Effects of Dams and Water Power on River Ecosystems, Fish, and Fisheries: 

*Not Green for Fish!*

John M. Casselman

Department of Biology, Biosciences Complex
Queen’s University, Kingston, Ontario, K7L 3N6

John.casselman@queensu.ca

November 2013
Fish and fisheries have been important indicators of the aquatic ecosystems of the Great Lakes Basin.

Fish and fish communities have led the way in revealing many things and have signalled:

- Eutrophication and changes in water quality
- Aquatic contamination
- Aquatic acidification
- Changing climatic conditions
- Habitat changes and loss, including river conditions

Let’s examine fish, fisheries, and river alterations.
Water-power production and dam construction have a long and important history as a valuable source of renewable energy.

Historically, the impact on fish and fisheries was a concern only for highly valued migratory species; e.g., Atlantic salmon.

We now know that damming and altered water regimes can dramatically affect aquatic ecosystems and fish, another important renewable resource.

After 50 years of science and practical experience, we better understand the impacts of these alterations on fish productivity and fisheries.
Effects of Dams

Environmental, habitat, and water-regime alterations

Upstream
- Riverine conditions change from flowing to non-flowing
- Water temperature increases
- Dissolved oxygen can be reduced
- Fine sediments and organic material accumulate
- Fractionates – restricts downstream movement and migration

Downstream
- Alters flow regime
- Water temperatures increase
- Supersaturation of gases is possible; e.g., nitrogen
- Substrate becomes scoured and coarser, sediments reduced
- Fractionates – restricts upstream movement and migration

Water-power operating systems can dramatically change water regimes, flows, and levels
Ontario Examples

- Effects of impoundment, stabilization, and altered water-level dynamics on northern pike recruitment and abundance in the upper St. Lawrence River
- Effects of passage and declining abundance of the migratory American eel in the Ottawa and St. Lawrence rivers
- Effects of dams and river fractionation on lake sturgeon abundance and commercial catch in the upper St. Lawrence River
- Climate change as a compounding factor affecting water regimes, flows, levels, and future operating systems
Hypothetical stream

From Raymond Li, U.S. Fish and Wildlife Service
Hypothetical stream – impounded
Hypothetical stream – impounded

Water surface

Stream bed

sedimentation
Hypothetical stream – impounded

Water surface

Stream bed

sedimentation
What does this mean to fisheries?

- fish passage blocked
- fish community changes:
  - coldwater to warmwater
  - flowing water to littoral zone
- some invertebrates are buried
Impoundment and Creation of Lake St. Lawrence

Flooding initially increased pike recruitment and abundance
IMPOUNDMENT OF UPPER ST. LAWRENCE RIVER
Establishment of Lake St. Lawrence, a reservoir, 1958
ST. LAWRENCE SEAWAY AND HYDROELECTRIC PROJECT
Resulted in major large-river upper St. Lawrence alterations
IMPOUNDMENT OF UPPER ST. LAWRENCE RIVER

In 1958, 6,150-ha Lake St. Lawrence was created, average depth 8.0 m, producing 20% increase in nearshore aquatic habitat, shallow littoral zone, and wetlands but with annual drawdown of approximately 2.0 m.
IMPOUNDMENT AND PIKE PRODUCTION
Recruitment dynamics and flooding

Data from McLeod

A – Northern Pike Recruitment

Mean = 6.3 ± 3.1

B – Morrisburg

Mean = 71.3 ± 1.2

Impoundment, June 30, 1958
Impoundment, Water-Level Dynamics, and Pike Recruitment and Abundance

Water-level regulation, stabilization, and drawdowns
PIKE ABUNDANCE, UPPER ST. LAWRENCE RIVER

Early dynamics related to commercial fishing

Mean = 10.2 ± 2.4
Pike Spawning and Nursery Habitat

Spring and early summer inundation of wetlands and adjacent shallows
UPPER ST. LAWRENCE RIVER
ANNUAL – Regulated water level
1950 – 2000

\[ Y_{\text{level}} = 81.401 - 0.003 \times X_{\text{year}} \]

\[ N = 51 \quad r = 0.278 \quad P = 0.0479 \]

Mean = 74.53 ± 0.05
Long-Term Changes in Pike Recruitment Pre- and Post-Impoundment

