetized, the PIT-tag code was read and the treatment group determined. Fish that did not require a Torry measurement were returned directly to the raceway without further handling. The fish to be measured were placed in a PVC measuring rack and a series of four readings on each side were recorded and then the fish returned to the raceway. Torry readings were taken on 21 September, 11 October, 1 November, and 22 November 2000.

Once the series of four Torry readings had been completed, the fish were checked for ripeness on a weekly basis. Spawning occurred from 6 February to 2 April, with the peak of spawning on 19 March 2000. Ripe fish were killed by a blow to the head and spawned manually after making an incision with a spawning knife. The eggs were rinsed with a buffered saline solution (50 mM glycine, 25 mM tris, and 0.5% NaCl). Approximately 200 mL of the buffered saline was added to the eggs and a pooled milt sample was added. The eggs were incubated in Heath trays divided by inserts so that eggs from each female remained separate.

At the eyed stage, the eggs were sorted to determine survival. Three subsamples of approximately 200 eggs were sorted from each egg lot. The eggs were sorted into three categories: eyed embryos, unfertilized (blank), and dead (white). The blank eggs were those that did not respond to physical shocking and remained transparent. These eggs cannot be removed by machine sorters and were removed by hand. The mean of the three subsamples were used for all statistical analysis.

Statistical Analysis

One way analysis of variance, student t test, and regression were used to analyze the data (Dunn and Clark 1974). The data was compared with ANOVA or student t with $\alpha = 0.05$ to detect significant treatment effects. Cricket Graph and StatView were used for processing data.

RESULTS

Preliminary Protocol Development

Experiment 1 - Effects of Surface Drying

In the first surface drying experiment, the mean Torry reading showed a positive linear relationship for the two fish tested ($r^2 = 0.465$ and 0.719) with the reading number (Fig. 2). The body surface was noticeably drier by the end of the 30 sets of measurements, although the degree of dryness was not quantified.

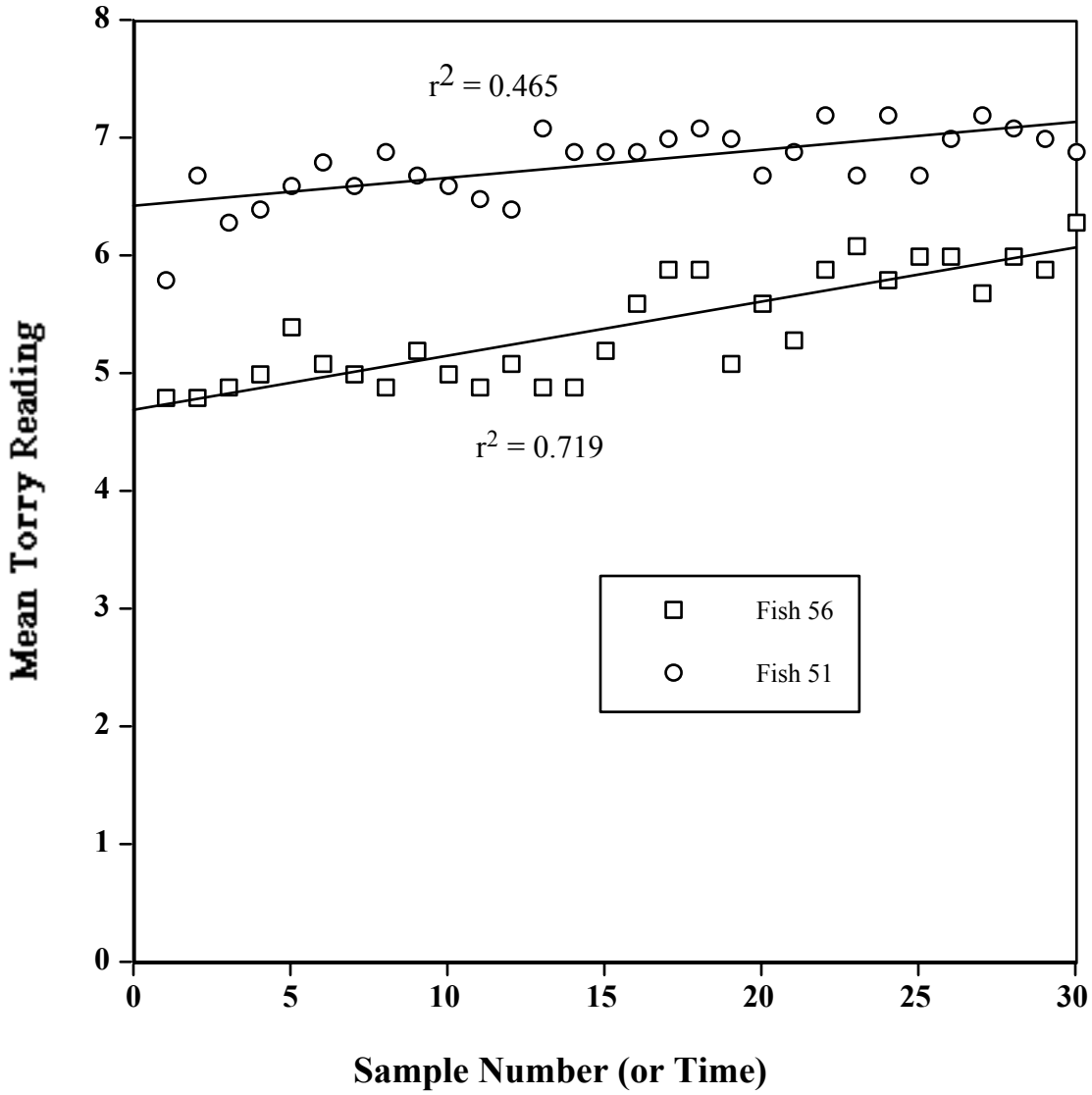
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
Mean Torry Reading
Sample Number (or Time)
r2 = 0.465
r2 = 0.719
Fish 56
Fish 51

Figure 2. Impact of surface drying on mean Torry reading for two fish (30 sets of eight readings were collected over a 3 hour period).

Experiment 2 - Effects of Moisture Levels

The results of the moisture level experiment are presented in Table 2. There was a significant effect of drying on the meter readings ($P < 0.05$). The readings were significantly higher for dry fish compared to wet fish.

Table 2. Mean (± SD) Torry readings for three levels of dryness.

Fish No.	n	"Wet"	"Dry"	"Very Dry"
61	4	6.71 ± 0.20	7.14 ± 0.27	7.43 ± 0.42
60	4	5.01 ± 0.09	5.67 ± 0.15	5.94 ± 0.18
55	4	7.50 ± 0.14	8.13 ± 0.27	8.17 ± 0.16
54	4	5.03 ± 0.06	5.57 ± 0.24	5.36 ± 0.66

Experiment 3 - Impact of Tissue Temperature on Torry Reading

In the temperature experiment, the average mean Torry readings for all 14 fish were 2.87 ± 2.38 for the cold measurements and 2.93 ± 2.28 for the warm measurements (Fig 3). There was no statistical significant effect ($P > 0.05$) of tissue temperature on the Torry readings (Appendix A, Table A-7) based on a paired t-test.

Experiment 4 - Impact of Eggs on Torry Readings

In the egg experiment, the average Torry Meter readings was 1.02 ± 0.24 for the fish with eggs and 1.07 ± 0.31 after the eggs were removed. There was no statistical

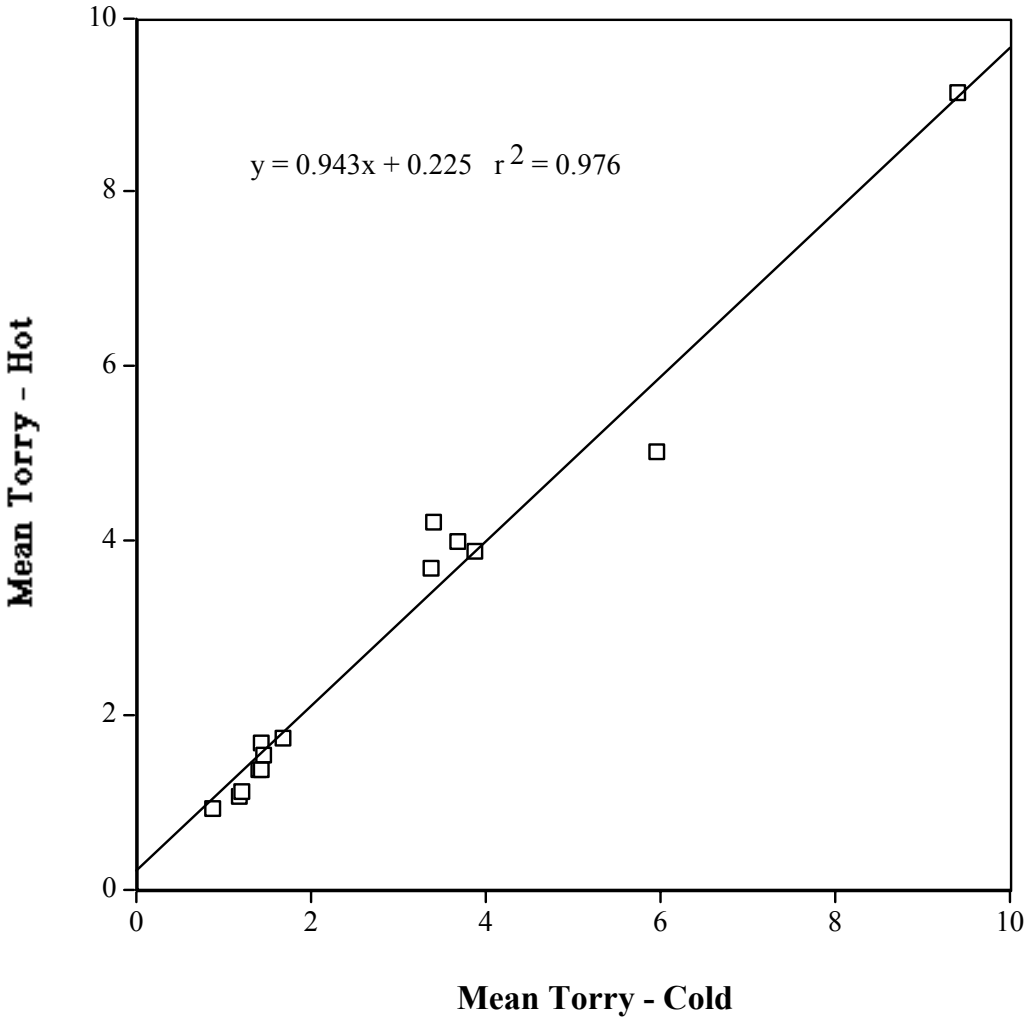
y = 0.943x + 0.225 r 2 = 0.976
Mean Torry - Hot
Mean Torry - Cold
0
2
4
6
8
10

Figure 3. Comparison of mean Torry readings for fish measured under cold and warm conditions.

significant effect ($P > 0.05$) of egg presence on the Torry readings (Appendix A, Table A-8) based on a paired t-test.

Torry-Lipid Relationship

Detailed information on the relationship between Torry readings, lipid content, solids content, protein content, fish length and weight, sex, and reproductive status are presented for each batch of fish (Appendix A, Tables A-1 to A-6). Summary information for mean Torry readings, weight, lipids, and solids for each batch of fish are presented in Table 3. The lipid content of the post-spawners was consistently lower than the pre-spawners ($P < 0.05$).

There was a significant difference between the males and females for the mean Torry readings, lipids, and solids. This appears to be due primarily to the fact that the fish in Batch 6 were almost all female (60 out of 66) and this batch contributed 60 out of the total 89 females. It is likely that this difference is due to the fact that the majority of the females were post-spawners and had lower lipid and solids content. These differences are apparent in the overall means for the sexes (Table 4).

Table 4. Comparison of mean Torry readings, lipids, and solids for male and female fish (means superscripted with the same letter are significantly different at $P < 0.05$).

Sex	n	Mean Torry	Weight (g)	Lipids(Wet %)	Solids (%)
Males	39	3.45 ± 2.57^{a}	$4{,}047 \pm 1{,}817$	8.47 ± 3.99^{b}	27.04 ± 5.05^{c}
Females	90	1.50 ± 2.09^{a}	$4{,}054 \pm 1{,}030$	3.79 ± 3.51^{b}	20.84 ± 5.52^{c}

There were no statistically significant differences ($P > 0.05$) between sexes in the pre-spawning fish (Batches 1-3) for mean Torry, lipids, or solids. No statistical significant relationships ($P > 0.05$) were found between either weight or length and mean Torry, lipids, or solids.

Table 3. Summary information for the six batches of fish used in determination of the Torry-lipid relationship (means (range)).

