Effects of Aquatic Herbicides on Survival of Salmon and Steelhead Smolts During Seawater Transition

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Eurasian Watermilfoil

Credit: Hugh McEachen

Medication Inhibits Tolerance to Seawater in Coho Salmon Smolts

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Abstract

Applications of 10 therapeutic and two anesthetic agents to healthy smolts of coho salmon (Oncorhynchus kisutch) by conventional methods were followed by two different posttreatment circumstances. In condition I, fish were treated and then transferred directly to 28‰ seawater for 10 days; in condition II, fish were treated and held in fresh water for 4 days before their exposure to seawater. In condition I, mortality was reduced by copper sulfate, potassium permanganate, malachite green (one protocol), and heavy doses of MS-222. In condition II, mortality was reduced but still high for copper sulfate and potassium permanganate, much lower for malachite green, and hyamine 1622, and zero for the other agents. The results indicate that additional recovery time in fresh water is necessary between some treatments and exposure to seawater.

Artificial propagation of anadromous Pacific salmon (Oncorhynchus spp.) is an increasingly important [illegible] both to maintain [illegible] and to provide for increasing demands for more salmon. Both the cultural practices and the economic gains that result from them have been established (Leitritz 1962; Wahle et al. 1974) and provide ample stimulus for increasing output at existing salmon hatcheries. However, increased production is often accompanied by increased incidence or severity of fish diseases (or parasites) and thus requires the use of therapeutic or prophylactic drugs. Effects of disease treatments on saltwater tolerance of salmon smolts have not been established.

Physical or chemical treatments can influence smoltification, tolerance to seawater, and inclination to out-migrate. For example, Lorz and McPherson (1976) reported that chronic low-level exposure to Cu^{+2} had deleterious effects on out-migration, gill ATPase activity, and survival in seawater. However, it is not known if a single treatment with copper sulfate, such as 37 mg/liter for 20 minutes as suggested by Snieszko and Bullock (1976), would have a similar effect; other therapeutic agents might have similar adverse effects.

Many chemicals have been used previously as therapeutic agents in fish culture. More recently, the United States Government has required that all such chemicals be approved and [illegible] for specific therapeutic use to [illegible] of this requirement is to ensure that the treatments are effective and have no deleterious side effects. As far as we know, there are few or no data regarding the impact of common therapeutics on saltwater tolerance. Such data might influence both the registration and potential beneficial uses of a drug in a salmon hatchery.

Smolts of coho salmon (Oncorhynchus kisutch) were selected for this study because they readily tolerate direct transfer to full-strength seawater (Zaugg and McLain 1970), and because they tend to be reared in coastal regions where they can migrate to the ocean in less than a day. However, the results may apply to other species of anadromous Pacific salmonids, which with increasing frequency are trucked to sites near the ocean for release.

Methods

Two anesthetic and 10 therapeutic agents (Table 1) were selected for testing, based in part on (1) availability of an established protocol for their use on fish; (2) general potential for use in hatcheries; (3) availability of the test chemical in high-quality form; and (4) testing limitations. Each chemical was used as recommended by

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Seawater Challenge of Coho Salmon Smolts Following Exposure to the Herbicide Endothall

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[illegible] was conducted to determine the [illegible] (reported as [illegible] formulation not specified) in freshwater for [illegible] (Bouck and Johnson 1979). There were no deaths in a second trial, and the inconsistency was not investigated further. The researchers suggested that endothall may interfere with [illegible] or [illegible] regulate.

Another investigation showed that juvenile chinook salmon suffered high mortality when challenged by seawater following exposure to 4 mg/L dipotassium endothall/L for 4 or 14 d (Ligouri et al. 198[illegible]. The [illegible] of reduced osmoregulatory capacity. Clarke and Blackburn (1977) and Clarke (1982) have suggested that smolts with an extended osmoregulatory adjustment period suffer great marine mortality because [illegible] swimming [illegible]

To assess the osmoregulatory performance of coho salmon smolts exposed to endothall, a two-step procedure was used. Fish were [illegible] fresh [illegible] was used because it is the herbicidal agent common to Aquathol and Hydrothol and because the effects of this chemical on salmon smolts are unknown. The fish were given a 24-h seawater challenge following the endothall exposure. Blood plasma sodium concentrations were then compared with those of control fish and with values associated with normal marine adaptation for coho salmon smolts challenged by seawater for 24 h.

