The Potential Consequences of Cold Shock on Fish in the Nechako River, B.C.

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Cold Shock

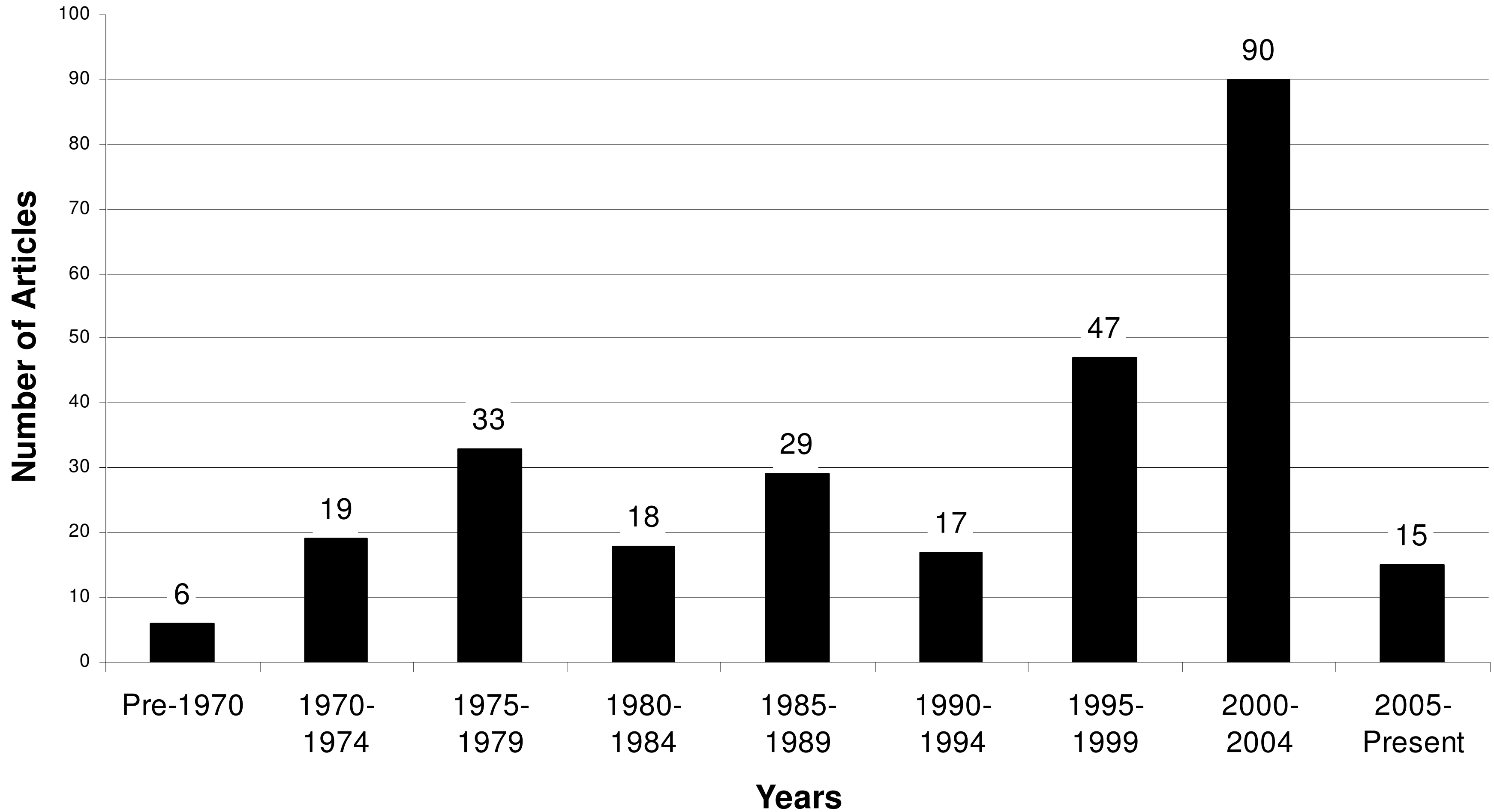
- Cold shock is a stress response to a rapid decrease in water temperature
- Cold shock initiates adaptive primary, secondary and tertiary physiological and behavioural stress responses
- Outcomes can be sublethal or lethal
- The consequences of cold shock are highly variable and depend on:

Magnitude of temperature change and rate of flow	Interspecific and intraspecific physiological differences
Genetic differences	Interspecific and intraspecific behavioural differences
Stage of development	Acclimation and thermal history