Batch	Source of Fish	Species	Type	Mean Torry	Weight (kg)	Lipids (Wet %)	Solids (%)	n
1	Carson NFH[1]	Spring chinook	Pre-spawning adults	2.4 (0.9-4.4)	4.35 (1.59-6.67)	9.33 (6.45-12.95)	29.43 (27.24-32.46)	25
2	Little White Salmon NFH	Spring chinook	Pre-spawning adults	6.0 (2.9-10.1)	4.96 (4.39-5.48)	12.99 (9.69-16.25)	32.88 (29.74-36.46)	10
3	Minter Creek Hatchery	Coho	Immature	8.2 (5.6-9.9)	0.72 (0.36-1.10)	12.44 (6.00-15.26)	32.34 (31.17-33.75)	5
4	Carson NFH	Spring chinook	Post spawning adults	1.2 (0.7-2.2)	4.83 (3.56-5.98)	6.26 (3.26-9.17)	25.96 (23.39-28.65)	7
5	Dworshak NFH	Spring chinook	Post spawning adults	1.2 (0.7-1.7)	3.77 (1.66-4.96)	4.95 (2.78-7.24)	22.51 (19.80-25.30)	18
6	Dungeness Hatchery[2]	Spring chinook	Post spawning adults	0.7 (0.5-1.4)	4.02 (1.27-7.00)	2.00 (0.08-6.77)	17.92 (12.74-25.10)	66

[1] NFH = National Fish Hatchery
[2] Reared at Manchester Marine Experiment Station for exercise experiment

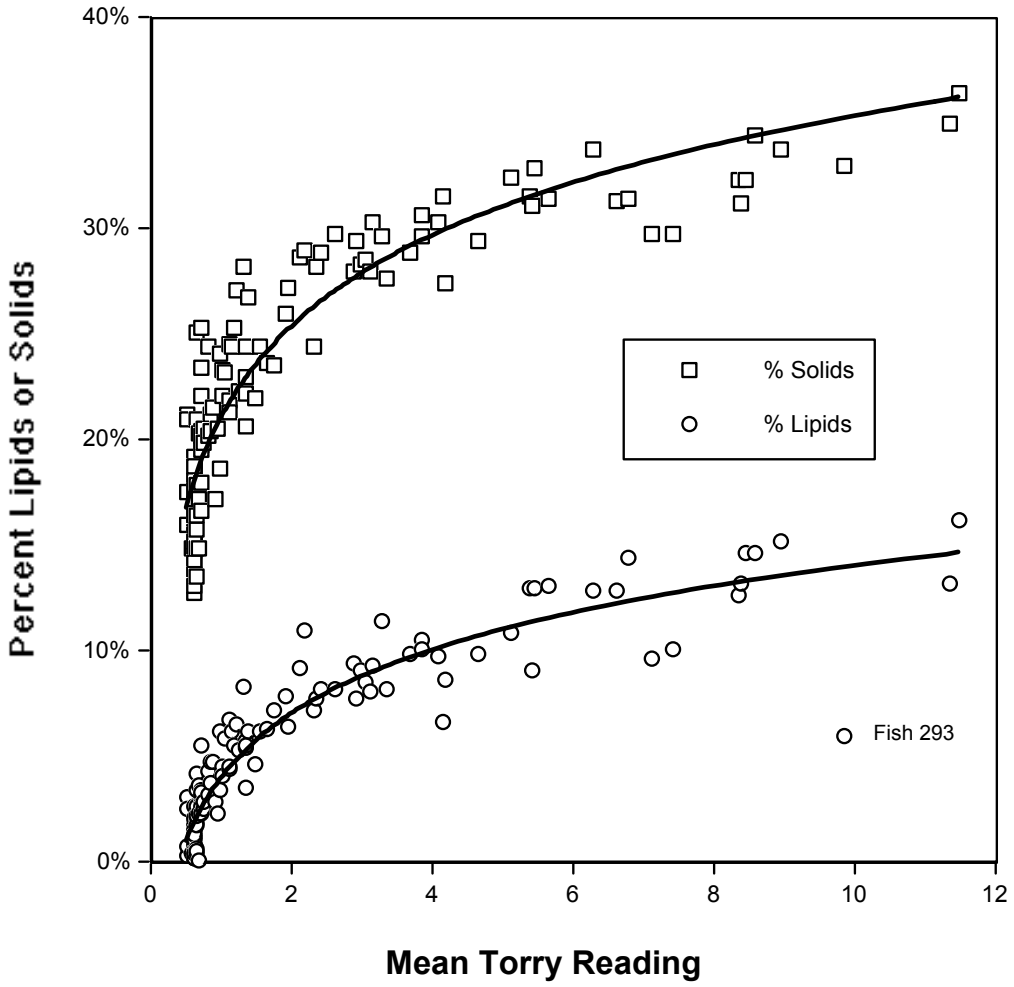

Figure 4. Relationship between mean Torry readings and percent whole body lipids and percent solids for all batches of fish.

There was a significant relationship ($P < 0.05$) between the mean Torry reading and the lipid content (Fig. 4) as measured by Soxlet method. Fish number 293 appeared to be an outlier, possibly due to analytical error and was removed from the data set. Linear, logarithmic, and second order polynomial equations were fitted to the mean Torry-lipids and mean Torry-solids data (Table 5).

Table 5. Regression analysis of mean Torry readings versus total lipids and solids

Equation	r^2	
	Mean Torry-Lipids (%)	Mean Torry-Solids (%)
linear	0.771	0.665
logarithmic	0.913	0.848
2nd order polynomial	0.864	0.788

The logarithmic regression equation had the highest r^2 value:

$$\%\text{Lipid} = 0.104 \times \log(\text{mean Torry}) + 0.040 \qquad r^2 = 0.913$$

$$\%\ \text{Solids} = 0.143 \times \log(\text{mean Torry}) + 0.211 \qquad r^2 = 0.848$$

The residual values for logarithmic regression curve for lipids (actual - predicted) showed no trends in variance.

The linear regression plots of the mean Torry versus whole body lipid content show two distinct slopes: a high sloped region between 0-2% lipids and a lower sloped region between 2-12% lipids. To detect differences in lipid relationships, the logarithm of the weight was plotted against the logarithm of the total lipid content in grams

(lipid%× total weight) for each batch of fish. There was a clear division between the pre-spawning and post-spawning fish using this method (Fig. 5). When the two groups of fish were plotted separately, there was a significant linear relationship between both mean Torry readings and

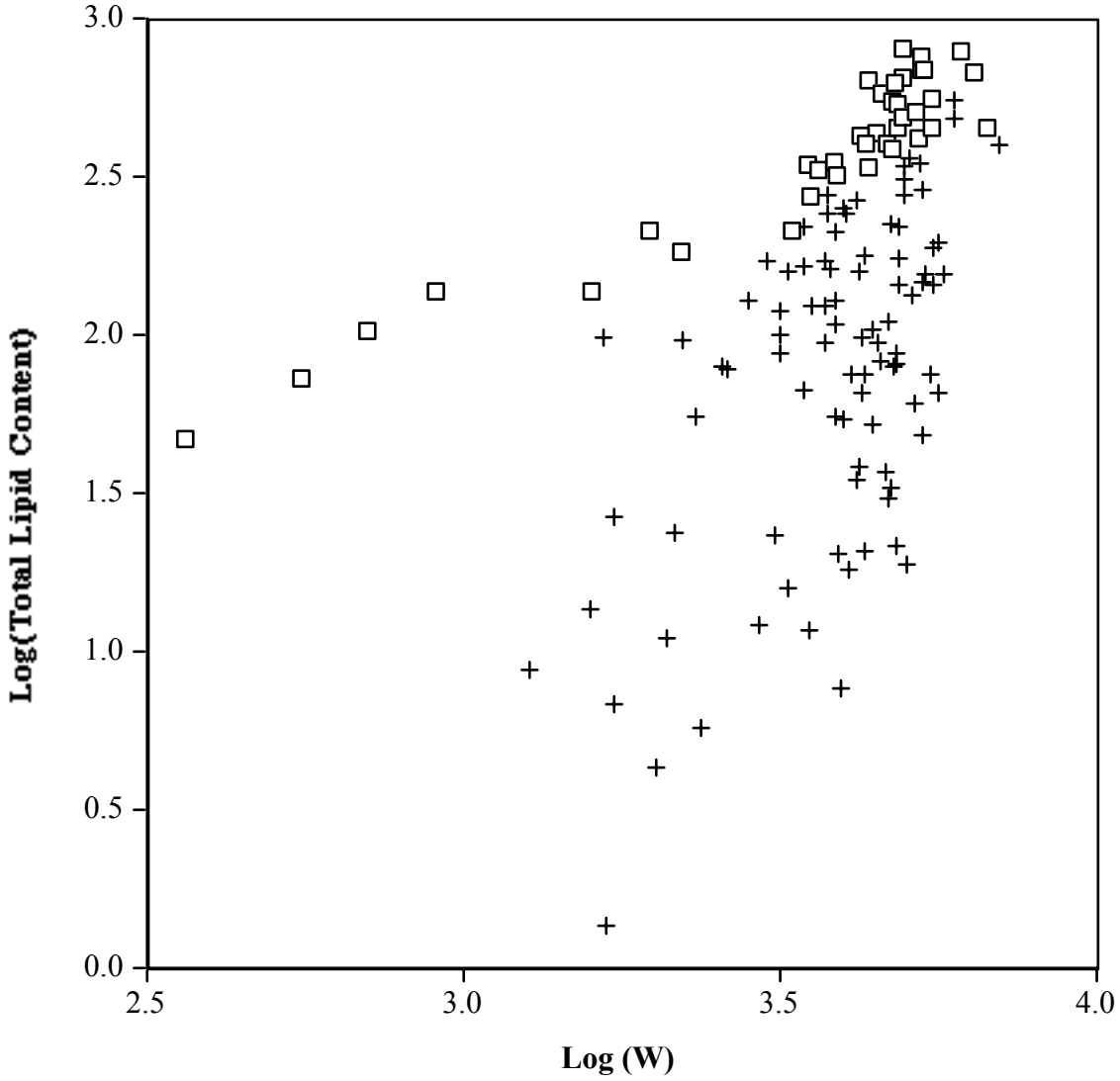

Figure 5. Relationship of log (total lipids) vs. log (weight) for pre-spawning fish (square symbol) and post-spawning fish (cross symbol).

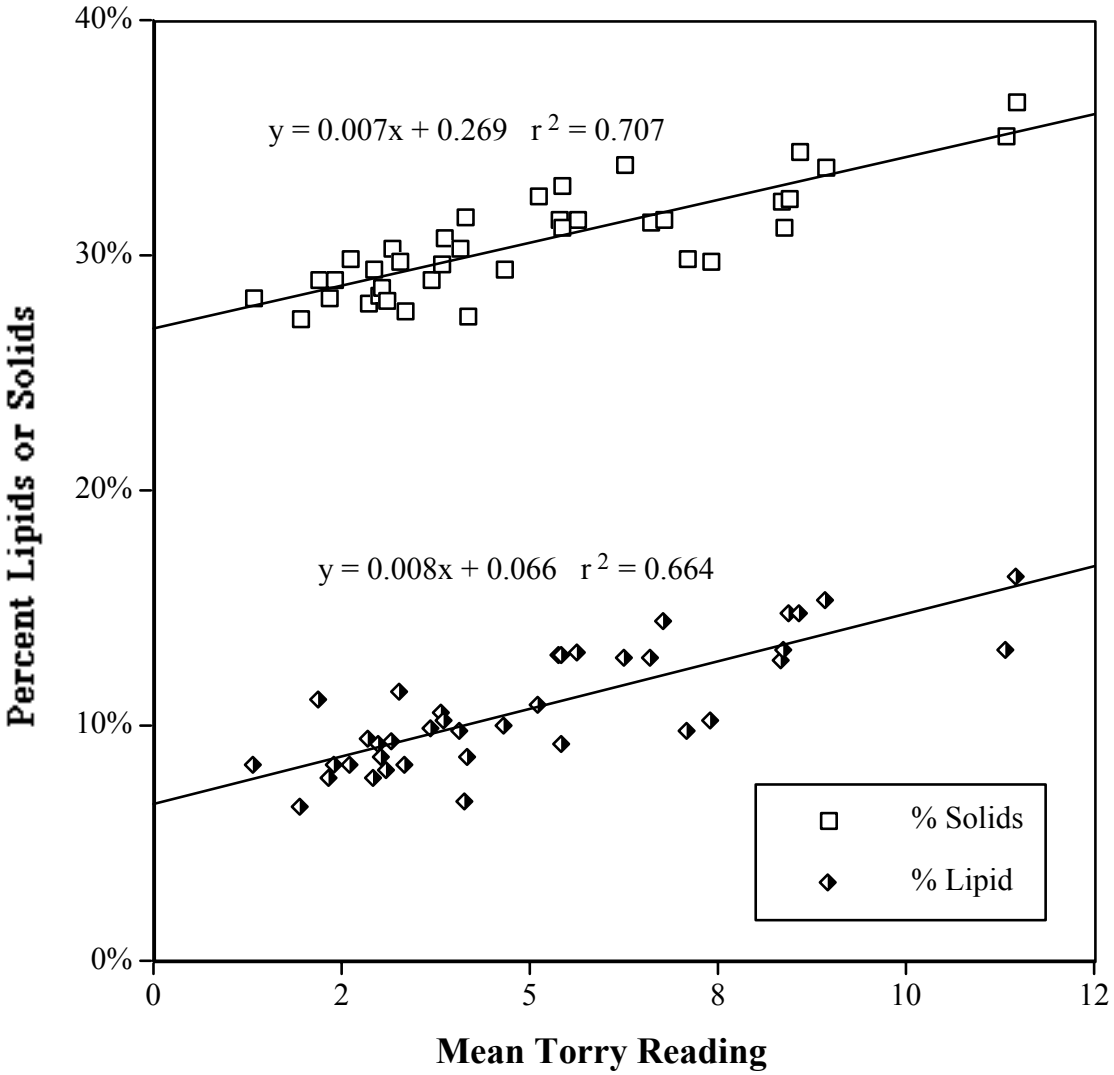

Figure 6. Relationship between mean Torry reading and percent whole body lipids or percent solids for pre-spawning fish (Batches 1-3).

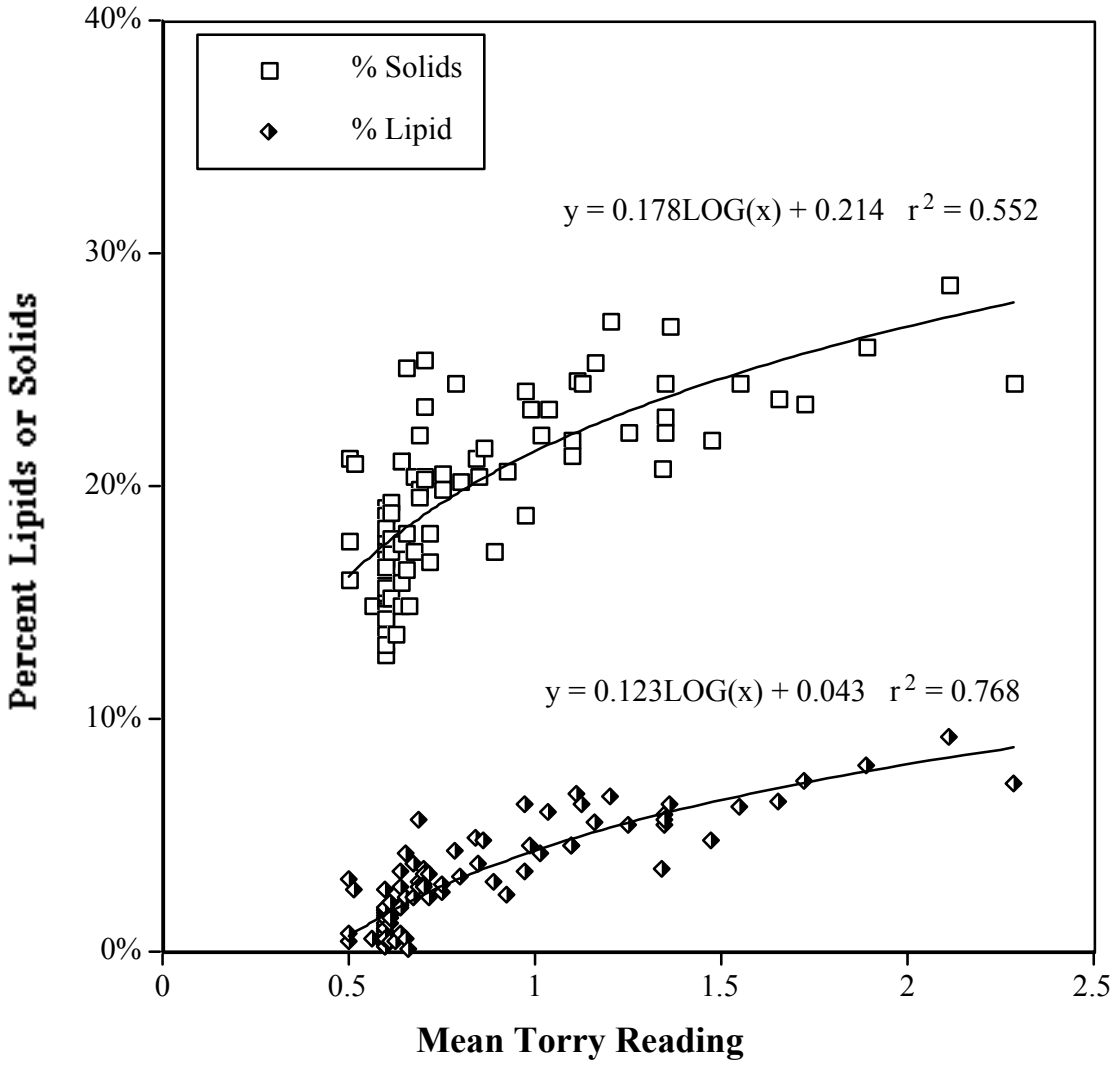

Figure 7. Relationship between mean Torry reading and percent whole body lipids or percent solids for post-spawning fish (Batches 4-6).

lipid or solids content (Figs. 6 and 7). The residual values for linear regression curves for lipids for the two groups of fish (actual - predicted) showed no trends in variance.