Methods

The coho salmon smolt bioassay and seawater challenge was conducted at the Washington State Department of Ecology and U.S. Environmental Protection Agency Manchester Environmental Laboratory in Manchester, Washington. Coho salmon smolts (mean weight, 27 g) were obtained from the Minter Creek State Hatchery near Purdy, Washington, during the second week of May. Smolts were transported to Manchester by truck, and appropriate precautions were taken to reduce

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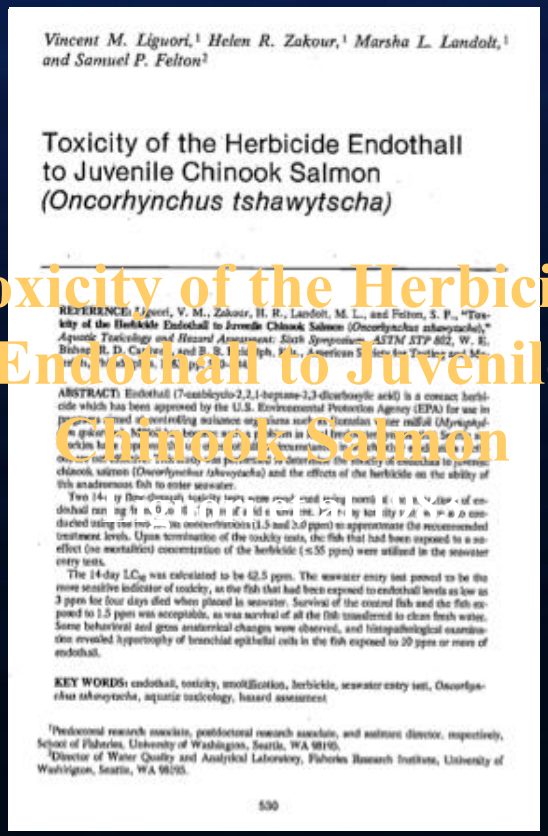

Toxicity of the Herbicide Endothall to Juvenile Chinook Salmon (Oncorhynchus tshawytscha)

Vincent M. Ligouri,[1] Helen R. Zakour,[1] Marsha L. Landolt,[1] and Samuel P. Felton[2]

Toxicity of the Herbicide Endothall to Juvenile Chinook Salmon (Oncorhynchus tshawytscha)

REFERENCE: Ligouri, V. M., Zakour, H. R., Landolt, M. L., and Felton, S. P., "Toxicity of the Herbicide Endothall to Juvenile Chinook Salmon (Oncorhynchus tshawytscha)," Aquatic Toxicology and Hazard Assessment: Sixth Symposium, ASTM STP 802, W. E. Bishop, R. D. Cardwell, and B. B. [illegible]ph, Eds., American Society for Testing and Materials, [illegible] pp. [illegible]-[illegible].

ABSTRACT: Endothall (7-oxabicyclo-2,2,1-heptane-2,3-dicarboxylic acid) is a contact herbicide which has been approved by the U.S. Environmental Protection Agency (EPA) for use in [illegible] and controlling nuisance aquatic plants such as [illegible] water milfoil (Myriophyllum spicatum). [illegible] in [illegible] were [illegible] to determine the toxicity of endothall to juvenile chinook salmon (Oncorhynchus tshawytscha) and the effects of the herbicide on the ability of this anadromous fish to enter seawater.

Two 14-day flow-through toxicity tests were [illegible] using normal [illegible] of endothall ranging from [illegible] to [illegible] ppm. [illegible] were conducted using two [illegible] concentrations (1.5 and 2.0 ppm) to approximate the recommended treatment levels. Upon termination of the toxicity tests, the fish that had been exposed to a no-effect (no mortalities) concentration of the herbicide (≤ 55 ppm) were utilized in the seawater entry tests.

The 14-day LC_{50} was calculated to be 42.5 ppm. The seawater entry test proved to be the more sensitive indicator of toxicity, as the fish that had been exposed to endothall levels as low as 3 ppm for four days died when placed in seawater. Survival of the control fish and the fish exposed to 1.5 ppm was acceptable, as was survival of all the fish transferred to clean fresh water. Some behavioral and gross anatomical changes were observed, and histopathological examination revealed hypertrophy of branchial epithelial cells in the fish exposed to 10 ppm or more of endothall.

KEY WORDS: endothall, toxicity, smoltification, herbicide, seawater entry test, Oncorhynchus tshawytscha, aquatic toxicology, hazard assessment