Fifty years of insights from the upper St. Lawrence River
PIKE
Upper St. Lawrence River
Regulated water level

Dynamic Levels

Transitional Period

Stabilization

Mean = 2.08 ± 0.45

CUSUM (%)
NORTHERN PIKE – Upper St. Lawrence River

SPRING – Dynamic water level
Early period (1950 – 1974)

$log \text{Y}_{(ycs)} = 42.619 + 0.575 X_{(level)}$

$N = 22 \hspace{1cm} r = 0.612 \hspace{1cm} P = 0.0025$
NORTHERN PIKE – Upper St. Lawrence River

SPRING WATER LEVEL – Stabilized

1970 – 2000

\[ \log Y_{(ycs)} = -20.035 + 0.271 \times (\text{level}) \]

\( N = 31 \quad r = 0.288 \quad P = 0.1162 \text{ ns} \)
NORTHERN PIKE – Upper St. Lawrence River

- **Regulated water level**
- **Unregulated water level**

**CUSUM**

Mean = 0.99 ± 0.08


**RELATIVE STOCK SIZE**

**NORTHERN PIKE** – Upper St. Lawrence River

Water level declines and stabilization decreased the population by 70%.

Mean = 0.30 ± 0.04


Mean = 0.99 ± 0.08


Mean = 0.30 ± 0.04

1962

1956

1971
Recruitment and Water Level Extremes in Relation to Stabilization

Pike Upper St. Lawrence River 1970 – 2000
NORTHERN PIKE
Upper St. Lawrence River
Regulated water level

YEAR – CLASS STRENGTH (%)

1970 – 2000 Water Level Control

CUSUM (%)

Mean = 2.08 ± 0.45
NORTHERN PIKE – Upper St. Lawrence River

SPRING WATER LEVEL
1970 – 2000

$log Y_{(ycs)} = -20.035 + 0.271 \times X_{(level)}$

$N = 31 \quad r = 0.288 \quad P = 0.1162 \text{ ns}$
NORTHERN PIKE – Upper St. Lawrence River

SPRING WATER LEVEL
1970 – 2000 (nine strongest year-classes)

$log Y_{(ycs)} = -16.631 + 0.228 X_{(level)}$

$N = 9 \quad r = 0.680 \quad P = 0.0437$
Declining Abundance and Recruitment at the Extremities of the Ontario Range

With special reference to the Ottawa and Mississippi rivers and their watersheds
LOWER OTTAWA, MISSISSIPPI, ST. LAWRENCE RIVERS

The last remnants of wild eels in Ontario
DAMS ON ONTARIO’S OTTAWA RIVER WATERSHED
Hydro generating facilities and control dams

No dams have fish passage facilities
Dam Construction Restricts Passage, Abundance, and Distribution

Changes in the province of Quebec and in Ottawa and Trent rivers over time
NEW DAMS CONSTRUCTED IN QUEBEC
Number by decade from 1850 to 2005

n = 4586

From J.-P. Dutil 2008
DAM CONSTRUCTION, OTTAWA AND TRENT RIVERS
By year and cumulated number, 1880s to 1970s

MacGregor et al. 2009
TRAP-NET CATCH OF EELS IN OTTAWA R. REACHES
Each reach separated by a barrier, passage not facilitated

![Graph showing catch rates at different Ottawa River reaches](image-url)

- Lac Dollard des Ormeaux
- Lac Deschenes
- Lac des Chats
- Lac Rocher du Fendu
- Lac Coulonge
- Lower Allumette Lake
- Upper Allumette Lake
- Holden Lake
- Lac la Cave

- Carillon
- Chaudière
- Chats
- Chenaux
DECLINING ABUNDANCE IN OTTAWA R. REACHES
Progressively decreasing abundance above upstream dams
Index Trap Netting of Mississippi River System and Ottawa River Reaches

_Eel catches for six lakes netted several times over a five-decade period and for five reaches._
TRAP NET CATCH OF EELS IN LAKES
Mississippi R. watershed, 1961-2009

A

B

\[
\log Y_{(\text{catch})} = 33.85 - 0.0174 X_{(\text{year})}
\]