Relationship Between the Number of Torry Measurements and Accuracy of Estimate

To evaluate the relationship between the number of Torry readings and the accuracy of the Torry estimate, correlation matrixes were computed for each individual Torry reading, mean Torry reading, and lipid data for all batches (Table 6), pre-spawning fish (Table 7), and post-spawning fish (Table 8).

Table 6. Correlation matrix for all batches (with fish 293 removed).

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Torry**	**Lipid %**
1	1									
2	0.981	1								
3	0.950	0.966	1							
4	0.913	0.932	0.932	1						
5	0.965	0.957	0.952	0.908	1					
6	0.966	0.968	0.972	0.931	0.985	1				
7	0.936	0.934	0.961	0.912	0.963	0.982	1		1	
8	0.928	0.923	0.923	0.924	0.925	0.949	0.953	1		
Mean Torry	0.981	0.983	0.980	0.947	0.984	0.994	0.978	0.959	1	
Lipid%	0.860	0.856	0.814	0.796	0.870	0.860	0.815	0.775	**0.857**	1

Table 7. Correlation matrix for pre-spawning fish (Batches 1-3; with fish 293 removed).

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Torry**	**Lipid %**
1	1									
2	0.952	1								
3	0.891	0.930	1							
4	0.766	0.822	0.843	1						
5	0.904	0.883	0.897	0.753	1					
6	0.909	0.914	0.946	0.821	0.964	1				
7	0.850	0.844	0.915	0.792	0.922	0.965	1		1	
8	0.856	0.842	0.839	0.843	0.849	0.903	0.902	1		
Mean Torry	0.949	0.953	0.961	0.859	0.958	0.986	0.954	0.925	1	

Lipid%	0.749	0.771	0.741	0.536	0.797	0.804	0.748	0.679	**0.785**	1

Table 8. Correlation matrix for post-spawning fish (Batches 4-6).

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Torry**	**Lipid %**
1	1									
2	0.929	1								
3	0.898	0.883	1							
4	0.817	0.818	0.897	1						
5	0.924	0.884	0.918	0.792	1					
6	0.906	0.900	0.875	0.762	0.915	1				
7	0.895	0.884	0.872	0.791	0.888	0.906	1		1	
8	0.844	0.812	0.846	0.809	0.842	0.802	0.906	1		
Mean Torry	0.964	0.952	0.951	0.870	0.957	0.950	0.949	0.895	1	
Lipid%	0.836	0.810	0.802	0.673	0.812	0.858	0.767	0.671	**0.841**	1

Those correlation coefficients for the individual Torry-lipid content that were larger than mean Torry-lipid content have been underlined.

By averaging the correlation coefficients for the same position on each side of the fish, an average correlation coefficient was computed. These values were normalized by dividing by the value for Position 1 (Table 9).

Table 9. Average relative correlation coefficients for location of Torry Meter reading. (Average correlation coefficient have been normalized by dividing by the values for Position 1.)

	Position			
	1(head end)	2	3	4 (tail end)
Pre-spawning	1.00	1.02	0.96	0.79
Post-spawning	1.00	0.99	0.94	0.91

The Torry reading from locations 1 and 2 have higher relative average correlation coefficients than from locations 3 and 4. The relative average correlation coefficients were used as weighting factor for the computation of a new weighted mean Torry reading

for each fish. This parameter was plotted against the lipid data and linear equations were fitted to the data. The use of the correlation coefficients resulted in minor changes in the linear regression equation but did not improve the r^2 values of the equations for a) all the combined data, b) pre-spawning data, or c) post spawning data.

The impact of decreasing the number of Torry Meter readings was evaluated by comparing the previously determined r^2 values (positions 1-8) to those computed from four readings (positions 1-4), for only two readings (positions 1-2), and for a single reading (position 1) (Table 10).

Table 10. Effects of the number of Torry Meter readings on r^2 value of the Torry-whole body lipid relationship.

	r^2			
Data /regression curve type	8 readings	4 readings	2 readings	1 reading
All data/logarithmic	0.913	0.906	0.913	0.915
Pre-spawners/linear	0.705	0.618	0.650	0.762
Post-spawners/linear	0.713	0.696	0.699	0.702

For combined data set and pre-spawners, the r^2 value was actually higher for 1 reading (position 1); for the post-spawners, the r^2 value slightly decreased. The predictive ability did not improve as the number of reading was increased.

The data collected in Experiment 3 of the tag-interaction work was used to estimate the error in repeated Torry readings for individual fish. Four sets of four Torry measurements were made on 10 individual fish for tagged and non-tagged conditions.

The mean ± SD for the individual sets of readings and average of 4 sets of Torry reading are:

Individual sets of readings:	0.011 ± 0.082 n=40
Mean of 4 sets of readings:	0.008 ± 0.05 n=10
Absolute value (Individual sets of readings):	0.067 ± 0.048 n=40
Absolute value (Mean of 4 sets of readings):	0.04 ± 0.029 n=10

The average absolute error for the mean Torry reading between individual tagged and non-tagged measurements was 7%. The average absolute error for the average of 4 sets of readings was only 4%.

Torry-Protein Relationship

Protein levels were determined for Batch 6 fish. The slope of the relationship between protein and the Torry readings did not differ significantly from 0 (Fig. 8).

Tag Interaction Research

Experiment 1 - Impact of Torry Meter on PIT Tag Operation (prior to insertion in fish)

All of the PIT tags were operating at the end of experiment. The Torry Meter had no impact on the operation of the PIT tags before insertion in the fish.

Experiment 2 - Impact of Torry Meter Radio Tag Operation (prior to insertion in fish)

Both of the radio tags were operating at the end of experiment (including correct code transmission). The Torry Meter had no impact on the operation of the radio tags before insertion in the fish.

Experiment 3 - Interaction of Torry Meter on PIT and Radio Tag Operation (after insertion in fish)

The operation of the Torry Meter had no impact on the operation of each tag when inserted into the fish. All of the PIT and radio tags were operating at the end of experiment.

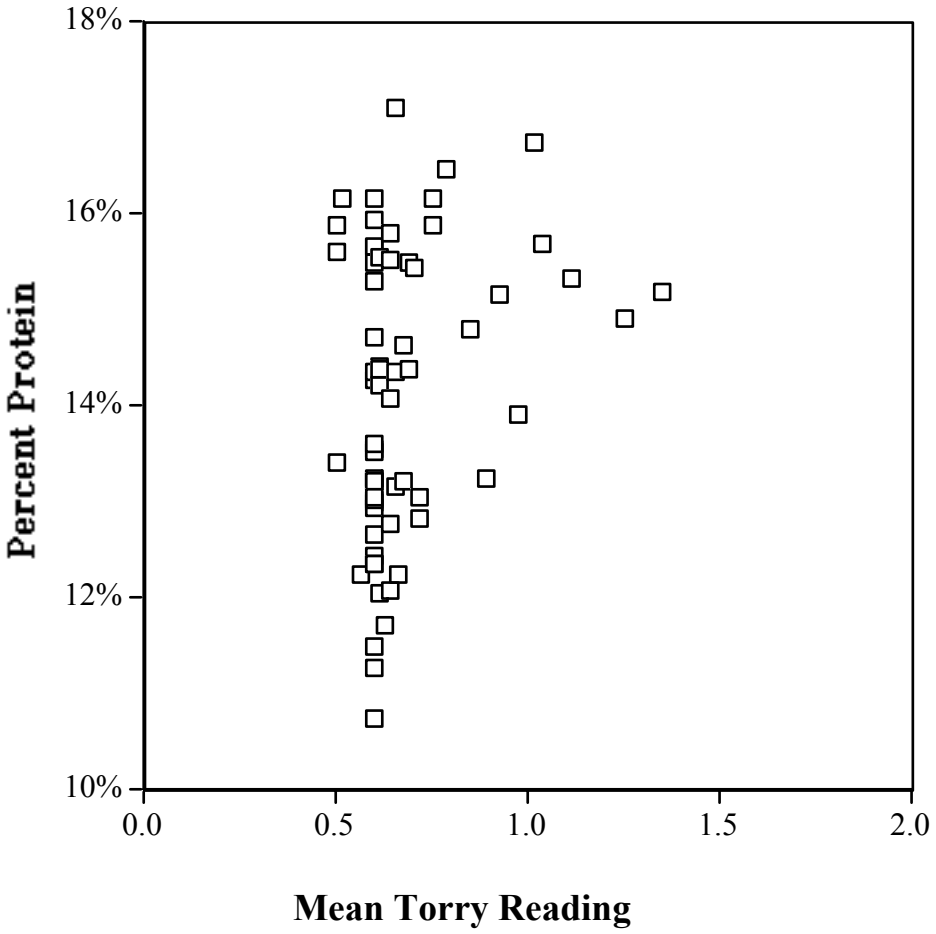
18%
16%
14%
12%
10%
Percent Protein
0.0
0.5
1.0
1.5
2.0
Mean Torry Reading

Figure 8. Relationship between mean Torry reading and percent protein for Batch 6 fish.

The presence or absence of PIT and radio tags (see Table A-9 in Appendix A) had no significant impact on the Torry readings ($P > 0.05$).

Impact of Torry Meter on Egg Quality

The detailed information on the Torry readings are presented in Appendix B (Tables B1 to B4) for the four sampling dates. Variation of the Torry readings for individual fish for the four readings are presented in Fig. 9. The final Torry readings were not statistically significantly different ($P > 0.05$) from the first Torry readings for group B.

Of the 34 female fish used in the reproductive study, 19 were successfully spawned (Appendix B, Table B-5). There were four mortalities, one fish was euthanized due to fungus, and one fish was missing (probably due to poaching). An additional nine fish were inadvertently killed during one check for ripeness.

The mean percent survival and SD of embryos to the eyed stage was 81 ± 17 for the no Torry measurement group, 80 ± 24 for 1 Torry reading group, and 71 ± 35 for the 4 Torry reading group (Table 11).

Table 11. Impact of Torry readings on reproductive success (Mean ± SD).

Parameter	Group A (n=7) (No Torry measurements)	Group B (n=5) (one Torry measurements)	Group C (n=7) (four Torry measurements)

% survival to eyed stage	81 ± 17	80 ± 24	71 ± 35
% blank eggs	4.4 ± 5.5	16.3 ± 21.1	4.5 ± 4.8
% white eggs	15.1 ± 16.8	12.8 ± 6.9	24.8 ± 32.1
Spawning date (Julian day)	66 ± 15	78 ± 14	72 ± 16

The Torry measurements had no statistical detectable impacts ($P > 0.05$) on the percent survival to eyed stage, percent blank eggs (dead), percent white eggs (dead), or spawning date. There was a general trend toward reduced survival to eyed stage at the end of spawning period (Fig. 10).

The green-egg to eyed-egg survival for fish number 598 3871 was only 2.32% (Table B-5 in Appendix B). This fish was spawned on the last spawning date. This low egg survival is likely to be due more to the spawning date than treatment effects. With this fish removed from the data set, the eye-egg to green-egg survival for group C was 82 ± 19.

Re-analysis of the data showed no statistical detectable impacts ($P < 0.05$) of Torry reading on egg yield. For $\alpha = 0.05$, the power of test was only 0.0892 for the whole data set and 0.1172 with fish 598 3871 removed.

DISCUSSION

Preliminary Protocol Development

The preliminary protocol development work showed that while tissue temperature did not have any effect on the Torry reading, surface moisture had a significant impact. To

try to standardize surface moisture, the following protocol was used: all fish were held in water prior to the measurements and a single swipe of the hand was used to remove any excess moisture or slime.

For fish over appropriately 30 cm fork length, four measurements were made on each side of the fish. For fish smaller than 30 cm, only three measurements were made on each side. The sensor head was oriented parallel to the long axis of the fish and placed just above the lateral line. These are similar to the manufacturer's recommended locations for adult salmon (Distell Industries Ltd.).

