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Aquaculture Collaborative Research and Development Program (ACRDP) Fact Sheet

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Predictive Modeling for Paralytic Shellfish Poisoning in Baynes Sound, British Columbia

Aerial view of Baynes Sound. (Photo: G. McLellan, Mac's Oysters Ltd.)

Summary

Paralytic shellfish poisoning (PSP) is a potentially lethal condition that is caused by the consumption of shellfish which have concentrated paralytic shellfish toxins (PST) from phytoplankton. This Aquaculture Collaborative Research and Development Program (ACRDP) project explored the development of a predictive model to help identify and predict where and when phytoplankton blooms might occur. Various environmental and hydrographic data relevant to Baynes Sound, British Columbia (BC) were compiled and relationships between these factors and PSP events were evaluated using statistical analyses (correlations). The most important factors in predicting PSP levels were: time of the year, salinity and rainfall pattern. Specifically, the amount of measurable rain that fell 3 and 4 days prior to sampling was found to correlate with PSP levels. The PSP model hindcasts[1] were accurate 97% of the time, making this a promising real-time tool to help identify periods of increased risk to shellfish culture. The results of this research will help improve the overall sustainability of the aquaculture industry in BC by facilitating decision making by the department on aquaculture siting, as well as allowing the aquaculture industry to plan harvests and avoid costly product recalls.

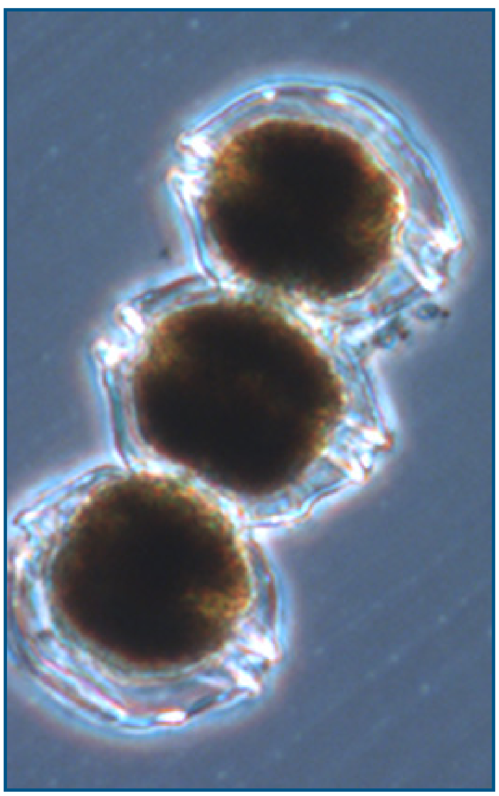
The Aquaculture Collaborative Research and Development Program (ACRDP) is a Fisheries and Oceans Canada (DFO) initiative to increase the level of collaborative research and development activity between the aquaculture industry and DFO. Projects under ACRDP seek to improve aquaculture environmental performance and support optimal fish health.

[1]*These hindcasts are developed using historical environmental and hydrographic data to test the ability of the model to predict events.*

Introduction

Paralytic shellfish poisoning (PSP) is a potentially lethal condition that is caused by the consumption of shellfish that have concentrated paralytic shellfish toxins (PST) from feeding on phytoplankton. In British Columbia (BC), the source of PST are generally dinoflagellates of the genus *Alexandrium* (Figure 1) which can cause toxicity in shellfish from April to late fall, depending on environmental conditions and location. To minimize the risk of PSP, the Canadian Food Inspection Agency monitors various stations throughout the BC coast on a weekly basis. Until now, however, no reliable method has been developed to predict when an elevated risk of PSP might occur. Development of a model to help identify and predict when phytoplankton blooms might occur would provide the tools necessary for decision-making and improve food safety and harvest efficiency.

The objective of this project was to develop a predictive model for PSP in Baynes Sound, BC. This would provide a real-time tool that could indentify high-risk periods prior to a PSP event.



Alexandrium sp.

Figure 1.
In British Columbia, Paralytic shellfish poisoning (PSP) toxins are produced by dinoflagellates in the *Alexandrium* genus. (Photo: Microthalassia Consultants Inc.)

Figure 2.
Aerial view of Chrome Island Lighthouse (Baynes Sound, BC) where salinity measurements for the PSP model were collected. (Photo: G. McLellan Jr.)

Methods

Environmental and hydrographic data (physical features of the ocean) relevant to Baynes Sound from 1983–2013 were compiled. Corresponding PSP levels were obtained from Fisheries and Oceans Canada (1983–1997) and Canadian Food Inspection Agency (1998–2013) databases. Correlations between PSP levels and the following variables were analyzed (further details within Table 1): rainfall, river discharge, salinity (Figure 2), air temperature, water temperature, degree days, and tidal cycles.

Table 1.
Environmental and hydrographic data collected for correlations with PSP levels, detailing data source.