N = 17  \quad r = 0.598  \quad P = 0.0113

Large Mississippi Lake eel 2009, held by Emily Verhoek
TRAP-NET CATCH OF EELS IN LAKES
Mississippi R. watershed, 1961-2009

Extrapolated estimate of 0 catch in 2005 for combined and 2011 for Mississippi Lake
Abundance and Distribution of Eels in the Ottawa and Mississippi Rivers

As determined by quantitative electrofishing upstream to the Chenaux and High Falls dams
Quantitative boat electrofishing was used to precisely determine eel density on a unit area basis, an absolute measure.
Replicate sampling in the upper St. Lawrence River and eastern Lake Ontario, where eels were abundant, gave the following ranges:

<table>
<thead>
<tr>
<th>SAMPLING METHOD</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eel ladder passage</td>
<td>16-18</td>
</tr>
<tr>
<td>Quantitative electrofishing</td>
<td>20-24</td>
</tr>
<tr>
<td>Bottom trawling</td>
<td>95-185</td>
</tr>
<tr>
<td>Trap nets</td>
<td>110-250</td>
</tr>
<tr>
<td>Hoop nets</td>
<td>140-310</td>
</tr>
</tbody>
</table>
Precise and Intensive Assessment Methods Are Needed

Quantitative electrofishing
Abundance and Distribution of Eels in the Ottawa and Mississippi Rivers

Locations of sites and transect tracks quantitatively electrofished, showing specific locations of eels
Baie de Carillon, below Carillon dam, Ottawa River

Lac des Deux Montagnes
Reach 1 Location 1

Image © 2009 TerraMetrics
Eels caught at Baie de Rigaud, Ottawa River
Snye, Chats Falls, Ottawa River

Lac Dollard des Ormeaux
Reach 3 Location 6
Below Chats Falls Dam, Ottawa River

Lac Dollard des Ormeaux
Reach 3 Location 7
Chats Falls Dam, Ottawa River
Table 1. Electrofishing effort, catch, and eel occurrence (percent of sites containing eels) by location, reach, and river system for the lower Ottawa, Mississippi, and Bonnechere river systems and tributaries, 2009-2013. NC – not conducted. Funds provided by the Ontario SARSF.

| Combined | Number of locations | Length (m) | Total catch (N) | Occurrence by site (%) | Occurrence and Effort
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Below Carillon – occurrence 4.4x greater</td>
</tr>
<tr>
<td>OTTAWA RIVER SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reach 1 – Lac des Deux Montagnes</td>
<td>3</td>
<td>33</td>
<td>6,500</td>
<td>112</td>
<td>59</td>
</tr>
<tr>
<td>Reach 2 – Lac Dollard des Ormeaux</td>
<td>5</td>
<td>42</td>
<td>8,400</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Reach 3 – Lac Deschenes</td>
<td>4</td>
<td>35</td>
<td>7,000</td>
<td>43</td>
<td>35</td>
</tr>
<tr>
<td>Reach 4 – Lac des Chats</td>
<td>8</td>
<td>56</td>
<td>11,200</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Reach 5 – Lac du Rocher Fendu</td>
<td>1</td>
<td>14</td>
<td>2,800</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ottawa R. system above Carillon</td>
<td>18</td>
<td>147</td>
<td>29,400</td>
<td>59</td>
<td>49</td>
</tr>
<tr>
<td>Ottawa R. system combined</td>
<td>21</td>
<td>180</td>
<td>35,900</td>
<td>171</td>
<td>108</td>
</tr>
<tr>
<td>BONNECHERE RIVER SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonnechere R. system combined</td>
<td>1</td>
<td>16</td>
<td>3,200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MISSISSIPPI RIVER SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mississippi River system combined</td>
<td>7</td>
<td>70</td>
<td>13,900</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>OTTAWA RIVER WATERSHED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>above Carillon</td>
<td>26</td>
<td>219</td>
<td>43,700</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>combined</td>
<td>28</td>
<td>252</td>
<td>50,200</td>
<td>174</td>
<td>111</td>
</tr>
</tbody>
</table>
Table 2. Annual electrofishing effort, catch, and eel occurrence (percent of 200-m sites containing eels) by location, reach, and river system for the lower Ottawa, Mississippi, and St. Lawrence river systems and tributaries, 2009 and 2011 to 2013. Funds provided by the Ontario SARSF

