NEW MECHANICAL SHOCK SENSITIVITY UNITS IN SUPPORT OF CRITERIA FOR PROTECTION OF SALMONID EGGS FROM BLASTING OR SEISMIC DISTURBANCE

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EXTENDED ABSTRACT ONLY – DO NOT CITE

Mechanical shock refers to the force on eggs that occurs as a result of disturbance to eggs. Disturbances can occur during handling (i.e., egg removal from female, pouring eggs into incubators, egg transportation, egg picking) or from outside sources such as pile driving or blasting and seismic shock. To overcome many of the difficulties and uncertainties of interpreting the egg survival responses to mechanical shock, a device was developed at the Pacific Biological Station in the early 1980s to expose salmonid eggs to standardized, quantifiable shock intensities (Jensen and Alderdice, 1983, 1989). The species tested were chinook (Oncorhynchus tshawytscha), chum (O. keta), coho (O. kisutch), pink (O. gorbuscha), sockeye (O. nerka), and rainbow or steelhead trout (O. mykiss).

Jensen and Alderdice (1983, 1989) reported changes in shock sensitivity in units of energy (ergs) transferred to eggs on impact, based on the drop height that caused 50 % and 10 % mortality. This standard unit was useful in demonstrating the changes of egg sensitivity during incubation. However, since these papers were published, requests have been received by Jensen to make recommendations about the potential hazards of disturbances such as pile driving or blasting for such activities as road construction and most recently explosive blasting for densification of the earth fill component of a dam.

This abstract describes a new approach to convert the original data, reported by Jensen and Alderdice (1983, 1989), from LC10s (i.e. drop height, cm, causing

10% mortality) to the final velocity (cm/sec) that the eggs reach when dropped from a height resulting in 10% mortality. This new unit of egg sensitivity can then be compared to the peak particle velocity (PPV) criteria of 1.3 cm/sec recommended by Wright and Hopky (1998) for blasting.

Jensen and Alderdice (1983, 1989) used a device developed to expose small groups of eggs to a series of standardized quantifiable shock intensities. The apparatus (Fig. 1) consists of a metal carrier with a slot to hold a petri dish (60-mm diameter x 15 mm) containing a single layer of eggs. The carrier is attached to a release platform by a release trigger. The platform can be moved to any drop height ranging from 0 to 100 cm. The carrier falls freely, guided by two guide wires when the trigger is released. Oversized Teflon sleeves mounted in the carrier guides minimize friction. The egg carrier was designed to come to an abrupt stop upon impact when dropped. This was accomplished by partially filling a hollowed-out portion of the carrier with lead shot. In addition, a 2-mm thick plate of synthetic elastomer, with high impact strength and ability to absorb shock, was fastened to the base to prevent the carrier from bouncing.

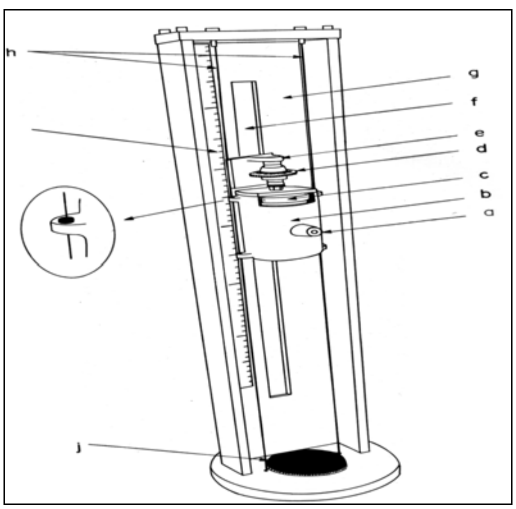

Figure 1. Mechanical shock device for salmonid eggs (from Jensen and Alderdice, 1983). a: handle for raising carrier; b: metal carrier; c: slot for petri dish in position; d: release trigger; e: release platform; f: slot for adjustment of release platform height; g: stage frame; h: metal guide wires; i: 100-cm scale; j: base plate. Inset: showing guide wire passing through Teflon sleeve.

Each shock test consisted of three drop heights (5 – 100 cm) and one control (0 cm); these tests were replicated three times at each time interval. Samples of 20 – 30 eggs were placed in a petri dish, free of surrounding fluid, and then placed in the carrier. The tests were carried out on eggs beginning with un-activated eggs, continued at very short time intervals (i.e. minutes and hours) post fertilization, followed by daily tests until egg sensitivity was no longer measurable.

The advantage of the shock device described herein is that it employs basic principles of physics which allow for the determination and reporting of the results using standard units of measure such as the acceleration (cm/sec2) and velocity (cm/sec) of eggs dropped from various heights, assuming minimal influence of friction. The drop heights that were determined to cause 10% mortality (Jensen and Alderdice, 1989) were used to determine the corresponding final velocity reached by the eggs. The relationship of the parameters of drop height (s; cm), initial velocity (vo; cm/sec), final velocity at time of impact (vt; cm/sec), and acceleration due to gravity (g; cm/sec2) is illustrated in the following equation:

$$vt = (vo^2 + 2 \bullet g \bullet s)^{1/2}$$

where vo=0, g=980. The LC10 velocities were calculated by substituting LC10 drop heights for s.