Variable	Source
Rainfall	Comox Airport, Station A
River discharge	Puntledge River, Station #08HB006
Salinity	Chrome Island Lighthouse
Air temperature	Comox Airport, Station A
Water temperature	Chrome Island Lighthouse
Degree days	Comox Airport, Station A
Tidal cycles	Canadian Coast Guard tide charts

Shellfish raft aquaculture in Metcalf Bay, BC. (Photo: R. Marshall)

As prolonged environmental and hydrologic conditions prior can have impacts on PSP events, the factors were examined cumulatively ranging from 1 to 30 days. Additionally, there may be time lags between an environmental/hydrological event and PSP blooms (e.g., it may take days or weeks for an algal bloom to develop after a triggering event like a temperature shift or heavy rainfall). Consequently, time lag was analyzed by time shifting the environmental and hydrologic data by 0 to 12 days in relation to PSP levels. For example, PSP levels were correlated to total rainfall on the day of the sample, one day before the sample, two days before, etc. Analyses were restricted from May to September, when water temperatures were warm enough for the phytoplankton source for PSP to grow.

Analyzing the model

Relationships between the various factors and PSP contamination were revealed using correlation matrices (Pearson and Spearman). High correlation factors (>0.20) were identified and a full predictive model was determined statistically, using multiple regression. The predicted versus actual readings were examined for all data points (1983–2013) to identify false predictions (positive or negative).

Results/Discussion

Significant variables

The factors that were found to be most important in predicting PSP levels were: time of the year, salinity, and rainfall patterns (Table 2). Even during high risk times of the year (warm water), low salinity alone was not sufficient to trigger high PSP levels in Baynes Sound.

Heavy rain 4 days prior to sampling, followed by a day of light rain, was found to produce the highest risk of PSP. Specifically, the amount of measureable rain that fell 3 and 4 days prior to sampling was found to correlate with PSP levels. This meant that if the average rainfall on days 3 and 4 before sampling was high, PSP levels increased. However, if the total rainfall on day 3 before sampling was high, PSP levels decreased.

Model accuracy

Model predictions were shown to be accurate 97% of the time, with only 2% false positives (i.e., indicating a PSP event when actual levels were low) and 1% false negatives (i.e., indicating there was not a PSP event when PSP levels were high).

Table 2.
Predictive model and regression coefficient for PSP levels in Baynes Sound, BC.

Model	
$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \Sigma\beta_i x_i + \epsilon$	
Independent variable	**Regression coefficient**
β_0 = Intercept	464.13
x_1 = 25 day cumulative rainfall	0.0127
x_2 = Salinity	-12.66
x_3 = 2 day average rainfall (3 days prior to sampling)	11.61
x_4 = Total rainfall 3 days prior to PSP reading	-7.87
x_5 = River 5 day average discharge	-0.54
x_i = i = Week of the year. 0 if week of sampling, value of 1 is attributed otherwise.	Week 1: 3.9, 2: 4.5, 3: 4.5, 4: 4.6, 5: 5.3, 6: 6.74, 7: 6.5, 8: 10.5, 9:-20.4, 10: -30.9; 11:-58.3, 12: 6.2, 13: 8.3, 14: 7.3, 15: -3.5, 16: 2.3, 17: 1.5, 18: 2.5, 19: -4.8, 20: -1.6, 21: -9.1
Statistical values: $\alpha = 0.05$, $R^2 = 0.91$, Adj $R^2 = 0.87$, Coefficient of variation = 0.83, Root MSE = 37.5	

Future research

Further refinements of the model could be performed to incorporate wind speed and sun intensity (UV index), as well as incorporate data from areas adjacent to Baynes Sound. This would be valuable from a management perspective as it would allow for modelling and prediction of more realistic scenarios in an ever-changing environment. The approach used in this research may be applied to other shellfish production areas in British Columbia and the Atlantic provinces, as well as other shellfish hazards (e.g., *Vibrio parahaemolyticus* and *Escherichia coli*).

Conclusion

Preliminary testing of this model within the Baynes Sound area has shown promise. The model does not replace direct monitoring for paralytic shellfish toxins, but provides a real-time tool to help identify periods of increased risk to shellfish culture. This tool may help facilitate harvesting decisions during high risk periods of the year and in more risk-prone areas.

This ACRDP project (P-13-02-002) is a collaborative effort between Fisheries and Oceans Canada (DFO) and Mac's Oysters Ltd. The lead scientists on this project were Dr. Rob Marshall (Mac's Oysters Ltd.) and Dr. Anya Dunham (DFO). Dr. Anya Dunham, can be contacted at **Anya.Dunham@dfo-mpo.gc.ca.**

For further information on this and other ACRDP projects, visit:
http://www.dfo-mpo.gc.ca/science/rp-pr/acrdp-pcrda/index-eng.html

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