Sources of Cold Shock

Anthropogenic Sources	Natural Sources
Thermal effluent from power generating plants	Thermocline exposure at different water depths
Thermal effluent from industrial plants	Abnormal seiches and water movements
Alterations in water control structures	Rapid temperature changes in shallow areas
Fish harvesting practices	Diel changes in water temperature

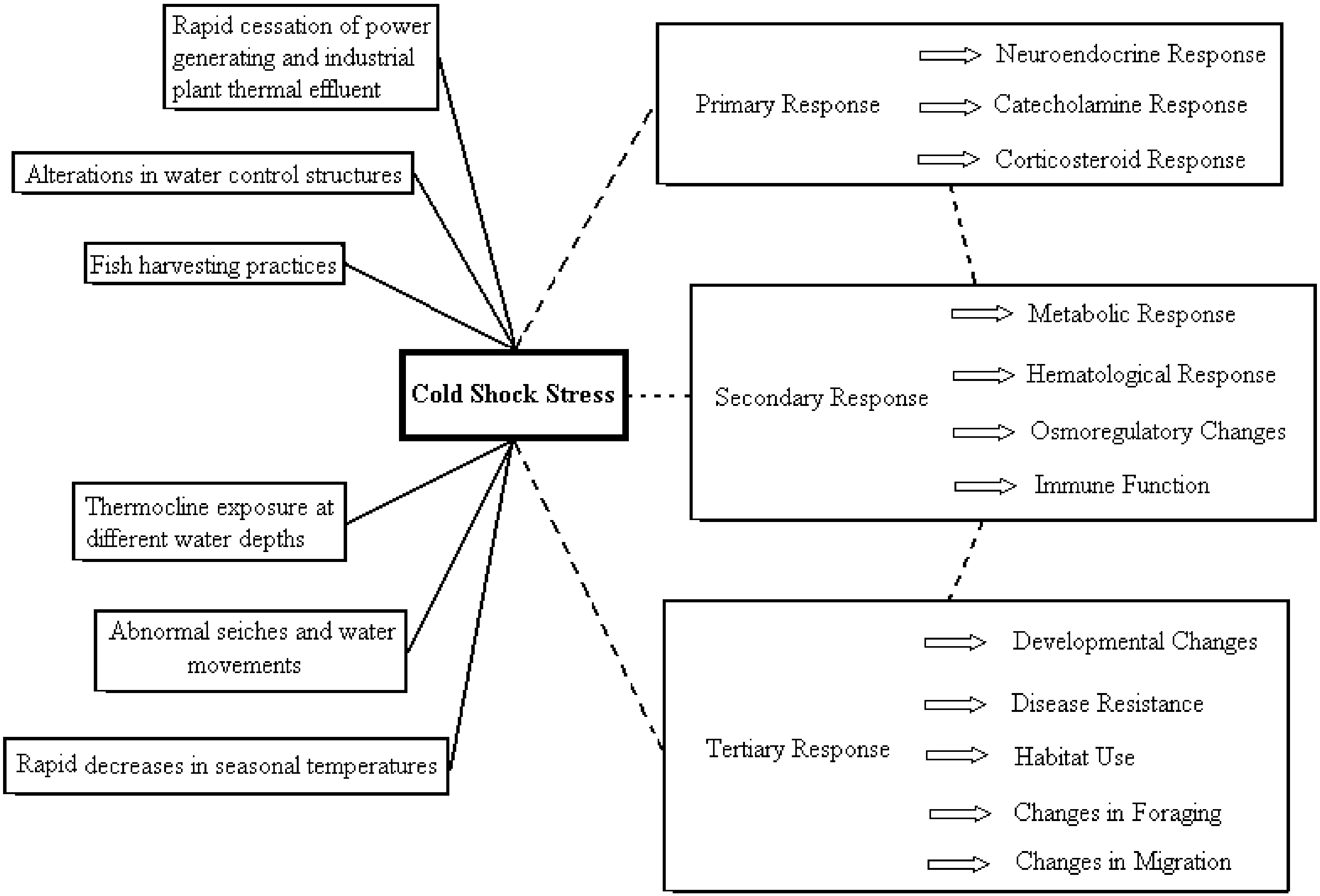
Trends in Cold Shock Research



Cold shock research

- The majority of cold shock studies prior to 1980 focused on:
  1. Assessing large fish kills following acute temperature changes
  2. Examining power plant and industrial thermal discharges on fish abundance, distribution and survival
- Recent shift in research toward:
  1. Understanding the sublethal effects of cold shock (i.e., physiological and behavioural stress response)
  2. Emphasizing the benefits of cold shock in fisheries science (i.e., induction of polyploidy, anesthetic)