In this paper the LC10 velocities were modelled in relation to accumulated temperature units (ATUs) instead of days from fertilization. Hence, the resultant equations can be applied to temperatures other than the 10 °C test temperatures, making the models much more versatile at various temperatures (Table 1).

Table 1. Log-linear and parabola model coefficients for LC10 velocities (cm/sec).

Species & Model type	ATUs (°-days)	Model coefficients a	b	c	r^2
Chinook					
Log-linear	0 - 50	191.813486	-27.604286		0.826208
Parabola	50 -230	372.914357	-6.468933	0.029199	0.904477
Chum					
Log-linear	0 - 40	161.876465	-26.359391		0.554601
Parabola	60 -240	203.083120	-3.237649	0.016230	0.925421
Coho					
Log-linear	0 - 50	126.211035	-15.956642		0.649024
Parabola	50 - 180	216.596882	-4.087539	0.021588	0.925421
Pink					
Log-linear	0 - 30	168.386172	-25.844475		0.804388
Parabola	30 - 190	248.262505	-4.233782	0.024102	0.900141
Sockeye					
Log-linear	0 - 50	225.228193	-33.570647		0.729549
Parabola	50 - 200	273.584965	-4.189878	0.023123	0.953769
Steelhead					
Log-linear	0 - 40	138.671408	-22.213301		0.611474
Parabola	40 - 150	284.510542	-6.420712	0.041003	0.909880

[1] Log-linear model: $y = a + b\ln x$
[2] Parabola model: $y = a + bx + cx^2$

To illustrate these changes in egg sensitivity as embryonic development progresses, the predicted LC10 velocities (based on log-linear models and parabolic models as described above) for chinook salmon eggs, are plotted against ATUs (°C-days) from fertilization (Figure 2).

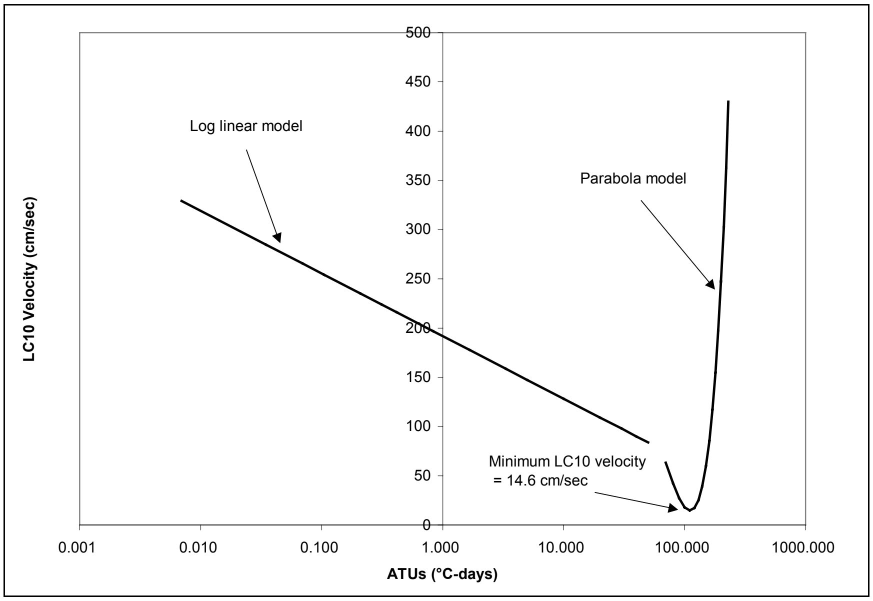

Figure 2. Predicted LC10 velocity for chinook salmon eggs (from model coefficients in Table 1) are plotted against ATUs (°C-days) from fertilization. The minimum LC10 velocity was 14.6 cm/sec. and occurred at 110.8 ATUs.

Wright and Hopky (1998) describe guidelines for protection of fish in response to explosives. In their report they recommend that no explosives should produce a peak particle velocity (PPV) greater than 1.3 cm/sec. Hence, it follows that the LC10 velocities reported herein should be much greater than 1.3 cm/sec. to ensure that no egg mortality occurs. The worst case scenario occurs at the minimum LC10 velocity (i.e. the lowest velocity causing 10 % mortality). The LC10 velocity minima were determined from parabolic models for each species.

These LC10 velocity minima and the ATUs when they occur, for the 6 salmonid species tested, are listed in Table 2.

Table 2. Predicted minimum LC10 velocities (cm/sec) at ATUs post-fertilization. Based on the parabolic equation coefficients from Table 1.

Species	Minimum LC10 Velocity (cm/sec)	ATUs (°C-days)
Chinook	14.6	110.8
Chum	41.6	99.8
Coho	23.1	94.7
Pink	62.3	87.8
Sockeye	83.8	90.6
Steelhead	33.2	78.3

Notice that these values are at least ten times greater than the PPV of 1.3 cm/sec recommended as a safe criterion for the use of explosives by Wright and Hopky (1998). For example, in order to cause 10 % egg mortality in chinook (the most sensitive salmonid species tested) at 111 ATUs (the most sensitive time of development for chinook), the recommended safe criterion of 1.3 cm/sec PPV would have to be exceeded by more than ten times, which it is (i.e. minimum LC10 Velocity is 14.6 cm/sec.). Hence, these new egg sensitivity units are in good agreement with the current guidelines for the use of explosives or other disturbances near salmonid spawning redds.

References

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