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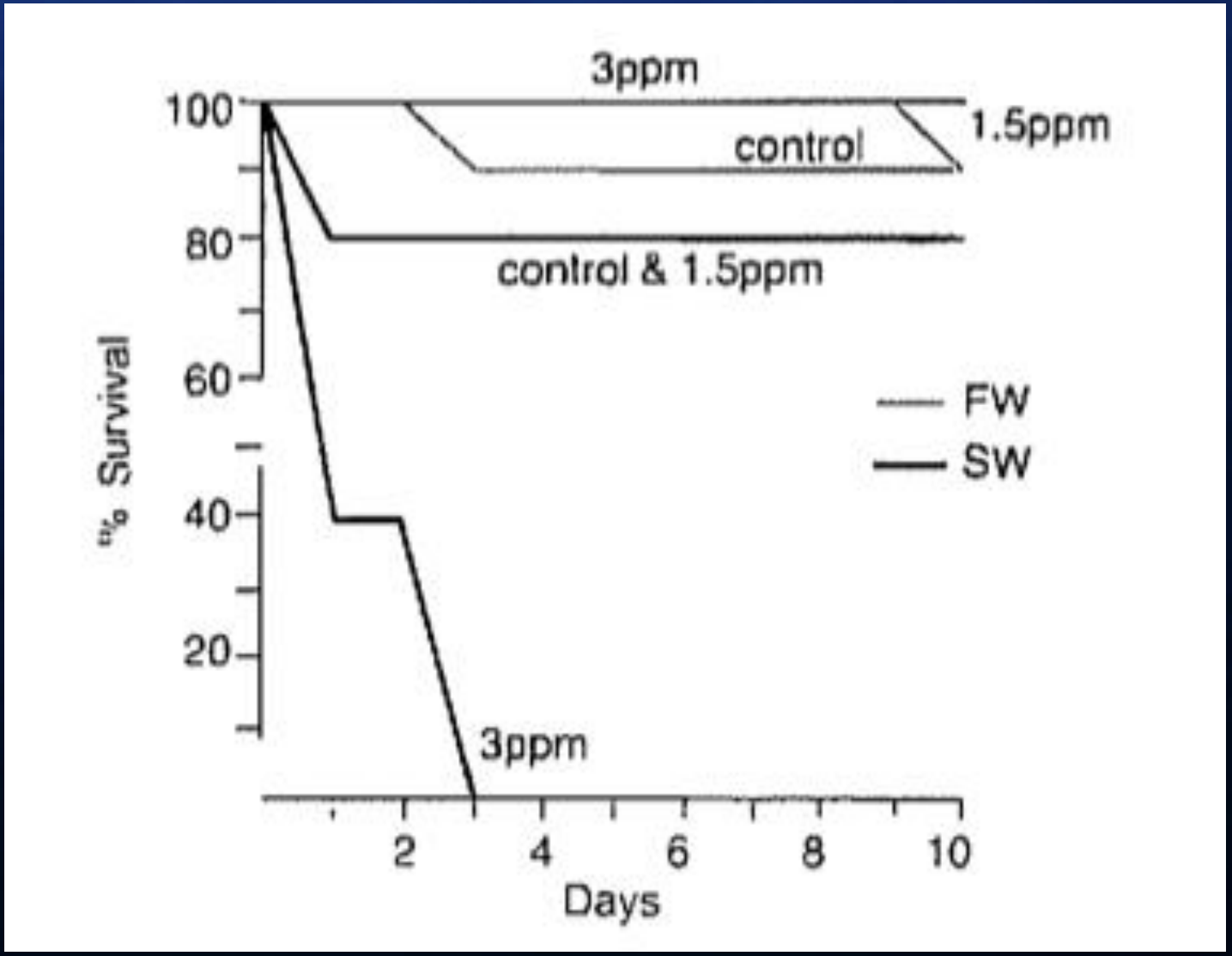
Previous Findings



Sources of Uncertainty

- Small Sample Sizes
- Static Exposures & Seawater Challenge
- Various life-stages
- Conflicting results between and within studies

