Quantifying risk of once-through cooling systems at power plants

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Motivation for analyzing once through cooling

- Clean Water Act essentially banned any new construction of power plants with once-through cooling.
- New Jersey is debating outlawing once through cooling.
- Many power plants might need to be retrofitted or replaced in the near future.

<table>
<thead>
<tr>
<th>Negatives</th>
<th>Positives</th>
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<tbody>
<tr>
<td>Intake structures</td>
<td>Simpler technology</td>
</tr>
<tr>
<td>Higher withdrawals</td>
<td>Less water consumption</td>
</tr>
<tr>
<td>Thermal discharges</td>
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Source: Bates, 2006
Method for quantifying risk

1. Model cooling water as a random variable
2. Model power plant operations as a random variable
3. Compute the joint probability
4. Apply to ecologic thresholds

Probability of optimal temperature
Study area: Joppa Generating Station

- Joppa, Illinois
- 1014 MW Coal
- 6 Electric generating units
- Ohio river as cooling source

Source: Wikipedia Commons
Thermal energy varies within the Ohio River

Source: EIA
Yearly thermal discharge is relatively constant

Source: EIA
Considering the river as a random variable

Gamma distributions

Source: EIA
Considering discharge as a random variable.

[Graph showing Gamma distributions for discharged energy (J/g) by month.]

Source: EIA, USGS
Joint probability: January

Thermal Energy (J/g)

Thermal Discharge (J/g)

Red = highest probability
Joint probability: February

Red = highest probability
Joint probability: March

Red = highest probability

Thermal Energy (J/g) vs. Thermal Discharge (J/g)
Joint probability: April

 Thermal Energy (J/g)

 Thermal Discharge (J/g)

 Red = highest probability
Joint probability: May

Red = highest probability
Joint probability: June

Red = highest probability
Joint probability: July
Joint probability: August

Thermal Discharge (J/g)

Thermal Energy (J/g)

Red = highest probability
Joint probability: September

Red = highest probability
Joint probability: October

Red = highest probability
Joint probability: November

Red = highest probability
Joint probability: December

Red = highest probability
Thermal tolerance of adult Largemouth Bass.

- Ecology is effected by thermal discharge.
  - Reproduction, growth, mortality
  - Shifts through out the year

- During early fall:

  \[ P(X_{low} + Y_{low} < Range \leq X_{high} + Y_{high}) \]

  - \( X \) = River Energy
  - \( Y \) = Discharged Energy from PP

Source: EPA; San Juan River, 2007
Calculating the probability of risk

\[ P(X_{\text{low}} + Y_{\text{low}} < \text{Range} \leq X_{\text{high}} + Y_{\text{high}}) \]

\[ \int\int_{\text{low}}^{\text{high}} P_{xy} \, dx \, dy \]

<table>
<thead>
<tr>
<th></th>
<th>August</th>
<th>September</th>
<th>October</th>
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<tbody>
<tr>
<td>P(Cold Risk)</td>
<td>0%</td>
<td>0%</td>
<td>97%</td>
</tr>
<tr>
<td>P(Optimal)</td>
<td>5%</td>
<td>99%</td>
<td>2%</td>
</tr>
<tr>
<td>P(Hot Risk)</td>
<td>94%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
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Conclusions:
Better data and sound methods yield better decisions.

- Environmental and cooling operations can be modeled as random variables to quantify risk.
- Seasonal variability requires analysis to be on a small time scale.
- Translating to thermal energy allows for combination of flow and temperature.
- More data are needed on species tolerances and power plant operations.
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Questions

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