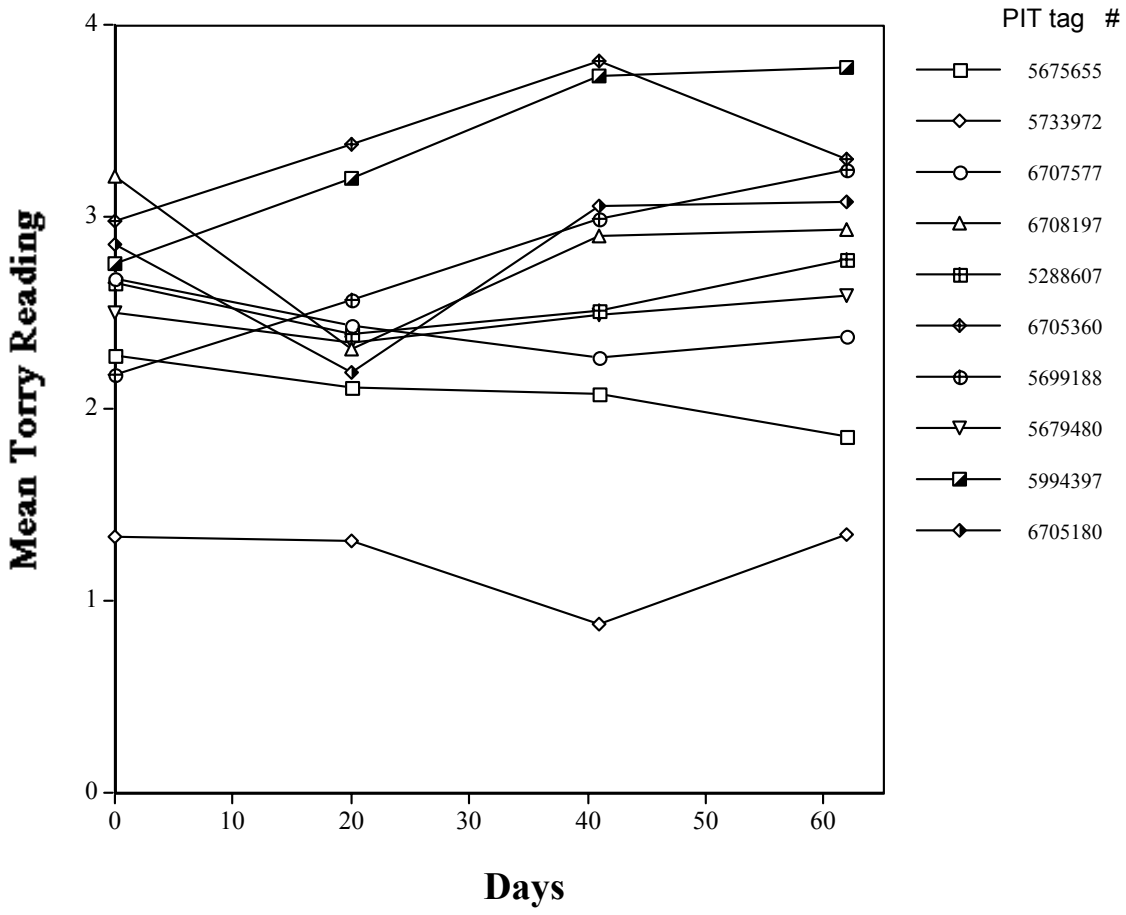

Figure 9. Mean Torry readings for individual fish for the four measurement dates. (day 0 = September 21, 2000; day 20 = October 11, 2000; day 41 = November 1, 2000; and day 62 = November 22, 2000).

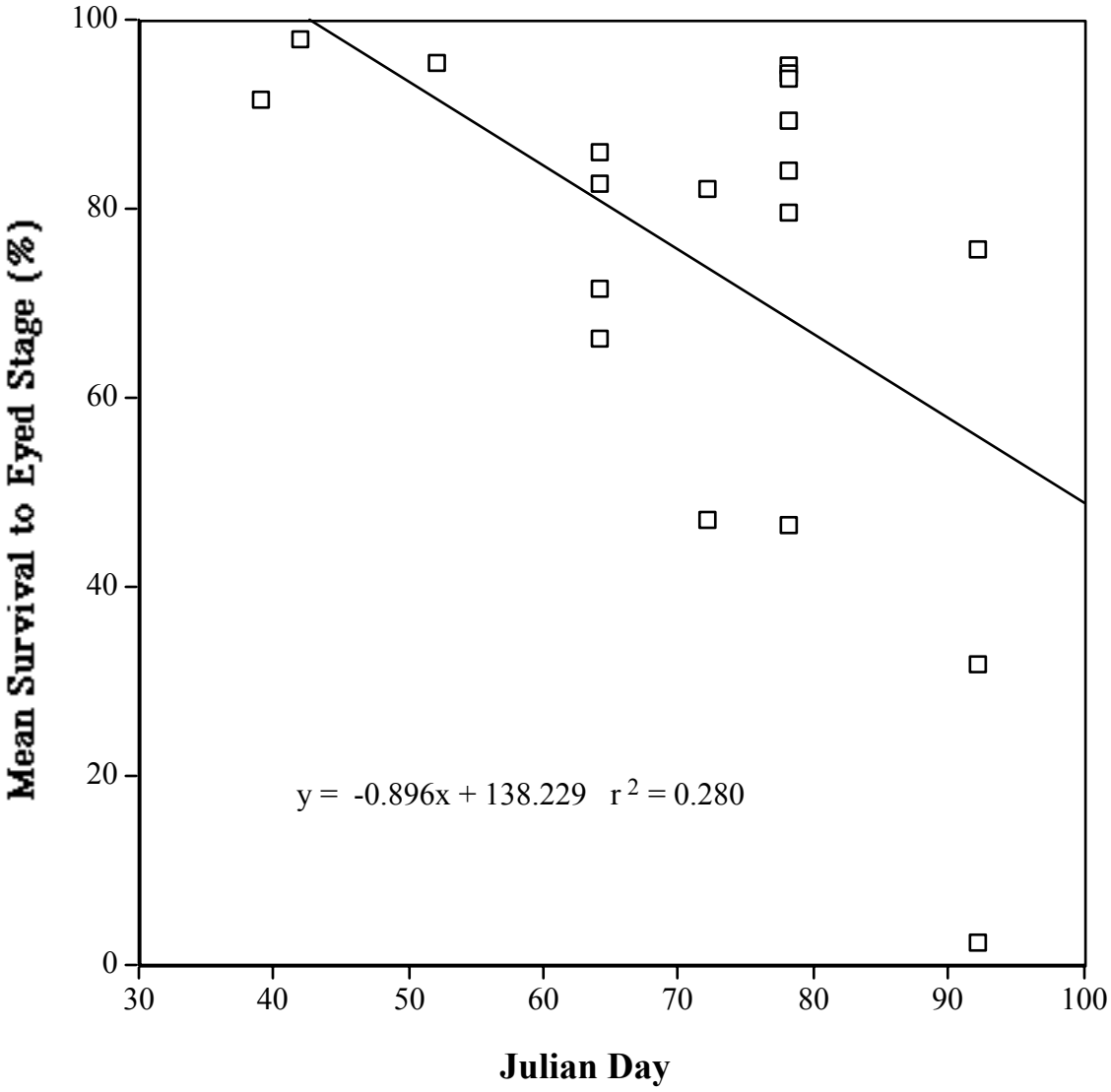
Mean Survival to Eyed Stage (%)
100
80
60
40
20
0
30
40
50
60
70
80
90
100
Julian Day
y = -0.896x + 138.229 r 2 = 0.280

Figure 10. Relationship between spawning date and survival to eyed stage (for all groups).

Torry-Lipid Relationship

The Torry Fish Fatmeter fundamentally measures water content (Kent 1990) using a microwave sensor. This measurement can be used to estimate lipid content because of the inverse relationship between percent lipids and percent body water in the fish (Craig et al. 1978; Flath and Diana 1985). Douirin et al. (1998) found that removal of mucus increased the r^2 of the mean Torry reading vs. lipid content from 0.48 to 0.58.

For combined pre-spawning and post-spawning adult spring chinook salmon, there was a significant logarithmic relationship between the mean Torry readings and whole body lipid level ($r^2 = 0.913$). The r^2 values for the linear and 2nd order polynomial were 0.771 and 0.864, respectively. The slope of the curves were significantly different for the pre-spawning and post-spawning fish.

When the pre-spawning and post-spawning fish were separated, there was a significant linear relationship between the Torry reading and lipid levels for each group of fish ($r^2 = 0.664 - 0.713$). Both the logarithmic and linear regression curves were normally distributed. These r^2 values are less than some regression equations presented by the manufacturer (Distell Industries Ltd.), but are larger than those reported by Douirin et al. (1998) for 1 - 3 kg rainbow trout.

The lack of a significant regression between either weight or length, and body composition (see Barziza and Gatlin 2000, Hartman and Brandt 1995) may be due to the relatively limited size range of fish tested. The 10 and 90 percentiles for fork length were 56 and 78 cm, respectively (80% of the fish had fork lengths in the range of 56-78 cm).

The Torry Fish Fatmeter was developed for use in management of food fish rearing and food processing. As a result, the meter is designed to measure lipids in the edible portion of the fish rather than whole body lipids. For adult fish with very low lipid content (0-1% wet weight), the minimum Torry reading was 0.5 to 0.6. The penetration depth of the meter is in the range of only 1-3 cm. Using the standardized measuring locations, there were no significant differences in the readings with or without eggs present, even though eggs comprised 15-26% of the total body weight.

In addition, the fat content of salmon is not uniformly distributed in the body. In pre-spawning fish, there are significant anterior-posterior and dorso-ventral gradients in muscle lipids. For example, the first four readings for fish #41 were 4.8 (nearest the head), 4.5, 3.4, and 2.3 (nearest the tail). The highest muscle lipid levels occurred near the head and decreased toward the tail and the belly. These gradients were less apparent in post-spawning fish.

When comparing the r^2 values determined in this work with those reported in the literature, it is important to note that many of these workers are not trying to find a relationship between the Torry reading and whole body lipids. They are commonly interested in the relationship between the Torry reading and fillets or the edible portion of the fish. For example, the manufacturer reports:

> "The fish are then filleted, the belly walls removed and the excess dorsal fat deposit also removed. The skin is peeled off, care being taken that no flesh is removed with the skin. The remaining fillet of the fish are then minced together in

a blender for approximately two minutes" (Distell Industries Ltd.).

Therefore, the head, tail, skin, internal organs, spinal column, and dorsal fat is not included in this lipid determination. The use of a homogeneous sample will also eliminate the sampling errors due to the non-uniform distribution of fat. Because the Torry meter is unable to measure lipid in the head and tail areas or contained in internal organs, the whole-body lipid regression coefficients are likely to be lower than published values from farm or fish processing work.

Relationship Between the Number of Torry Measurements and Accuracy of Estimate

Correlation coefficients for all fish, pre-spawning, and post-spawning fish showed that all the individual Torry Meter readings were highly correlated with each other, the mean Torry Meter readings, and lipid content. In general, mean Torry-lipid correlation coefficient was higher than individual Torry-lipid correlation coefficients. In those cases where the individual Torry-lipid correlation coefficients were higher than the mean Torry-lipid correlation coefficient, the differences were very small.

Individual readings were weighted by the mean correlation coefficient for each measuring position and a weighted mean Torry Meter reading computed. There were slight changes in the regression curves, but there were negligible increases in the r^2 values.

The mean Torry-lipid regression lines did not depend strongly on the number of individual measurements. In fact, for "all data" (logarithmic curve) and "pre-spawners"

(linear curve), the r^2 values were higher for a single reading (position 1 - nearest the head) than either eight (all standard positions), four (positions 1-4), or two (positions 1-2) readings. For the "post-spawners" group of fish, the r^2 values for the single reading was higher than for 2 or 4 readings, but slightly less than that for the 8 reading case. One to two reading (positions 1 and 2) should be adequate for most measurements, although a complete set of four measurements would take only 2-5 seconds more. There does not appear to be any reason to measure the Torry readings on both sides of the fish.

Torry-Protein Relationship

Based on Batch 6 fish, there did not appear to be a strong relationship between the mean Torry reading and protein content. This may be due to the narrow range of protein values present in the post-spawners.

Tag Interaction Research

The Torry Meter had no effect on the operation of either the PIT or radio-tags. These tags did not affect the accuracy of the Torry Meter. There was no evidence of any Torry Meter-tag interaction.

The testing of the radio tags was less rigorous than for the PIT tags due to a limited availability of radio tags. If Torry readings were conducted on fish at Bonneville Dam, the Torry readings could be completed before the radio tag was inserted. After the fish enter the hatchery, the continued operation of the radio tag is not critical.

Impact of Torry Meter on Egg Quality

The signal output of the Torry Meter is 2 mW at 2,000 MHz. The dimensions of the sensor head is approximately 1.8 x 7.0 cm (1.26×10^{-3} m^2). Assuming 100% absorption of the signal by the fish, the specific absorption rate (SAR) is equal to about 2 W/m^2. The fish sampled for the Torry-lipid work ranged from 0.36 to 7.0 kg. Therefore, the weight specific absorption rate varies from 0.0017 to 0.0033 W/kg for the whole body and 0.0068 to 0.0133 for the gametes (assuming 25% of total body weight).

The potential impact of electromagnetic radiation depends strongly on frequency (Barnes 1989). Some common sources of EM radiation are (Masley et al. 1999):

TV (VHF)	54-216 MHz
TV (UHF)	470-806 MHz
Cellular Phone (analog)	804-894 MHz
PCS mobile phones (digital)	1,900-2,200 MHz
Microwave ovens	2,450 MHz

Current guidelines for occupational and general exposure to electromagnetic fields are based on thermal impacts (Masley et al. 1999); the non-thermal impacts due to low-level exposure are not well understood.

Because of concerns with potential impacts of cellular phones, a great deal of research has been conducted on 900 to 2,450 MHz radiation. A recent review of potential reproduction impacts found no evidence to either male or female reproductive processes in humans (Robert 1999). No information on the potential reproductive impacts of microwave radiation to salmon or fish could be found. Exposure of mice to

1,000 W/m^2 for 5 minutes and 100 W/m^2 for 260 minutes had no impact on spermatogonia type B, early primary spermatocytes, late primary spermatocytes, and secondary spermatocytes or on the sperm count (Saunders and Kowalczuk 1981). These no effects levels in mice were 50-500 larger on a SAR basis and about 3 to 4 orders of magnitude on a weight basis than the estimated Torry Meter levels (see Fig. 11).

While extrapolation between species must be made with great care, the potential impact of the Torry measurements on the reproductive success of salmon are likely to be negligible due to very small doses of radiation and very short exposures (30 - 40 seconds). In addition, the measuring locations are above the lateral line, which is a considerable distance away from the reproductive organs.

One to four Torry Meter readings had no statistical detectable impact on the reproductive success of commercial rainbow trout broodstock as measured by the percent survival to the eyed stage. Due high variability in green-egg to eyed-egg and pre-spawning mortality, the statistical power of this experiment was low (0.0892 - 0.1172). To detect a difference of 4.66% in green-egg to eyed-egg survival with α=0.05, 110 spawners would be needed.

Use of the Torry Meter to Estimate Lipid Reserves in Migrating Fish

The Torry Meter could be used to classify returning adults according to lipid reserves or to estimate changes in lipid level for individual migrating fish. These two uses will be discussed separately.