Primary, Secondary and Tertiary Response

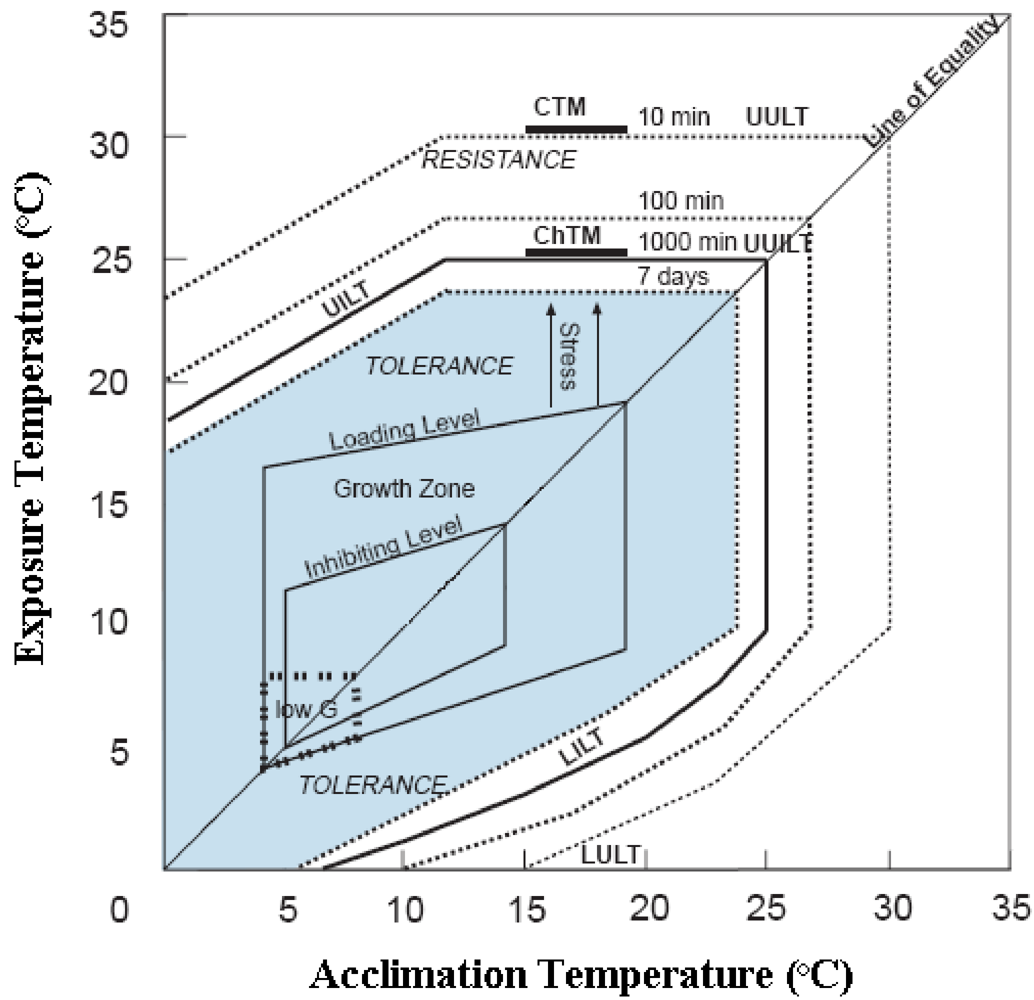


Developing Recommendations for Cold Shock

- Developing guidelines for mixed water temperatures downstream from the CWRF is difficult due to site-specific, inter and intra-species specific differences in thermal optima
- Further, previous guidelines that have been proposed are based more on “best guesses” rather than specific, scientific evidence

Thermal Tolerance Polygon

Example: Spring chinook salmon (*Oncorhyncus tshawytscha*)



McCullough 1999

B.C. Water Temperature Guidelines

- The Water, Air and Climate Change Branch of the B.C. Ministry of the Environment recommends that the rate of temperature change not exceed 1ºC/hour in water bodies, regardless of whether the fish distribution is known or unknown
- A change of 1ºC/hour may not be applicable to the Kenney Dam CWRF.