<table>
<thead>
<tr>
<th>River system locations</th>
<th>2009</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>Mean</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ST. LAWRENCE RIVER SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Lawrence, below Moses-Saunders</td>
<td>2</td>
<td>32</td>
<td>6,000</td>
<td>658</td>
<td>32.1</td>
<td>75.0</td>
</tr>
<tr>
<td>St. Lawrence, above Moses-Saunders</td>
<td>2</td>
<td>26</td>
<td>4,800</td>
<td>44</td>
<td>5.3</td>
<td>34.6</td>
</tr>
<tr>
<td>St. Lawrence River system combined</td>
<td>4</td>
<td>58</td>
<td>10,800</td>
<td>702</td>
<td>20.9</td>
<td>56.9</td>
</tr>
<tr>
<td><strong>OTTAWA RIVER SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reach 1 – Lac des Deux Montagnes</td>
<td>3</td>
<td>33</td>
<td>6,500</td>
<td>112</td>
<td>30.6</td>
<td>21.2</td>
</tr>
<tr>
<td><strong>MISSISSIPPI RIVER SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mississippi River system combined</td>
<td>7</td>
<td>70</td>
<td>13,900</td>
<td>5</td>
<td>2.2</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>OTTAWA RIVER WATERSHED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>above Carillon</td>
<td>26</td>
<td>219</td>
<td>43,700</td>
<td>52</td>
<td>5.4</td>
<td>7.3</td>
</tr>
<tr>
<td>combined</td>
<td>27</td>
<td>252</td>
<td>50,200</td>
<td>174</td>
<td>9.2</td>
<td>9.1</td>
</tr>
<tr>
<td><strong>ALL RIVER SYSTEMS COMBINED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>310</td>
<td>61,000</td>
<td>876</td>
<td>12.2</td>
<td>18.1</td>
</tr>
</tbody>
</table>

Occurrence and Effort
Below M-S dam – occurrence 2.8x greater
Above M-S dam,– effort 0.8x greater
EEL CARCASS SURVEY AND OCCURRENCE
Electrofishing and dam tailrace survey, 2009

Hydro dam | Visits | Carcasses | Carcass / visit | Occurrence upstream (%)
----------|--------|-----------|-----------------|------------------------
Carillon   | 11     | 13        | 1.18            | 24.4                   
Chaudière  | 10     | 10        | 1.00            | 23.2                   
Chats      | 9      | 1         | 0.11            | 3.2                    
Galetta*   | 43     | 2         | 0.05            | 1.8                    

* Mississippi River combined

Ottawa and Mississippi Rivers

\[ Y_{\text{mean}} = -0.1568 + 7.69E-05 \times X_{\text{abundance}} \]

\[ N = 4 \quad r = 0.989 \quad P = 0.0115 \]
A case history

Eel Ladders That Successfully Facilitate Upstream Passage Can Be Installed

Ladders at Beauharnois and Moses-Saunders assist and monitor passage up the St. Lawrence River
Moses-Saunders Dam and Eel Ladder, Upper St. Lawrence River
EEL LADDER INDEX – PEAK PASSAGE
Eels (N) passing during 31-day peak summer period, 40 yr

[Graphs showing the peak passage of eels from 1970 to 2015, with data points and error bars indicating the estimated values for 1977-1978 and the observed values for 2006-2013.]

[CUSUM plot showing the cumulative sum of the daily passage rates, peaking in 1985 and 1987, with a mean of 6,208.]
Eels Migrating Back to the Ocean to Spawn Are Exposed to Significant Turbine Mortality

This is one of a number of accumulative factors affecting overall species decline.

2. Turbine mortality of silver eels at the Beauharnois generating facility – 17.8% (Desrochers 1995)

3. The cumulative mortality of mature silver eels passing these two St. Lawrence River generating facilities is 40%
Life table model estimates of cumulative fishing, mortality, and exploitation rates (%) for a cohort of eels ascending the ladder in the early 1980s and subjected to various levels of yellow eel annual exploitation rates (%). Assuming that harvested yellow eels range in age from 14 to 22, that peak escapement occurs at age 20, and that downstream turbine mortality at Moses-Saunders = 26.5%, at Beauharnois = 17.8%, and that the estuary commercial fisheries exploitation rate = 21.5%.