Experimental Treatment Groups

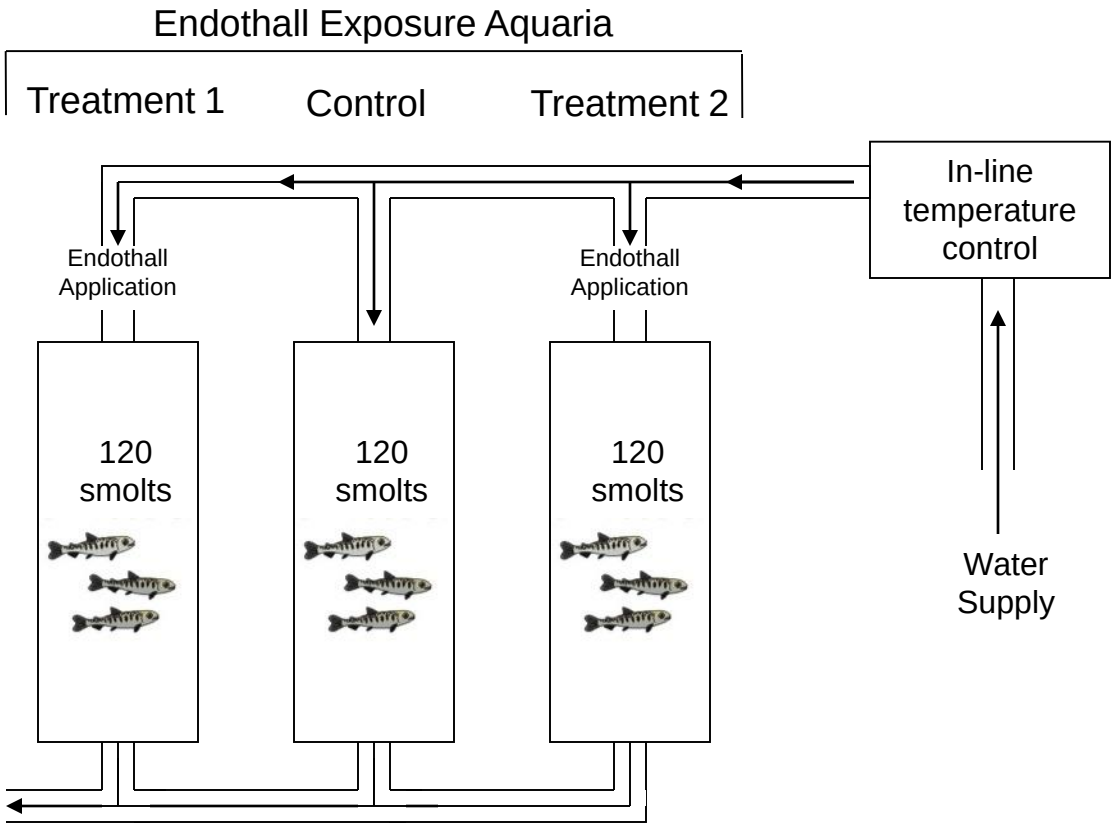
Exposure Concentrations

- 1 ppm
- 1.75 ppm
- 2.5 ppm
- 3.5 ppm
- 5 ppm
- 10 ppm

Temperatures

- 16
- 18
- 20

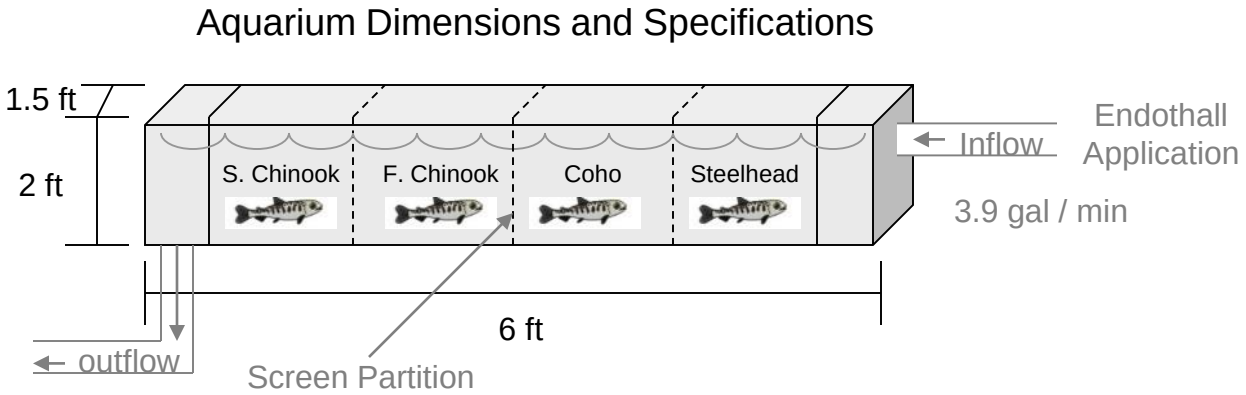
A.



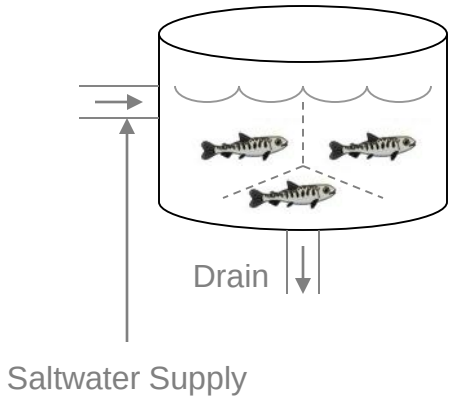
1-Day Acclimation

4-Day Exposure

B.