Recommendations for the CWRF

- Based on our review of approx. 250 papers on cold shock and our understanding of the Nechako System and CWRF, seven recommendations have been developed to ensure that the potential lethal or sublethal effects of cold shock are recognized and incorporated into planning and operation to protect aquatic life

- It is important to note that there were very few studies specific to the species of fish that are found in the Nechako system, so recommendations are generalized

1. Promote gradual volume and temperature changes

Rationale:

- Cold shock consequences are poorly understood
- Small variations in water temperature can result in sublethal stress
- In North America, thermal regulations vary among sites emphasizing the importance of recognizing site-specific differences and operational constraints
- Although it is difficult to propose specific maximal rates/magnitudes of change, there is general consensus that temperature should not change in an absolute sense by more than 1°C per hour and not deviate from ambient conditions (ΔT) by approx 3°C
- The maximum daily ΔT that we are aware of is a temporary exemption for the Nanticoke Thermal Generating Station on Lake Erie (typical maximal ΔT for this site is 7.5°C; exemption maximal ΔT 12.5°C. Included in this exemption is the expectation of research on this topic
- We argue that a precautionary approach should be adopted to minimize the risk of cold shock stress

2. ΔT between discharge and ambient waters should be adjusted on a seasonal basis to compensate for variable water temperatures

Rationale:

- Seasonal variation in water temperatures will result in an increased variability of ΔT between discharge and ambient waters at certain times of the year

- For example, if the discharge temperature is 4ºC and the receiving waters are 20ºC in mid to late-summer, the potential for “cold shocked fish” is much higher than in early summer and early fall where the ΔT between discharge may be much lower (i.e., 3 or 4ºC)

3. Promote heterogeneous mixing between cold discharge and ambient waters

Rationale:

- Rapid mixing minimizes the temperature difference (ΔT) at the discharge site
- Reduces the risk of cold shock near the discharge zone
- Recognize that fish can and will occupy the region at the “end of the pipe” and thus it may be inappropriate to use a thermal monitoring station located km’s downstream to assess thermal conditions and mixing. A series of thermal logging stations are required throughout the system beginning at the end of the pipe

4. Cold-water release facility should have a tempering system or “fine control” structure

Rationale:

- Fish can swim to the immediate vicinity of the cold water release site, therefore, this habitat must not exceed thermal limits

- Flows and temperatures must be controlled at the source prior to release in receiving waters

- A tempering system allows for manual control of release temperatures and flows to minimize the ΔT between discharge and ambient waters

- Tempering may have tradeoffs with impingement/entrainment

5. Develop a small-scale experimental laboratory to determine/test/refine operational strategies prior to formal implementation

Rationale:

- Current research from literature is insufficient to develop specific recommendations WRT flow and temperature release values
- This research is necessary to understand the site-specific, inter and intra-specific differences that are inherent to the Nechako River system, in order to minimize thermal stress on aquatic life
- The facility should be able to supply experimental tanks and raceways with water from the CWRF as well as ambient waters at rates that can be controlled by research personnel – such a facility should be incorporated into the design of the CWRF. Water volume to the site should reflect the need to study large adult fishes for long term periods in replicated experiments.

6. Initially operate the CWRF in a conservative manner and use the experimental testing facility to assess alternative thermal regimes prior to making them operational

Rationale:

- Adaptive management approach to ensure that the effects of cold shock are well understood prior to fish being exposed to potentially lethal or sublethal thermal conditions

- Such an approach will protect the fish and will also reduce the potential for Fisheries Act violations

7. *In situ* monitoring should be conducted to characterize optimal flow rates, discharge temperatures, mixing, and fish biology

Rationale:

- Careful monitoring of mixed water temperatures is imperative to manage aquatic life in the vicinity of the discharge from the CWRF

- A site-specific understanding of how water temperatures mix at the source will allow for a better characterization of how cold shock could affect fish in the cold water discharge zone

- Monitoring should also include field-based fisheries assessments and fish sentinel programs (i.e., use biotelemetry to monitor the *in situ* responses of fish to different thermal conditions)

Conclusions

- A number of excellent studies have been conducted on the effects of cold shock on fish
- However, more research is required before specific recommendations can be made regarding discharge flows and temperatures
- Conservative actions are recommended until we have a better understanding of the site-specific variability of the CWRF and the effects of cold shock on fish in the Nechako system
- Experimental laboratory research as well as long-term monitoring is necessary to determine the effects of cold water release on aquatic life in the Nechako River and to refine operational strategies to protect and enhance the aquatic environment