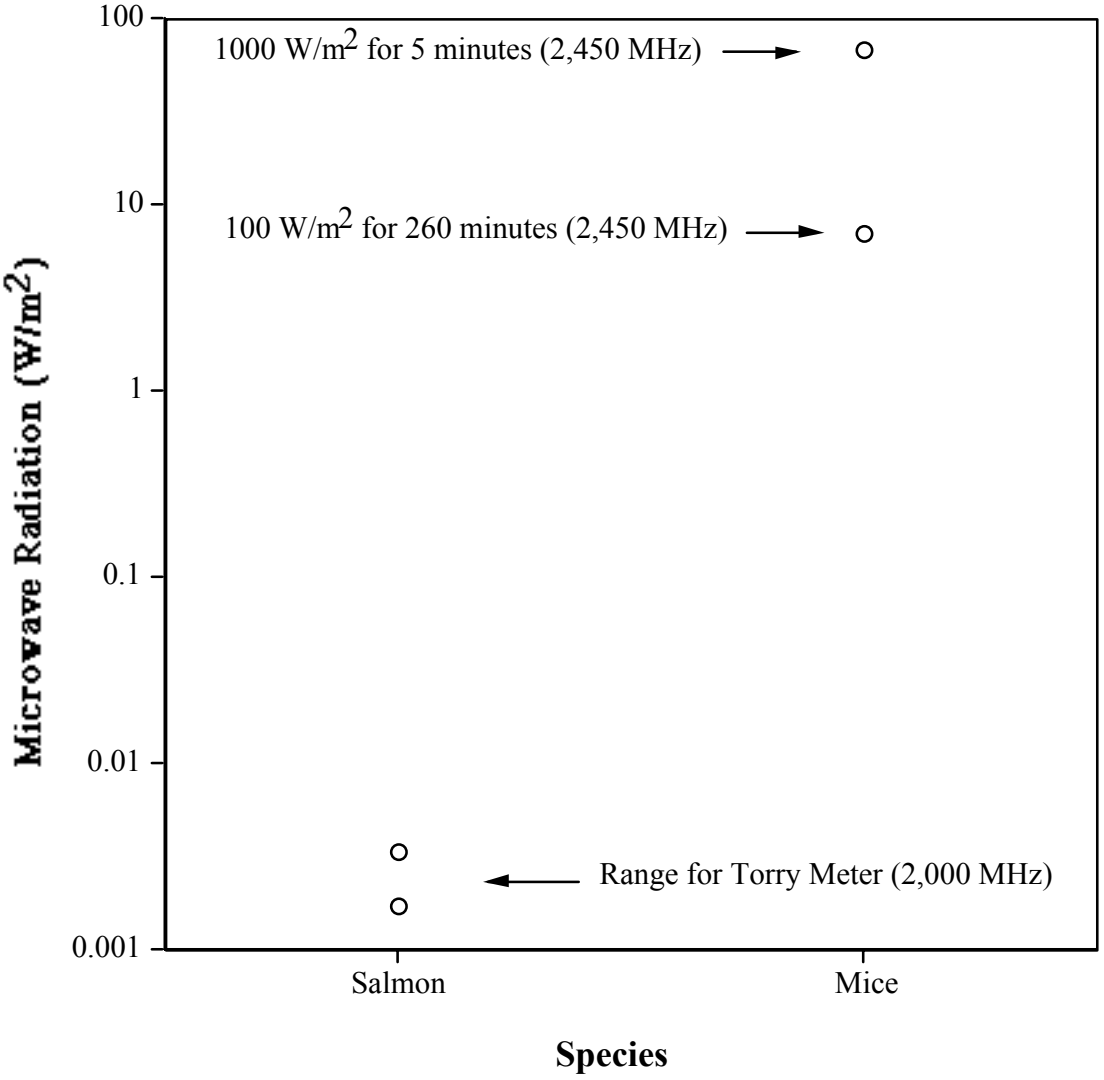
100
10
1
0.1
0.01
0.001
Microwave Radiation (W/m2)
1000 W/m2 for 5 minutes (2,450 MHz)
100 W/m2 for 260 minutes (2,450 MHz)
Range for Torry Meter (2,000 MHz)
Salmon
Mice
Species

Figure 11. Comparison of the microwave intensity of the Torry meter to reproductive no-effects levels in male mice.

Classification Of Fish According To Estimated Lipid Content

Some of the proposed future research on impact of whole body lipid reserves on reproductive success would try to detect a relationship between initial lipid reserves and reproductive success (egg yield or survival to eyed stage). The accuracy of the whole body lipid estimate is critical to this research.

Typically, the fit of a regression equation is described in terms of the coefficient of determination (r^2) and the residual error variance (σ_ε^2). The degree of categorical resolution of a regression model depends on its error variance relative to the total range covered by the dependent variable (Prairie 1996). The resolution power of a regression equation can be defined as the number of distinguishable classes that the dependent variable can be divided into (Prairie 1996):

$$\text{Number}_{\text{classes}} = \frac{1.31}{\sqrt{1 - r^2}} \qquad \text{(Equation 1)}$$

The greater the number of classes, the greater the predictive value of the model. Up to a r^2 value of about 0.8, the number of classes is less than two, then rapidly increases with increasing r^2 values.

Using the r^2 for the pre-spawners and post-spawners fish, each group of fish could only be divided into two distinguishable classes (high lipid content and low lipid content) based on the Torry Meter reading. Therefore, any future experimental work will be limited to comparison between low and high lipid fish.

Estimation of Change in Individual Fish During Migration.

For all batches of fish examined, the lipid levels varied from approximately 0 to 16%. Detailed energy balances are not available for hatchery and wild salmon during their spawning migration in the Columbia River. The following estimates are based on the assumption that 60% of the lipids are used for migration and 40% for spawning. These values are based on wild pink salmon migrating up the Fraser River (Williams et al. 1986).

Initial lipid content of fish:	13% (average for Batch 2)
Final lipid content of fish:	2% (average for Batch 6)
Lipids used in migration	6.6%
Lipids used in spawning	4.4%
10% increase in migrational energy demand:	0.66%
20% increase in migrational energy demand:	1.32%
30% increase in migrational energy demand:	1.98%

Therefore, to detect a 10 to 30% increase in migrational energy demand, it would be necessary to be able to detect a 0.66 to 1.98% reduction in whole body lipids. The number of classes needed to detect these changes can be computed by dividing the range (11%) by the change in lipids and the required r^2 values can be computed from Equation 1 (Table 12):

Table 12. Required r^2 values needed to detect a given increase in migrational lipid demand.

Increase in migration energy demand	Decrease in whole body lipid content	Number of classes needed	Required r^2 for regression
10%	0.66%	16.67	0.9938
20%	1.32%	8.33	0.9753
30%	1.98%	5.56	0.9445
38%	2.48%	4.44	0.913[a]

[a] Value determined in the current work (all batches of fish).

Based on the above assumptions and the precision of the Torry measurements, we predict the Torry Meter measurements of lipids would only detect a 38% increase in total migrational energy demand. Therefore, the Torry Meter is only useful for detection of major increases in migrational energy demand of migrating adult salmon in the Columbia River

The Torry Meter was designed to measure moisture and lipid content in the edible portion of fish. As a result, the depth of penetration is limited to about 3 cm. Therefore, this technique will not measure lipids contained in gonads or visceral fat deposits. Since the visceral fat is used preferentially to lipids contained in muscle tissue, the Torry Meter may give a better estimate of remaining lipid reserves during the latter stages of the migration or spawning. In addition, conventional analysis measures lipids contained in brain, nerve tissues, and tail, that are not total available for energy production.

A number of other methods have been used to nondestructively estimate body composition in living animals. Common methods include: total body electrical conductive (TOBEC) and computerized tomography (CT).

TOBEC involves placing the fish within a low-frequency electromagnetic field and measuring the total body electrical conductivity. While simple and rapid to operate, it currently does not have the accuracy needed for bioenergetic studies of Columbia River salmon work (Barziza and Gatlin 2000, Jaramillo et al. 1994, Lantry et al. 1999). For largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), and alewife (*Alosa pseudoharengus*) weight and length were better predictors of body composition than TOBEC (Barziza and Gatlin 2000, Lantry et al. 1999).

Computerized Tomography (CT) or CAT scan uses x-rays to construct a three dimensional view of a crosssection through a living animal. This method is commonly used for medical diagnostic work. In early work with Atlantic salmon (*Salmo salar*) (Rye 1991), the use of CT data improved the prediction of lipid and dry matter content by 38% compared to the use of simple weight and condition factor. The r^2 values for lipid content regression were only 0.85. This is slightly less than the overall Torry-lipid regression value, but larger than r^2 values for the pre-spawning and post-spawning groups.

CT work with Atlantic salmon (Rye 1991) is based on only three sections through each fish; current procedures would measure 12-15 sections and would improve accuracy of the body composition estimates. Computerized tomography provides the most accurate technique of all *in vivo* measurements of body composition (Vangen and Jopson 1996). Compared to mammals, the estimates of body composition of migrating salmon

are probably more accurate because it is not a necessity to try to remove the contents in the small intestine. With the ability to repeatedly sample individual animals, this method has been used to monitor long term changes in body composition of mammals (Ball et al. 1996, Jopson et al. 1997). The use of CT technology in animal production and fisheries research has been slowed by its high cost. This method appears to have the highest potential to determine differential energy utilization in migrating Pacific salmon.

RECOMMENDATIONS

Based on the experimentally determined Torry-total lipid relationship, this method has the ability to divide the lipid measurements into about four classes and detect a 38% increase in migrational energy (based on an assumed energy distribution). The Torry Meter may be a better predictor of the lipids remaining in the muscles during the latter stages of migration and spawning than conventional whole body lipid analysis. Computerized Tomography (CT) has the best potential to determine differential energy utilization in migrating Pacific salmon.

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REFERENCES

AOAC [Association of Official Analytical Chemists]. 1990. Official methods of analysis, 15th edition, Section 920.39 Fat (crude) or ether extract in animal feed, Volume 1:79, Arlington, Virginia.

Ball, A.J., J.M. Thompson, and G.N. Hinch. 1996. Seasonal oscillations in the mass of body components of mature ewes fed at a constant intake. Aust. Soc. Animal Prod. 21:479.

Barnes, F.S. 1989. Radio-microwave interactions with biological materials. Health Phys. 56:759-766.

Barziza, D.E. and D.M. Gatlin III. 2000. An evaluation of total body electrical conductivity to estimate body composition of largemouth bass, *Micropterus salmonides*. Aquat. Living Resour. 13:439-447.

Bjornn, T.C. and C.A. Peery. 1992. A review of literature related to movements of adult salmon and steelhead past dams and through reservoirs in the lower Snake River. Idaho Cooperative Fish and Wildlife Research Unit. U.S. Army Corps of Engineers, Walla Walla, Washington.

Craig, J. F., M.J. Kenley, and J.F. Talling. 1978. Comparative estimates of the energy content of fish tissue from bomb calorimetry, wet oxidation and proximate analysis. Freshwat. Biol. 8:585-590.

Distell Industries Ltd. no date. Technical Manual, Distell Fatmeter, 692-CDF, West Lothian, Scotland.

Douirin, C., P. Haffray, J.-L. Vallet, and B. Fauconneau. 1998. Determination of the lipid content of rainbow trout (*Oncorhynchyus mykiss*) filets with the Torry Fish Fat Meter. Sciences des Aliments 18:527-535. (in French)

Dunn, O.J. and V.A. Clark. 1974. Applied statistical: analysis of variance and regression. John Wiley & Sons, New York, 387 pp.

Flath, L.E. and J.S. Diana. 1985. Seasonal energy dynamics of the alewife in southeastern Lake Michigan. Trans. Am. Fish. Soc. 114:328-337.

Hartman, K.J. and S.B. Brandt. 1995. Estimating energy density of fish. Trans. Am. Fish. Soc. 124:347-355.

Hendry, A.P. 1998. Reproductive energetics of Pacific salmon: strategies, tactics, and trade-offs. Ph.D. Dissertation, School of Fisheries, University of Washington, Seattle, Washington, 193 pp.

Jaramillo, Jr., F.,S.C. Bai, B. R. Murphy, and D.M. Galtin III. 1994. Application of electrical conductivity for non-destructive measurement of channel catfish, *Ictalurus punctatus*, body composition. Aquat. Living Resour. 7:87-91.

Jopson, N.B., J.M. Thompson, and P.F. Fennessy. 1997. Tissue mobilization rates in male fallow deer (*Dama dama*) as determined by computed tomography: the effects of natural and enforced food restriction. Anim. Sci. 65:311-320.

Kent, M. 1990. Hand-held instrument for fat/water determination in whole fish. Food Control, January, 47-53.

Lantry, B.F., D.J. Stewart, R.S. Rand, and E.L. Mills. 1999. Evaluation of total-body electrical conductivity to estimate whole-body water content of yellow perch, *Perca flavescens*, and alewife, *Alosa pseudoharengus*. Fish. Bull. 97:71-79.

Masley, M.L., B. F. Habbick, W.O. Spitzer, and M.A. Stuchly. 1999. Are wireless phones safe - A review of the issue. Can. J. Publ. Health 90:325-329.

Prairie, Y.T. 1996. Evaluating the predictive power of regression models. Can. J. Fish. Aquat. Sci. 53:490-492.

Robert, E. 1999. Intrauterine effects of electromagnetic fields -- (low frequency, mid-frequency RF, and microwave): review of epidemiologic studies. Teratology 5:292-298.

Rye, M. 1991. Prediction of carcass composition in Atlantic salmon by computerized tomography. Aquaculture 99:35-48.

Saunders, R.D. and C.I. Kowalczuk. 1981. The effect of acute far field exposure at 2.45 GHz on the mouse testis. Int. J. Radiat. Biol. Relat. Stud. Phys. Chem. Med. 39:587-596.

Sigurgisladottir, S., O. Torrissen, O. Lie, M. Thomassen, and H. Hafsteinsson. 1997. Salmon quality: methods to determine the quality parameters. Rev. Fish. Sc. 5:223-252.

Thurston, C.E. and H.W. Newman. 1962. Proximate composition changes in sockeye salmon (*Oncorhynchus nerka*) during spawning migration. Fish. Indust. Res. 2:15-22.

Vangen, O. and N.B. Jopson. 1996. Research application of non-invasive techniques for body composition, Abstract No. PS5.1, 47th Annual Meeting of the European

Association for Animal Production Lillehammer, Norway, 25-29 August, 1996. (also available at http://ansc.une.edu.au/catscan/newzealand/1996/jopson96.htm).

Williams, I.V. and 15 coauthors. 1986. The 1983 early run Fraser and Thompson River pink salmon; morphology, energetics and fish health. Bulletin XXIII, International Pacific Salmon Fisheries Commission, New Westminster, British Columbia, Canada.

Appendix A - Detailed Data for Torry-Lipid Work

Table A-1. Torry reading and chemical composition for pre-spawning fish from Carson National Fish Hatchery.