Species X, Treatments 1 and 2, Replicate 1



40 Gallon Capacity

30 Total Fish

2-Day Acclimation

24-Hour Seawater Transition

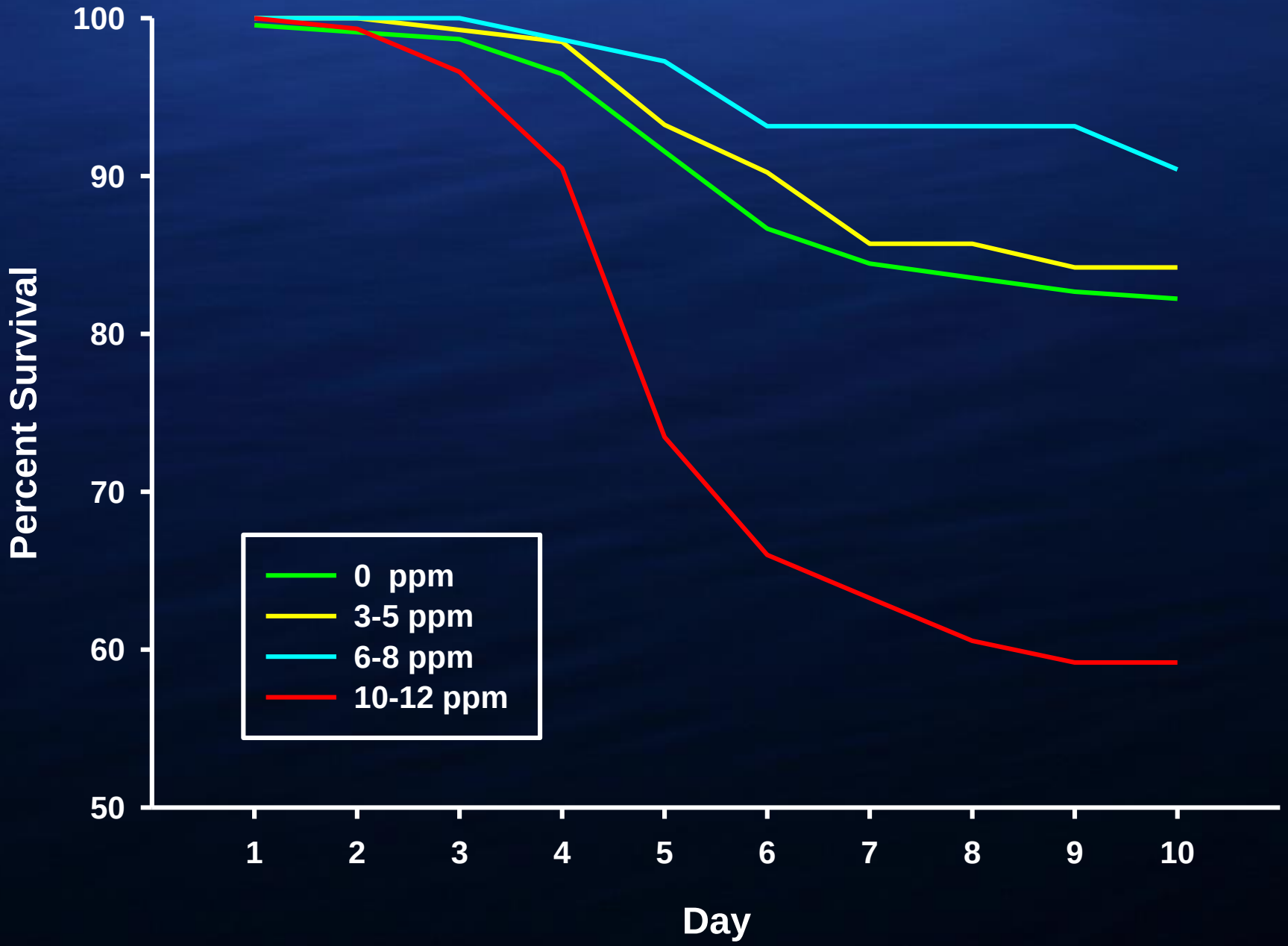
10-Day Challenge


B

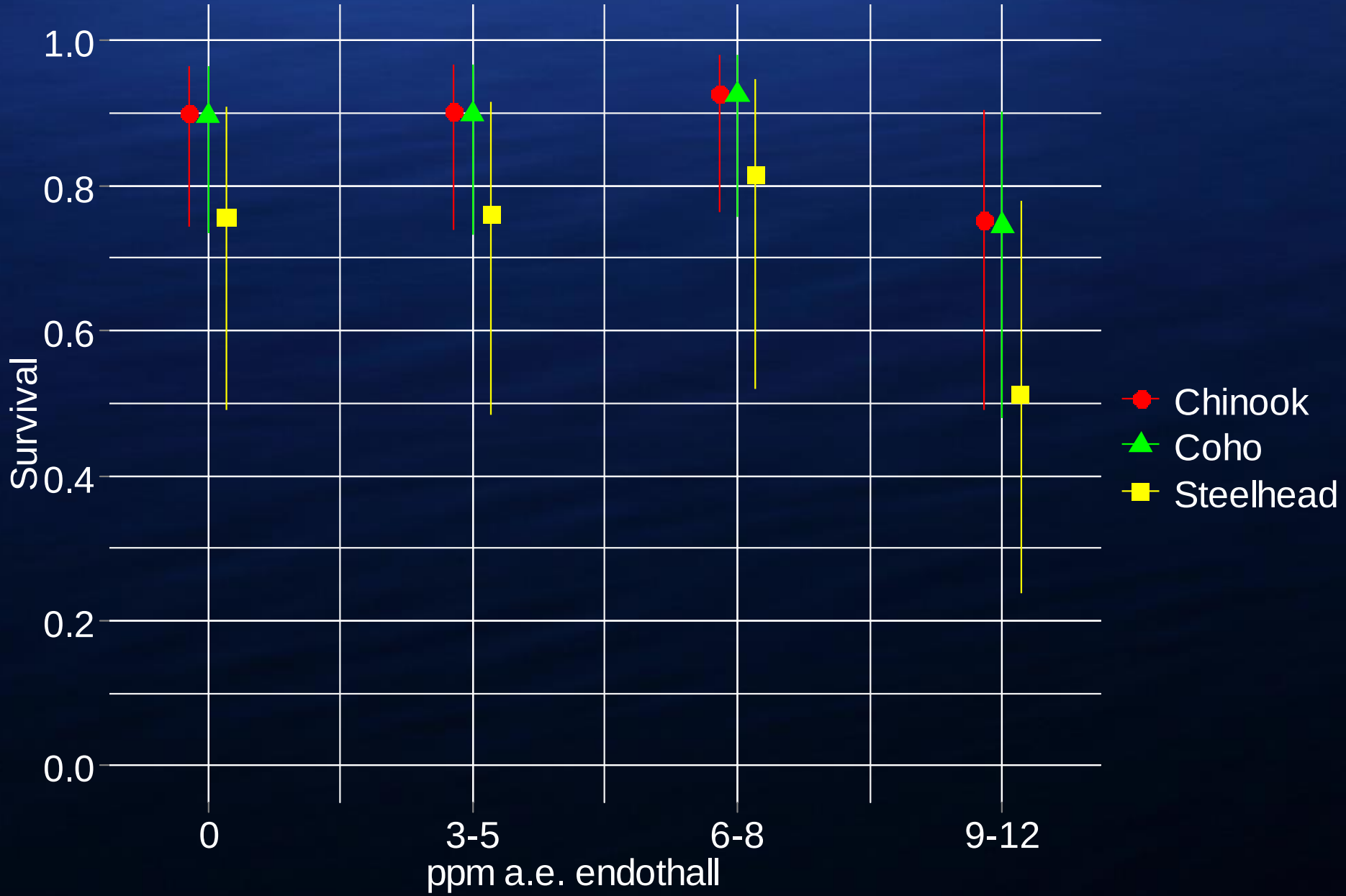
Quality Controls

- Water Quality Data Collection
- Exposure Concentration Confirmation
- Continuous Temperature Monitoring
- Simulated Day and Night
- Chemical Handling and Data Collection Protocols
- Blood Sodium Analysis

Results


100
90
80
70
60
50
Percent Survival
0 ppm
3-5 ppm
6-8 ppm
10-12 ppm
1
2
3
4
5
6
7
8
9
10
Day

Statistical Comparisons



Findings

1. Mortality in all groups occurred after 48 hours in seawater.
2. >80% Survival in control and 3-8 ppm treatment groups after 10 days in seawater.
3. <60% survival in treatment groups >8 ppm.
4. Blood sodium analysis did not show any non-lethal effects of Cascade® exposure on osmoregulation.
5. Effects of chemical exposure occurred at much lower doses in the seawater challenge assay relative to standard acute toxicity assays.