Number	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Mean	Weight	Length	Sex	Spawned?	%DW	%Fat	% Protein
1	4.9	4.8	4.0	3.6	4.4	4.5	3.8	3.3	4.2	1590.2	50.0	m	no	27.41%	8.64%	
3	4.9	4.4	3.1	3.5	5.7	4.8	3.2	3.5	4.1	6674.6	81.0	m	no	31.56%	6.71%	
6	5.4	3.8	2.6	2.0	3.2	3.8	1.8	1.7	3.0	4651.7	71.5	f	no	28.59%	8.58%	
10	1.4	1.5	1.1	1.0	1.5	1.6	1.5	0.9	1.3	2187.2	56.5	m	no	28.20%	8.30%	
13	3.6	5.7	4.0	3.3	3.7	4.8	2.9	2.6	3.8	6367.1	84.0	m	no	29.65%	10.53%	
15	4.3	5.0	2.8	3.0	5.5	5.7	3.0	3.2	4.1	5139.2	75.0	f	no	30.30%	9.77%	
16	4.0	3.5	2.9	1.6	3.3	3.0	2.8	1.8	2.9	4308.0	73.0	m	no	28.00%	9.42%	
17	3.9	3.8	2.6	2.3	3.8	3.9	2.8	2.1	3.2	4812.4	61.5	f	no	30.30%	9.33%	
19	5.0	5.1	2.8	2.4	5.2	4.9	2.8	2.6	3.9	4225.2	73.0	m	no	30.68%	10.15%	
20	3.3	3.4	2.2	1.6	3.6	3.2	2.0	1.6	2.6	3868.1	68.0	f	no	29.78%	8.24%	
21	2.8	3.9	2.5	3.1	4.0	3.4	2.8	2.2	3.1	5224.2	77.0	m	no	28.01%	8.07%	
24	7.3	8.2	4.3	2.9	5.9	6.6	4.4	3.8	5.4	3630.2	68.0	f	no	31.15%	9.14%	
25	3.7	3.7	2.8	2.2	4.0	4.0	3.5	2.9	3.4	5472.8	80.0	m	no	27.63%	8.27%	
26	5.6	3.6	2.3	2.3	5.3	4.8	2.8	2.7	3.7	4915.6	75.0	m	no	28.93%	9.87%	
30	7.1	5.9	4.8	n/a	5.1	3.7	4.0	n/a	5.1	1961.2	53.0	m	no	32.46%	10.86%	
31	5.4	3.9	2.4	1.4	4.4	2.7	2.1	1.5	3.0	3845.2	68.0	m	no	28.30%	9.15%	
33	4.1	3.9	2.4	1.9	4.3	4.4	2.8	2.3	3.3	4753.7	71.5	m	no	29.68%	11.42%	
36	6.9	7.8	4.6	3.2	5.7	5.9	5.2	3.7	5.4	4797.6	72.0	f	no	31.54%	12.95%	
39	3.1	2.7	1.9	1.9	1.5	3.1	2.6	1.8	2.3	4352.0	70.0	f	no	28.20%	7.72%	
41	4.8	4.5	3.4	2.3	7.4	6.7	5.5	2.6	4.7	3494.4	66.5	m	no	29.41%	9.89%	
42	6.1	7.5	6.3	5.2	7.8	8.9	6.6	4.4	6.6	6070.4	81.0	m	no	31.34%	12.87%	
43	2.8	2.2	1.4	1.4	3.1	3.4	1.6	1.5	2.2	4823.1	75.0	m	no	28.99%	11.04%	
44	3.6	3.3	1.8	1.5	3.1	2.4	1.6	1.8	2.4	4717.9	84.5	f	no	28.90%	8.25%	
45	3.7	3.2	2.4	1.9	4.1	3.4	2.5	2.0	2.9	3518.8	65.5	f	no	29.41%	7.76%	
49	2.4	2.3	1.4	1.2	2.8	2.8	1.6	1.1	2.0	3292.0	66.0	f	no	27.24%	6.45%	
Maximum	7.3	8.2	6.3	5.2	7.8	8.9	6.6	4.4	6.6	6674.6	84.5			32.46%	12.95%	
Average	4.4	4.3	2.9	2.4	4.3	4.3	3.0	2.4	3.5	4347.7	70.7			29.43%	9.33%	
Minimum	1.4	1.5	1.1	1.0	1.5	1.6	1.5	0.9	1.3	1590.2	50.0			27.24%	6.45%	

Data Key

Number	Fish number
1-8	Torry reading, locations 1-8 (see Figure 1)
Mean	Mean Torry reading for locations 1-8
Weight	Weight (g)
Length	Fork length (cm)
Sex	f = female, m = male
Spawned?	Reproductive status
%DW	Percent solids
%Fat	Percent lipids on a wet weight basis
%Protein	Percent protein on a wet weight basis

Table A-2. Torry readings and chemical composition for pre-spawning fish from Little White National Fish Hatchery (see Table A-1 for key).

Number	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Mean	Weight	Length	Sex	Spawned	%DW	%Fat	%Protein
62	7.3	6.7	6.4	5.6	8.4	9.0	8.2	5.1	7.1	4485.6	68.0	f	no	29.81%	9.69%	
63	7.4	7.1	3.6	2.5	6.7	6.7	5.6	3.8	5.4	5260.9	74.0	m	no	32.93%	12.95%	
65	13.3	13.9	11.0	7.3	12.2	13.0	9.8	10.1	11.3	4914.9	72.0	f	no	35.02%	13.19%	
66	14.5	12.4	10.5	5.4	14.8	14.6	11.3	8.3	11.5	4930.6	71.0	f	no	36.46%	16.25%	
67	10.2	10.7	8.7	4.5	6.7	8.7	6.1	3.6	7.4	5483.4	76.0	m	no	29.74%	10.13%	
68	8.4	9.8	7.0	4.3	8.1	8.1	4.4	4.1	6.8	5281.1	73.0	m	no	31.45%	14.41%	
69	8.4	7.9	7.2	4.8	8.1	10.9	9.8	9.7	8.4	4558.8	69.5	f	no	32.31%	12.70%	
70	11.2	10.8	6.8	2.9	11.3	11.0	8.1	6.5	8.6	4358.5	68.5	m	no	34.43%	14.71%	
71	5.1	6.2	8.0	2.1	8.9	9.2	7.7	2.9	6.3	5328.0	73.0	f	no	33.79%	12.87%	
Maximum	14.5	13.9	11.0	7.3	14.8	14.6	11.3	10.1	11.5	5483.4	76.0			36.46%	16.25%	
Average	9.5	9.5	7.7	4.4	9.5	10.1	7.9	6.0	8.1	4955.8	71.7			32.88%	12.99%	
Minimum	5.1	6.2	3.6	2.1	6.7	6.7	4.4	2.9	5.4	4358.5	68.0			29.74%	9.69%	

Table A-3. Torry readings and chemical composition for juvenile fish from Minter Creek Fish Hatchery (see Table A-1 for key).

Number	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Mean	Weight	Length	Sex	Spawned	%DW	%Fat	%Protein
291	11.9	7.0	4.0	n/a	14.3	7.7	5.4	n/a	8.4	551.6	29.5	m	no	31.17%	13.20%	
293	14.1	8.9	6.1	n/a	13.6	9.9	6.5	n/a	9.9	1103.4	34.5	m	no	32.94%	6.00%	
296	13.4	7.9	3.6	n/a	14.2	8.8	5.6	n/a	8.9	897.4	33.0	m	no	33.74%	15.26%	
298	13.8	6.9	3.0	n/a	14.1	8.6	4.3	n/a	8.5	703.7	31.0	m	no	32.38%	14.69%	
300	9.8	4.4	2.4	n/a	9.8	5.6	1.7	n/a	5.6	362.0	25.0	m	no	31.47%	13.07%	
Maximum	14.1	8.9	6.1		14.3	9.9	6.5		9.9	1103.4	34.5			33.74%	15.26%	
Average	12.6	7.0	3.8		13.2	8.1	4.7		8.2	723.6	30.6			32.34%	12.44%	
Minimum	9.8	4.4	2.4		9.8	5.6	1.7		5.6	362.0	25.0			31.17%	6.00%	
No head; some internal body parts missing																

Table A-4. Torry readings and chemical composition for post-spawning fish from Carson National Fish Hatchery (see Table A-1 for key).

Number	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Mean	Weight	Length	Sex	Spawned	%DW	%Fat	%Protein
253	1.5	1.2	1.6	0.8	1.7	1.2	0.9	0.7	1.2	5234.4	76.0	f	no	27.11%	6.57%	
256	2.1	1.6	1.0	0.7	1.4	1.5	1.5	1.1	1.4	4186.7	71.0	f	no	26.79%	6.26%	
264	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3556.0	69.0	f	no	25.36%	3.46%	
272	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3884.7	72.5	f	no	23.39%	3.26%	
275	2.7	2.2	1.9	1.1	3.4	2.3	1.8	1.5	2.1	5962.7	80.0	m	yes	28.65%	9.17%	
282	2.5	2.3	2.1	1.8	1.9	1.4	1.5	1.6	1.9	5979.2	84.0	m	yes	26.00%	7.93%	
290	2.9	2.3	1.9	1.4	3.0	2.5	2.1	2.2	2.3	5048.2	79.0	m	yes	24.40%	7.16%	
Maximum	2.9	2.3	2.1	1.8	3.4	2.5	2.1	2.2	2.3	5979.2	84.0			28.65%	9.17%	
Average	1.9	1.6	1.4	1.0	1.8	1.5	1.3	1.2	1.5	4836.0	75.9			25.96%	6.26%	
Minimum	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3556.0	69.0			23.39%	3.26%	

Table A-5. Torry readings and chemical composition for post-spawning fish from Dworshak National Fish Hatchery (see Table A-1 for key).

Number	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Mean	Weight	Length	Sex	Spawned	%DW	%Fat	%Protein
303	1.4	1.4	0.9	0.8	1.5	1.4	1.0	0.9	1.2	4961.5	77.0	m	yes	25.30%	5.50%	
305	1.2	1.2	1.1	0.9	1.3	1.3	1.0	1.0	1.1	3457.6	69.0	m	yes	24.40%	6.25%	
306	1.2	1.3	0.9	0.7	1.2	1.2	0.8	0.6	1.0	4860.2	77.0	m	yes	23.30%	4.51%	
308	1.6	1.3	0.8	n/a	1.9	1.5	1.0	n/a	1.4	1664.6	54.0	m	yes	24.40%	5.82%	
312	1.6	2.4	1.4	1.0	1.7	1.8	1.3	1.2	1.6	4944.5	79.5	m	yes	24.40%	6.21%	
314	1.1	1.5	0.8	0.6	1.1	1.3	0.7	0.7	1.0	3969.4	74.0	m	yes	24.10%	6.27%	
318	1.7	1.7	1.2	1.0	2.2	1.4	1.4	1.2	1.5	4721.5	74.0	m	yes	22.00%	4.70%	
320	2.1	2.0	1.5	1.6	1.9	1.9	1.3	0.9	1.7	3770.1	71.0	f	yes	23.70%	6.37%	
322	0.7	0.7	0.7	0.7	0.7	0.8	0.6	0.6	0.7	2622.0	65.5	f	yes	19.80%	2.93%	
324	1.0	1.1	0.9	0.7	1.0	0.9	0.7	0.6	0.9	3449.8	74.0	f	yes	21.60%	4.73%	
325	0.8	0.9	0.8	0.6	1.0	1.0	0.8	0.8	0.8	3265.5	73.5	f	yes	21.20%	4.78%	
326	2.4	2.1	1.6	1.3	2.5	1.9	1.1	0.9	1.7	3760.5	74.5	f	yes	23.50%	7.24%	
328	0.8	0.8	0.7	0.6	0.8	0.7	0.6	0.6	0.7	3874.5	75.0	f	yes	20.40%	2.78%	
329	1.6	1.8	1.2	0.9	1.6	1.5	1.2	0.9	1.3	4888.1	82.0	f	yes	20.70%	3.52%	
330	1.8	1.5	1.2	0.9	1.5	1.6	1.3	1.0	1.4	3872.8	72.5	f	yes	23.00%	5.40%	
331	0.9	0.9	0.7	0.6	0.8	1.1	0.8	0.6	0.8	3154	71	f	yes	20.20%	3.16%	
332	1.2	1.3	1.2	0.7	1.4	1.4	0.9	0.7	1.1	2825.3	69.0	f	yes	21.90%	4.47%	
333	1.2	1.4	0.8	0.7	1.4	1.5	1.0	0.8	1.1	3737.2	74.0	f	yes	21.30%	4.52%	
Maximum	2.4	2.4	1.6	1.6	2.5	1.9	1.4	1.2	1.7	4961.5	82.0			25.30%	7.24%	
Average	1.4	1.4	1.0	0.8	1.4	1.3	1.0	0.8	1.2	3766.6	72.6			22.51%	4.95%	
Minimum	0.7	0.7	0.7	0.6	0.7	0.7	0.6	0.6	0.7	1664.6	54.0			19.80%	2.78%	

Table A-6. Torry readings and chemical composition for post-spawning fish from Dungeness Fish Hatchery Held at Manchester, Washington (see Table A-1 for key).

Number	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Mean	Weight	Length	Sex	Spawned?	% DW	% fat	% protein
400	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2550	63.50	f	yes	21.17%	3.09%	15.87%
401	1.8	1.6	0.6	0.6	0.7	0.6	0.7	0.8	0.9	2319	58.10	f	yes	20.56%	2.36%	15.16%
402	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6	0.7	2091	56.30	f	yes	16.42%	0.52%	13.14%
403	0.6	0.6	0.6	0.7	0.6	0.8	0.6	0.6	0.6	1266	51.70	f	yes	15.82%	0.69%	12.76%
404	0.9	0.6	0.6	0.6	0.9	0.8	0.7	0.6	0.7	3740	58.30	f	yes	17.97%	3.30%	13.03%
405	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3505	68.10	f	yes	14.86%	0.33%	13.00%
406	0.8	0.6	0.6	0.6	0.7	0.7	0.6	0.6	0.7	3802	68.20	m	yes	25.10%	4.20%	17.10%
407	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	1725	56.50	f	yes	15.16%	0.39%	12.03%
408	0.6	0.6	0.6	0.6	0.6	0.6	1.0	0.7	0.7	1686	56.40	m	yes	14.84%	0.08%	12.24%
409	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	4443	70.20	f	yes	17.21%	1.15%	14.41%
410	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4204	67.00	f	yes	15.69%	0.91%	12.94%
411	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	1731	55.10	f	yes	19.27%	1.52%	15.54%
412	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	5141	75.80	f	yes	18.55%	1.16%	15.30%
413	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4276	73.20	f	yes	16.69%	1.53%	13.25%
414	1.2	1.6	0.7	0.7	1.1	1.0	1.2	0.6	1.0	4289	70.20	f	yes	22.15%	4.13%	16.75%
415	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5013	74.50	f	yes	17.58%	0.37%	15.61%
416	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3091	65.40	m	yes	16.00%	0.74%	13.40%
417	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5114	72.90	f	yes	21.00%	2.57%	16.14%
418	0.5	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.6	3255	64.80	f	yes	14.85%	0.48%	12.25%
419	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1592	53.80	f	yes	18.90%	0.84%	15.48%
420	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4065	68.90	f	yes	17.17%	0.44%	14.70%
421	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2014	59.30	f	yes	14.72%	0.21%	12.42%
422	0.8	0.6	0.6	0.6	0.7	0.8	0.7	0.6	0.7	4218	70.60	f	yes	20.35%	3.71%	14.62%
423	1.6	1.2	0.9	0.7	0.9	1.8	1.1	0.7	1.1	4980	74.20	f	yes	24.54%	6.77%	15.31%
424	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2146	60.90	f	yes	16.78%	1.10%	13.53%
425	0.7	0.7	0.6	0.6	0.7	0.6	0.6	0.6	0.6	3176	65.90	f	yes	21.03%	2.71%	15.51%
426	0.6	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4833	74.50	f	yes	13.59%	0.44%	11.72%
427	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4523	66.60	f	yes	18.78%	2.06%	14.20%
428	0.8	0.8	0.7	0.7	1.0	0.8	0.8	0.7	0.8	2226	57.50	f	yes	24.39%	4.28%	16.46%
429	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4314	42.80	f	yes	12.74%	0.48%	10.75%
430	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2371	59.50	m	yes	14.12%	0.24%	12.35%
431	1.0	1.0	0.9	0.7	0.8	0.9	0.9	0.6	0.9	3154	65.80	f	yes	20.42%	3.76%	14.80%
432	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4669	71.80	f	yes	17.87%	0.64%	15.64%
433	0.7	0.8	0.6	0.6	0.8	0.7	0.7	0.6	0.7	5287	72.10	f	yes	19.52%	2.76%	15.49%
434	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4315	69.20	f	yes	19.02%	1.71%	15.93%
435	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2934	59.20	f	yes	16.79%	0.41%	14.27%
436	0.7	0.7	0.6	0.6	0.7	0.7	0.6	0.6	0.7	4271	71.60	f	yes	17.92%	2.27%	14.34%
437	1.5	1.1	0.8	0.7	1.4	1.1	0.9	0.8	1.0	4038	69.40	f	yes	23.24%	5.91%	15.68%
438	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4781	72.60	f	yes	18.70%	1.66%	15.66%
439	1.3	1.5	1.3	1.0	1.5	1.6	1.5	1.1	1.4	3017	54.70	f	yes	22.26%	5.60%	15.17%
440	0.7	0.6	0.6	0.6	0.8	0.6	0.6	0.6	0.6	3436	67.90	f	yes	17.46%	1.93%	14.08%
441	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3969	70.50	f	yes	17.70%	1.34%	14.38%
442	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4661	71.90	f	yes	15.19%	0.78%	13.20%
443	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4167	69.40	f	yes	15.57%	0.82%	13.23%
444	0.8	0.9	0.7	0.6	0.8	0.9	0.7	0.6	0.8	3708	67.40	f	yes	20.50%	2.54%	16.14%
445	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4097	70.30	f	yes	14.23%	1.83%	12.36%
446	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4801	75.60	f	yes	15.89%	1.67%	13.01%
447	0.7	0.8	0.6	0.6	0.7	0.8	0.6	0.6	0.7	4419	72.50	f	yes	17.20%	2.31%	13.22%
448	0.7	0.7	0.6	0.6	0.7	0.6	0.6	0.6	0.6	4817	73.10	f	yes	14.85%	1.80%	12.06%
449	0.7	0.8	0.9	0.7	0.9	0.7	0.7	0.6	0.8	5336	78.50	f	yes	19.85%	2.87%	15.88%
450	1.4	0.8	0.8	0.6	1.4	0.9	0.6	0.6	0.9	4889	72.30	f	yes	17.22%	2.93%	13.24%
451	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4718	69.60	f	yes	15.33%	0.69%	13.22%
452	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	5438	74.80	f	yes	16.50%	1.36%	13.51%
453	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	5641	77.20	f	yes	18.73%	1.16%	16.16%
454	0.9	0.9	0.6	0.6	0.9	0.6	0.6	0.6	0.7	4687	70.90	f	yes	16.67%	2.33%	12.82%
455	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	5285	72.10	f	yes	13.66%	0.91%	11.27%
456	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3951	68.70	f	yes	13.14%	0.19%	11.50%
457	1.6	1.4	1.2	0.7	1.7	1.4	1.2	0.8	1.3	5328	74.70	f	yes	22.29%	5.38%	14.90%
464	0.7	0.8	0.6	0.5	0.7	0.7	0.6	0.5	0.6	5632	73.10	f	yes	21.04%	3.43%	15.78%
465	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3923	66.80	f	yes	15.42%	0.51%	13.59%
466	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3856	69.10	f	yes	15.70%	1.42%	13.05%
467	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4550	71.50	f	yes	15.58%	1.80%	12.66%
468	0.8	0.7	0.6	0.6	0.7	0.9	0.6	0.6	0.7	7000	79.60	m	yes	22.12%	5.59%	14.38%
469	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	5514	77.20	m	yes	18.20%	2.61%	14.34%
470	0.7	0.7	0.7	0.6	0.8	0.7	0.7	0.7	0.7	5758	79.40	f	yes	20.23%	2.69%	15.43%
471	1.2	1.0	0.9	0.7	1.2	1.3	0.8	0.7	1.0	5500	74.90	f	yes	18.69%	3.41%	13.90%
Maximum	1.8	1.6	1.3	1.0	1.7	1.8	1.5	1.1	1.4	7000.0	79.6			25.10%	6.77%	17.10%
Average	0.7	0.7	0.6	0.6	0.7	0.7	0.7	0.6	0.7	4018.9	67.8			17.92%	2.00%	14.11%
Minimum	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1266.0	42.8			12.74%	0.08%	10.75%

Table A-7. Comparison of Torry readings for two temperatures.

Cold Conditions													
Fish Number	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**Mean**	**Weight (g)**	**Length (cm)**	**Temp (C)**	**Sex**
302	2.2	1.2	1.2	0.8	1.3	1.1	1.0	0.7	1.19	4748.8	75.0	3	m
321	1.0	0.9	1.0	0.7	0.9	0.8	0.7	0.8	0.85	3196.0	70.0	3	f
64	11.3	12.2	9.3	5.1	12.7	9.6	8.9	6.1	9.40	5014.2	71.0	3	f
304	1.7	1.6	1.5	0.8	1.7	2.0	1.2	0.9	1.43	4772.0	75.0	3	m
309	1.8	1.5	1.1	0.9	2.0	1.6	1.1	1.5	1.44	3744.3	68.0	3	m
27	5.2	4.8	2.9	2.1	4.9	4.4	2.7	3.9	3.86	4135.2	70.0	3	m
A	6.3	5.5	3.7	1.8	9.8	8.4	6.0	6.0	5.94	4786.2	72.5	3	f
C	3.7	3.8	2.8	2.5	4.5	4.3	2.9	2.4	3.36	3761.0	69.0	3.1	m
E	4.5	4.3	2.7	1.8	6.0	5.1	3.1	1.9	3.68	4584.6	73.0	3.1	f
B	4.0	3.3	1.7	1.7	6.5	5.6	2.4	1.8	3.38	4043.9	69.5	3.1	f
D	2.2	2.1	1.1	0.8	1.8	1.8	0.8	0.7	1.41	4364.9	69.0	3.1	f
F	2.2	2.2	1.3	0.9	2.4	1.6	1.6	1.1	1.66	3398.3	66.5	3.3	f
329	2.0	1.2	1.0	0.7	1.4	1.4	1.0	0.7	1.18	4532.3	81.0	3.2	f
323	1.8	1.4	1.4	1.0	2.0	1.7	1.0	0.8	1.39	3752.4	73.0	3.3	f
Mean									**2.87**				
Warm Conditions													
Fish Number	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**Mean**	**Weight (g)**	**Length (cm)**	**Temp (C)**	**Sex**
302	1.6	1.4	1.1	0.8	1.4	1.2	1.0	0.8	1.16	Same as above	Same as above	18.5	Same as above
321	1.1	1.0	1.0	0.8	1.0	1.0	0.9	0.8	0.95	Same as above	Same as above	18.7	Same as above
64	10.6	10.4	6.7	5.9	13.8	11.3	6.8	7.6	9.14	Same as above	Same as above	18.7	Same as above
304	2.4	1.8	1.5	1.1	2.2	1.9	1.6	1.1	1.70	Same as above	Same as above	18.6	Same as above
309	2.0	1.8	1.3	1.2	2.1	1.7	1.1	1.3	1.56	Same as above	Same as above	18.5	Same as above
27	5.1	4.8	3.0	2.7	5.4	5.5	2.8	2.0	3.91	Same as above	Same as above	18.7	Same as above
A	5.0	6.5	4.0	2.3	8.0	6.8	4.5	3.3	5.05	Same as above	Same as above	18.6	Same as above
C	4.5	5.5	3.2	2.6	4.8	3.9	2.5	2.6	3.70	Same as above	Same as above	18.6	Same as above
E	4.9	4.1	3.0	2.6	5.8	5.3	3.6	2.7	4.00	Same as above	Same as above	18.6	Same as above
B	6.3	5.1	2.5	2.3	6.6	5.8	3.1	2.2	4.24	Same as above	Same as above	18.6	Same as above
D	2.1	1.6	1.0	0.9	2.1	1.7	0.9	0.8	1.39	Same as above	Same as above	18.7	Same as above
F	2.1	1.5	1.3	1.1	2.8	2.0	2.1	1.2	1.76	Same as above	Same as above	18.6	Same as above
329	1.5	0.9	1.1	0.7	1.3	1.4	1.2	0.7	1.10	Same as above	Same as above	18.6	Same as above
323	1.6	1.4	1.0	1.1	2.0	1.8	1.3	0.9	1.39	Same as above	Same as above	18.7	Same as above
									2.93				

Table A-8. Comparison of Torry reading for pre-spawned and post-spawned fish.

Unspawned Fish															
Number	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**Mean**	**Weight (g)**	**Length (cm)**	**Temp (C)**	**Sex**	**Spawned**	
251	1.6	1.4	0.9	1.3	1.8	1.5	0.9	0.7	1.3	4233.0	75.0	2.7	f	no	
252	0.7	0.7	0.7	0.6	0.7	0.6	0.7	0.7	0.7	4422.3	72.5	2.7	f	no	
253	1.5	1.2	1.6	0.8	1.7	1.2	0.9	0.7	1.2	5234.4	76.0	2.7	f	no	
254	1.3	1.5	0.7	0.7	1.4	1.3	0.7	0.7	1.0	4395.9	69.0	2.7	f	no	
255	1.3	0.8	0.7	0.7	1.4	0.8	0.8	0.7	0.9	4690.5	77.5	2.8	f	no	
Mean									1.02						
Spawned Fish															
Number	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**Mean**	**Weight (g)**	**Length (cm)**	**Temp (C)**	**Sex**	**Spawned**	**Egg Wt (g)**
251	1.3	1.2	0.9	0.8	2.0	1.9	1.3	1.2	1.3	3251.8	Same as above	2.2	Same as above	Same as above	981.2
252	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.7	0.7	3269.6	Same as above	2.3	Same as above	Same as above	1152.7
253	1.6	1.5	1.2	1.0	1.9	1.9	1.4	1.1	1.5	4455.6	Same as above	2.3	Same as above	Same as above	778.8
254	1.1	1.7	0.7	0.9	1.0	1.0	0.9	0.7	1.0	3254.2	Same as above	2.2	Same as above	Same as above	1141.7
255	1.2	0.9	0.7	0.7	1.2	1.0	0.9	0.6	0.9	3749.8	Same as above	2.2	Same as above	Same as above	940.7
Mean									1.07						

Table A-9. Comparison of Torry reading for fish with and without PIT and radio tags

Fish	No Tags					PIT and radio tags				
Number	**1.0**	**2.0**	**3.0**	**4.0**	**Mean**	**1.0**	**2.0**	**3.0**	**4.0**	**Mean**
10	1.3	2.3	0.9	1.0	1.4	1.3	1.4	0.9	1.2	1.2
	1.4	2.1	0.9	0.9	1.3	2.1	2.7	1.0	1.2	1.8
	1.4	2.2	0.9	0.9	1.4	1.5	1.9	1.0	1.0	1.4
	1.4	2.4	1.0	1.0	1.5	1.4	2.2	1.1	1.2	1.5
					1.4					1.4
15	4.0	4.9	2.9	2.6	3.6	4.3	4.9	3.4	2.7	3.8
	4.2	5.6	2.8	2.7	3.8	4.2	4.8	3.0	3.1	3.8
	4.2	5.2	3.4	3.1	4.0	4.4	5.0	3.1	2.3	3.7
	4.3	5.4	3.9	2.4	4.0	4.4	4.5	2.7	2.8	3.6
					3.9					3.7
17	3.9	3.2	2.4	2.4	3.0	4.1	3.2	2.3	2.5	3.0
	4.0	5.3	2.7	2.5	3.6	3.7	4.2	2.7	2.2	3.2
	4.0	3.7	2.7	2.5	3.2	4.2	3.6	2.8	2.7	3.3
	4.6	3.8	2.8	2.5	3.4	3.8	3.9	2.6	2.6	3.2
					3.3					3.2
31	4.3	3.6	1.9	1.5	2.8	4.5	3.3	2.0	1.5	2.8
	4.7	3.3	1.8	1.5	2.8	4.5	3.0	1.8	1.6	2.7
	4.3	3.7	1.8	1.5	2.8	4.7	3.6	2.2	1.6	3.0
	4.5	3.6	1.7	1.5	2.8	4.5	3.1	1.8	1.5	2.7
					2.8					2.8
39	4.0	2.7	1.7	1.7	2.5	3.3	2.7	1.7	1.6	2.3
	3.8	2.8	2.1	1.4	2.5	3.3	2.8	2.0	1.8	2.5
	3.8	2.8	1.7	1.7	2.5	3.6	2.9	1.8	1.7	2.5
	4.0	2.8	1.7	1.6	2.5	3.4	2.7	1.8	1.6	2.4
					2.5					2.4
J	2.4	1.9	1.9	1.2	1.9	2.5	2.0	1.3	1.2	1.8
	2.0	1.9	1.8	1.7	1.9	2.6	2.6	1.6	1.3	2.0
	2.5	2.0	1.7	1.3	1.9	2.7	2.5	1.6	1.2	2.0
	2.6	2.2	1.7	1.5	2.0	2.7	3.1	1.5	1.3	2.2
					1.9					2.0
K	5.2	4.7	3.6	2.7	4.1	5.3	5.6	3.8	2.5	4.3
	5.5	6.0	4.0	3.2	4.7	5.5	6.3	3.5	2.5	4.5
	5.9	6.5	3.9	3.1	4.9	5.2	6.7	3.7	2.7	4.6
	5.6	5.8	4.8	3.2	4.9	5.6	7.9	3.5	2.8	5.0
					4.6					4.6
L	5.5	4.6	3.4	3.3	4.2	5.3	5.2	3.7	3.9	4.5
	5.4	5.0	3.1	3.3	4.2	5.2	5.8	3.3	3.5	4.5
	6.3	6.1	4.4	4.1	5.2	6.7	5.1	4.5	3.3	4.9
	5.6	5.7	3.9	4.3	4.9	5.4	5.1	3.7	2.8	4.3
					4.6					4.5
M	3.4	3.1	2.1	1.6	2.6	3.1	2.5	1.9	1.5	2.3
	3.4	3.1	2.2	1.5	2.6	3.1	2.5	2.2	1.5	2.3
	3.7	3.4	2.3	1.9	2.8	3.5	3.1	2.3	1.5	2.6
	3.5	3.2	2.1	2.0	2.7	3.4	2.9	2.1	1.5	2.5
					2.7					2.4
N	5.7	3.9	2.6	2.4	3.7	5.4	4.0	2.7	3.1	3.8
	5.5	4.0	2.6	2.3	3.6	5.4	4.5	3.0	2.9	4.0
	5.1	3.9	2.7	2.2	3.5	5.4	4.3	3.0	2.7	3.9
	5.2	3.6	2.7	2.6	3.5	5.4	3.9	2.9	2.4	3.7
					3.6					3.8
					3.12					3.09