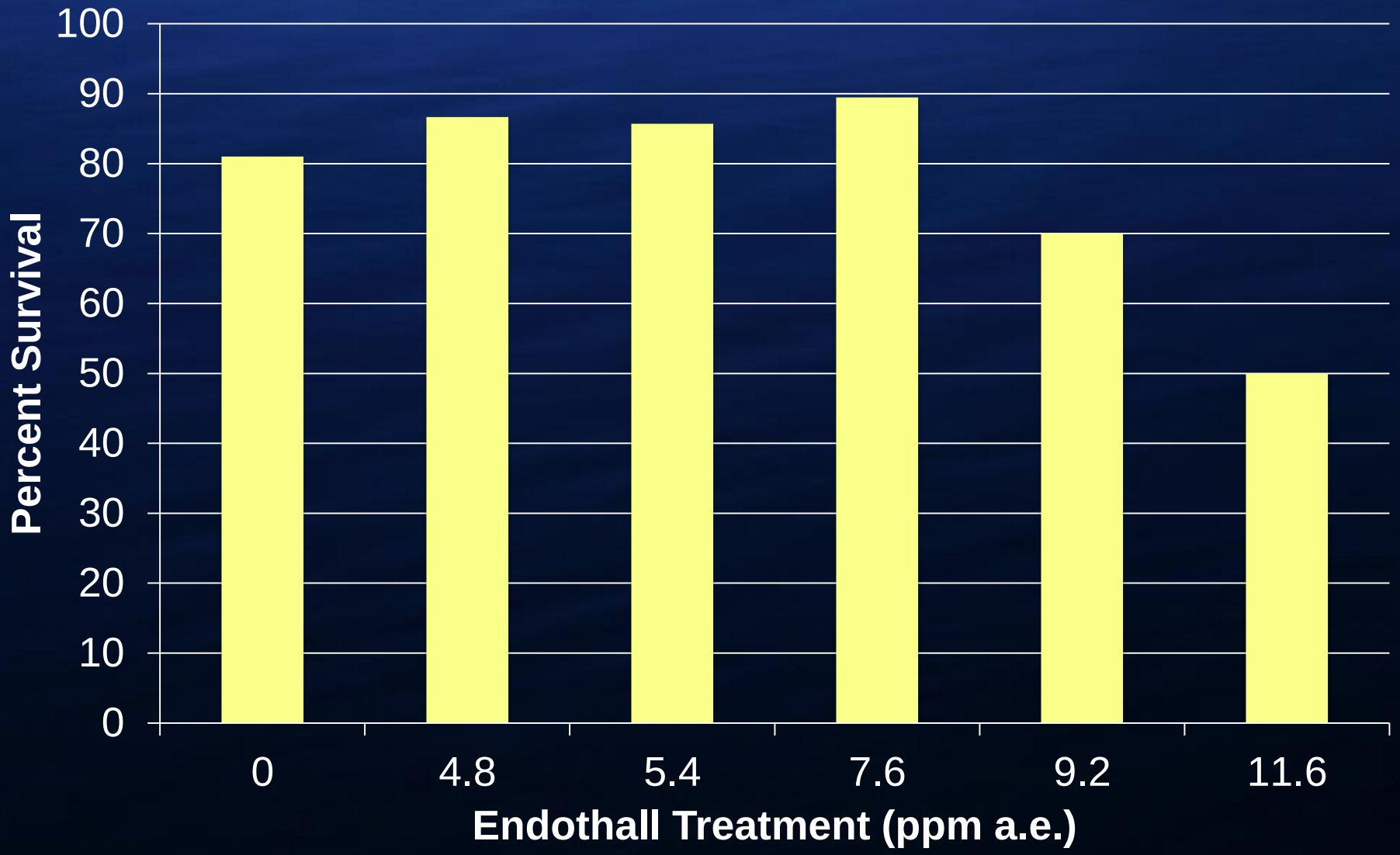
Management Implications

1. When anadromous species are a concern, chemical risk assessments should include an evaluation of effects during seawater transition.

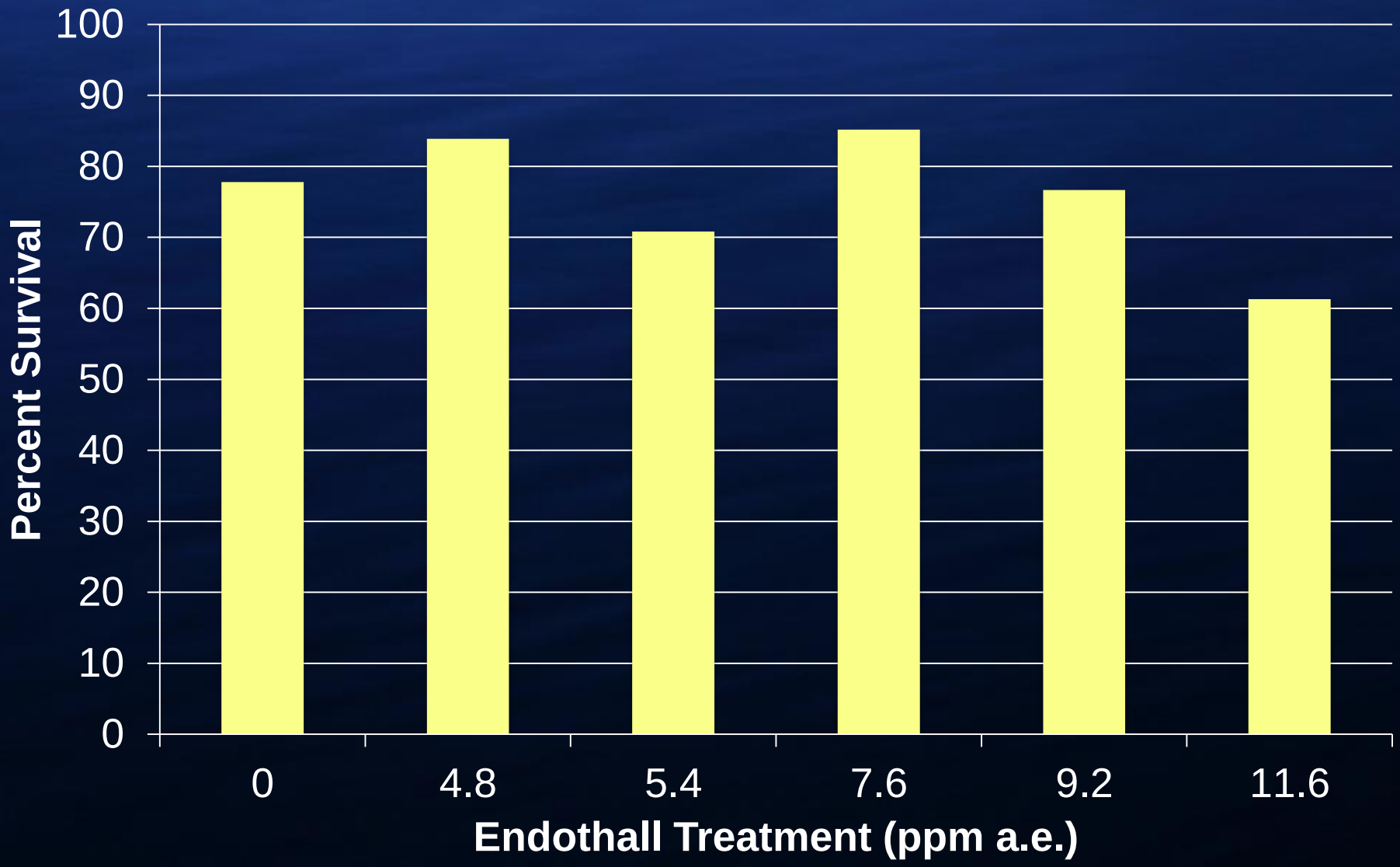
2. Regulation according to EPA's approved level of 5 ppm appears sufficient to protect anadromous salmonids.