Appendix B - Detailed Data Impact of Torry Meter on Egg Quality

Table B-1. Torry Reading for Reproductive Impacts Study (September 21, 2000).
Location: Orting Troutlodge Facility Fish: February Steelhead Operator: Colt Calibration: Chinook #4 (6.3, 16.1)

PIT Tag #	Group[1]	Torry Meter Location/Reading									Status	Length (cm)	Temp (C)	Sex
		1	2	3	4	5	6	7	8	Mean				
558 9194	A	4.2	4.3	2.3	1.3	2.7	2.6	2.1	0.7	2.53			9.7	F
599 1838	B	2.1	2.3	1.3	1.1	2.1	2.2	1.4	1.3	1.73				F
529 2561	C													F
520 5696	A	2.4	2.4	1.9	1.2	3.0	2.4	1.5	1.3	2.01				F
567 5655	B	3.1	2.3	1.9	1.1	3.2	2.8	2.3	1.5	2.28				F
529 3549	C													F
598 5420	A	4.4	3.1	1.9	1.4	4.0	3.6	2.2	1.0	2.70				F
573 3972	B	1.3	2.1	1.4	0.7	1.4	1.3	1.1	1.3	1.33				F
560 4868	C													F
670 5970	A	3.1	3.3	2.3	1.6	2.9	2.6	2.7	1.4	2.49				F
670 7577	B	3.9	3.5	2.2	1.7	3.0	3.5	2.2	1.4	2.68				F
598 3871	C													F
599 0111	A	2.2	1.6	1.0	0.7	1.2	1.6	1.0	0.8	1.26				F
597 0923	B	2.2	2.4	2.2	1.0	2.7	3.5	2.3	1.2	2.19				F
531 3696	C													F
572 3107	A	3.9	4.1	2.0	1.3	3.6	3.2	1.7	1.4	2.65				F
670 8197	B	4.3	4.3	2.6	1.6	4.8	4.2	2.4	1.5	3.21				F
531 2222	C													F
529 9281	A	3.6	3.5	2.2	1.6	3.5	4.9	3.0	1.2	2.94				F
528 8607	B	3.5	2.9	2.0	1.4	3.2	4.2	2.4	1.6	2.65				F
572 2050	C													F
531 7176	A	2.4	2.5	1.5	1.2	2.7	2.6	2.2	1.8	2.11				F
670 5360	B	4.0	3.3	2.5	1.4	4.1	4.6	2.3	1.6	2.98				F
530 7413	C													F
670 8295	A	3.7	3.1	2.4	1.5	3.6	3.7	2.4	1.9	2.79				F
569 9188	B	3.0	3.5	1.5	0.8	3.3	2.5	1.8	1.0	2.18				F
529 7102	C													F
531 3627	A	2.1	2.5	1.4	1.1	1.6	2.1	1.6	1.2	1.70				F
567 9480	B	3.5	2.8	1.8	1.4	3.9	3.1	2.3	1.2	2.50				F
599 3362	C													F
671 0090	A	6.0	4.7	2.7	1.6	6.0	5.1	3.1	1.9	3.89				F
599 4397	B	3.7	4.1	2.5	1.6	3.6	2.8	2.3	1.4	2.75				F
597 6577	C													F
670 5180	B	3.9	3.6	2.4	1.2	3.8	3.9	2.7	1.3	2.85			9.8	F

Group Key: C, no Torry; A, Torry once; B, Torry every 3 weeks.

Table B-2. Torry Reading for Reproductive Impacts Study (October 11, 2000).
Location: Orting Troutlodge Facility Fish: February Steelhead Operator: Colt Calibration: Chinook #4 (6.5/16.7)

PIT Tag #	Group[1]	Torry Meter Location/Reading									Status	Length (cm)	Temp (C)	Sex
		1	2	3	4	5	6	7	8	Mean				
558 9194	A											46	9.8	F
599 1838	B	1.7	1.6	1.4	1.5	1.6	1.5	1.1	0.9	1.41		46		F
529 2561	C											46		F
520 5696	A										missing	---		F
567 5655	B	3.5	2.6	1.7	1.0	2.2	2.7	1.7	1.5	2.11		46		F
529 3549	C											44.2		F
598 5420	A											46		F
573 3972	B	1.8	1.4	1.1	0.8	1.3	1.4	1.4	1.3	1.31		46		F
560 4868	C											48		F
670 5970	A											46.5		F
670 7577	B	3.6	3.4	1.9	1.3	3.7	2.7	1.7	1.1	2.43		49		F
598 3871	C											47		F
599 0111	A											43		F
597 0923	B	2.9	2.9	1.6	1.1	2.3	1.4	2.3	1.1	1.95		42		F
531 3696	C											46		F
572 3107	A											50		F
670 8197	B	3.2	2.9	2.4	1.3	3.4	1.9	2.1	1.3	2.31		48.5		F
531 2222	C											45		F
529 9281	A											47		F
528 8607	B	3.0	2.2	2.0	1.4	3.5	3.1	1.7	2.2	2.39		48		F
572 2050	C											50		F
531 7176	A											44		F
670 5360	B	5.4	3.8	3.0	2.0	4.3	4.2	2.5	1.8	3.38		47		F
530 7413	C											49		F
670 8295	A											46		F
569 9188	B	3.6	3.6	2.0	1.1	3.4	3.5	1.9	1.4	2.56		50		F
529 7102	C											49		F
531 3627	A											50		F
567 9480	B	4.0	2.7	2.1	1.5	3.3	2.2	1.7	1.2	2.34		50		F
599 3362	C											44		F
671 0090	A											41		F
599 4397	B	3.9	4.6	3.0	1.9	4.3	3.4	2.6	1.9	3.20		45		F
597 6577	C											40		F
670 5180	B	2.9	2.6	2.4	1.0	3.0	2.3	2.4	0.9	2.19		43		F

Group Key: C, no Torry; A, Torry once; B, Torry every 3 weeks.

Table B-3. Torry Reading for Reproductive Impacts Study (November 1, 2000).
Location: Orting Troutlodge Facility Fish: February Steelhead Operator: Colt Calibration: Chinook #4 (6.6/16.3)

PIT Tag #	Group[1]	Torry Meter Location/Reading									Status	Length (cm)	Temp (C)	Sex
		1	2	3	4	5	6	7	8	Mean				
558 9194	A												8.9	F
599 1838	B	---	---	---	---	---	---	---	---	---	Mort			F
529 2561	C													F
520 5696	A										Missing			F
567 5655	B	2.3	2.2	1.7	1.1	3.1	2.6	1.6	2.0	2.08				F
529 3549	C													F
598 5420	A										Mort			F
573 3972	B	1.3	0.7	1.0	0.9	0.7	0.6	0.9	0.9	0.88				F
560 4868	C													F
670 5970	A													F
670 7577	B	2.9	3.1	1.9	1.4	3.5	2.4	1.7	1.2	2.26				F
598 3871	C													F
599 0111	A													F
597 0923	B	---	---	---	---	---	---	---	---	---	Mort			F
531 3696	C													F
572 3107	A													F
670 8197	B	3.1	3.5	2.5	1.9	3.9	4.3	2.5	1.5	2.90				F
531 2222	C													F
529 9281	A													F
528 8607	B	3.4	3.2	2.2	1.5	3.5	3.1	1.9	1.3	2.51				F
572 2050	C													F
531 7176	A													F
670 5360	B	6.0	4.5	2.6	1.7	5.5	4.8	3.1	2.3	3.81				F
530 7413	C													F
670 8295	A													F
569 9188	B	4.3	4.2	2.6	1.4	4.3	3.9	2.1	1.1	2.99				F
529 7102	C													F
531 3627	A													F
567 9480	B	4.1	3.3	1.8	1.4	3.2	2.6	2.0	1.5	2.49				F
599 3362	C													F
671 0090	A													F
599 4397	B	5.1	4.9	3.0	1.9	3.9	5.1	3.3	2.6	3.73				F
597 6577	C										euthanized			F
670 5180	B	3.5	3.3	2.5	1.3	4.2	3.8	2.6	3.2	3.05				F

Group Key: C, no Torry; A, Torry once; B, Torry every 3 weeks.

Table B-4. Torry Reading for Reproductive Impacts Study (November 22, 2000).
Location: Orting Troutlodge Facility Fish: February Steelhead Operator: Colt Calibration: Chinook #4 (6.4/16.4)

PIT Tag #	Group[1]	Torry Meter Location/Reading									Status	Length (cm)	Temp (C)	Sex
		1	2	3	4	5	6	7	8	Mean				
558 9194	A												8.9	F
599 1838	B	---	---	---	---	---	---	---	---	---	Mort			F
529 2561	C													F
520 5696	A										Missing			F
567 5655	B	1.9	1.8	1.6	1.0	2.3	2.9	2.0	1.3	1.85				F
529 3549	C													F
598 5420	A										Mort			F
573 3972	B	1.3	1.6	1.3	1.2	1.6	1.9	1.2	0.6	1.34				F
560 4868	C													F
670 5970	A													F
670 7577	B	3.0	3.0	1.9	1.0	3.3	3.3	2.1	1.4	2.38				F
598 3871	C													F
599 0111	A													F
597 0923	B	---	---	---	---	---	---	---	---	---	Mort			F
531 3696	C													F
572 3107	A													F
670 8197	B	3.8	3.3	1.9	1.4	3.4	4.6	3.3	1.7	2.93				F
531 2222	C													F
529 9281	A													F
528 8607	B	3.9	4.2	2.5	1.3	2.9	3.8	2.3	1.3	2.78				F
572 2050	C													F
531 7176	A													F
670 5360	B	4.7	4.5	2.7	1.9	4.9	3.3	2.8	1.6	3.30				F
530 7413	C													F
670 8295	A										Mort			F
569 9188	B	4.5	3.8	2.4	1.3	5.2	4.9	2.5	1.3	3.24				F
529 7102	C													F
531 3627	A													F
567 9480	B	4.0	3.4	2.3	1.1	3.7	2.7	2.1	1.4	2.59				F
599 3362	C													F
671 0090	A													F
599 4397	B	5.6	5.3	3.3	2.3	4.7	4.2	2.7	2.1	3.78				F
597 6577	C										euthanised			F
670 5180	B	3.6	3.3	3.0	1.9	4.1	4.5	2.5	1.7	3.08				F

Group Key: C, no Torry; A, Torry once; B, Torry every 3 weeks.

Table B-5. Reproductive success of rainbow trout exposed to Torry meter measurements.

PIT Tag #	Group[1]	Status[2]	Spawning Date	Mean % to Eyed Stage	Mean % Blank Eggs	Mean % White Eggs	Mean Initial Torry Reading
558 9194	A		5 Mar	71.53	16.59	11.88	2.53
599 1838	B	Mort					
529 2561	C		19 Mar	46.47	1.95	51.58	n/a
520 5696	A	Miss					
567 5655	B	OD					
529 3549	C		5 Mar	82.55	11.45	6.00	n/a
598 5420	A	Mort					
573 3972	B	OD					
560 4868	C	OD					
670 5970	A		19 Mar	84.12	1.65	14.23	2.49
670 7577	B		5 Mar	66.13	13.33	20.54	2.68
598 3871	C		2 Apr	2.32	11.51	86.17	n/a
599 0111	A	OD					
597 0923	B	Mort					
531 3696	C		11 Feb	97.99	0.66	1.34	n/a
572 3107	A		13 Mar	47.05	2.93	50.02	2.65
670 8197	B	OD					
531 2222	C		13 Mar	81.98	1.18	16.85	n/a
529 9281	A		21 Feb	95.49	1.43	3.08	2.94
528 8607	B		19 Mar	95.14	1.12	3.74	2.65
572 2050	C	OD					
531 7176	A		19 Mar	94.34	4.01	1.65	2.11
670 5360	B		2 Apr	31.71	53.33	14.96	2.98
530 7413	C	OD					
670 8295	A	Mort					
569 9188	B		2 Apr	75.69	7.30	17.01	2.18
529 7102	C		19 Mar	89.44	3.02	7.54	n/a
531 3627	A		19 Mar	79.45	0.47	20.08	1.7
567 9480	B	OD					
599 3362	C		19 Mar	93.84	1.95	4.21	n/a
671 0090	A		8 Feb	91.56	3.81	4.63	3.89
599 4397	B		5 Mar	85.86	6.64		
597 6577	C	Euth				7.50	2.75
670 5180	B	OD					

[1] Group Key C: no Torry, A: Torry once, B: Torry every 3 weeks

[2] Mort = mortality, miss = missing, probably due to poaching, Euth = Euthanized due to fungus, OD = overdosed with MS-222 during ripeness check