Questions

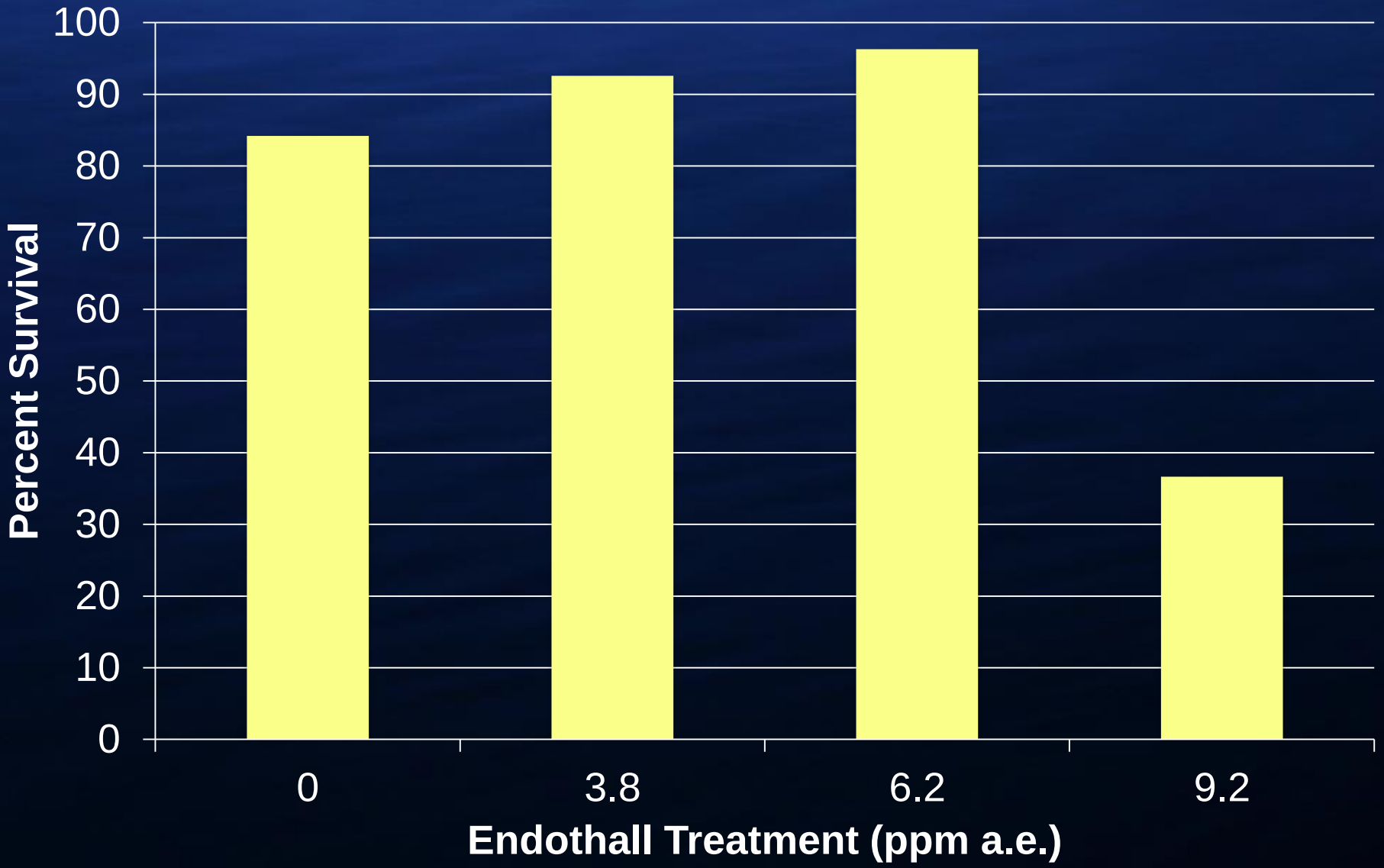
Coho


Percent Survival
100
90
80
70
60
50
40
30
20
10
0
0
4.8
5.4
7.6
9.2
11.6
Endothall Treatment (ppm a.e.)

Chinook


100
90
80
70
60
50
40
30
20
10
0
Percent Survival
0
4.8
5.4
7.6
9.2
11.6
Endothall Treatment (ppm a.e.)

Steelhead


100
90
80
70
60
50
40
30
20
10
0
Percent Survival
0
3.8
6.2
9.2
Endothall Treatment (ppm a.e.)