<table>
<thead>
<tr>
<th>Stage and aspect</th>
<th>Upper St. Lawrence River – Lake Ontario exploitation rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Yellow eel fisheries</td>
<td>5.7</td>
</tr>
<tr>
<td>Turbine mortality (combined)</td>
<td>30.1</td>
</tr>
<tr>
<td>Moses-Saunders</td>
<td>20.1</td>
</tr>
<tr>
<td>Beauharnois</td>
<td>10.0</td>
</tr>
<tr>
<td>Estuary fisheries</td>
<td>9.9</td>
</tr>
<tr>
<td>Escapement</td>
<td>36.2</td>
</tr>
<tr>
<td>Natural mortality</td>
<td>18.1</td>
</tr>
</tbody>
</table>
From 1950 to 2007, population numbers have decreased by 99.2%.
MODEL ESTIMATES – EMIGRANT NUMBERS
St. Lawrence River System

EMIGRATION ESTIMATES (numbers x 10^6)

- Beauharnois turbine mortality commences 1912, increasing to 1961
- Moses-Saunders turbine mortality commences 1958

- USLR/LO – Emigration
- Post Turbines – Below Hydro Facilities
- Escapement – Below LSLR Fishery

1650 1700 1750 1800

41,080 24,718 19,280

1850 1875 1900 1925 1950 1975 2000 2025
Impoundment, River Fractionation, and Lake Sturgeon Abundance

Long-term commercial catch in the upper St. Lawrence River
The location of a historic commercial sturgeon fishery on the upper St. Lawrence River
LAKE ONTARIO –
ST. LAWRENCE R.

Lake sturgeon

Lake Ontario

St. Lawrence R.

5.9 ± 1.7 t

1977

Harvest (t)


Lawrence Mallory ca 1950
George Vanston and catch of sturgeon, Princess Island, mouth of Jones Creek, upper St. Lawrence R. ca 1958
LAKE ONTARIO – ST. LAWRENCE R.

Lake sturgeon

Commercial fishermen attributed this upstream decline, commencing in 1965, to dam construction in 1958.
Catches after the late 1960s were only 14% (0.5 t vs. 3.5 t) of the 1940s to mid-1960s and variance was almost 4x greater (CV = 25% vs. 94%), excluding high-water period, 1952-55.
A large gravid female sturgeon, 110 pounds, caught by George Vanston in May 1964 in the vicinity of Jones Creek. The eggs were ripe and fully developed. This was the last mature female commercial fishermen saw in the upper St Lawrence after the mid-1960s until the sturgeon fishery was closed in the mid-1980s.
Operating Systems Can Have Both Direct and Indirect Effects

A couple of extreme examples: fish mortality and habitat alteration
CONTROL DAM SPILLAGE CAN CAUSE FISH MORTALITIES

Entrainment of lake sturgeon in Adam Creek Diversion

Adam Creek Diversion and Spillway
Mattagami River
Reservoir Water Level Extremes and Dynamics

Crotch and White lakes provide insights concerning importance of moderate natural water-level fluctuations.
Global Warming, Changing Thermal Conditions, and Shifting Baselines

Bay of Quinte and nearshore waters of Lake Ontario
APRIL TO SEPTEMBER WATER TEMPERATURE
Lake Ontario, inshore waters, Bay of Quinte

\[ Y_{\text{temp}} = -10.020 + 0.014 \times \text{year} \]

- \( N = 68 \)
- \( r = 0.364 \)
- \( P = 0.0023 \)

Increase in evaporation = 10%
DURATION OF ICE-COVER PERIOD
Bay of Quinte – temperature < $1.5^\circ$C, $112 \pm 4d$

$Y \text{ (days)} = 1031.4 - 0.466 X \text{ (year)}$

$N = 67 \quad r = 0.521 \quad P < 0.0001$
El Niño and La Niña conditions in tropical Pacific can predict conditions in Great Lakes Basin; 70 to 90% of temperature extremes in Great Lakes Basin are predicted by tropical Pacific conditions 2 to 8 months earlier.

La Niña, which occurred in the tropical Pacific in 2008 and winter, spring 2009, created conditions in the Great Lakes Basin that were entirely predictable and followed by El Niño in 2010, but a very strong La Niña appeared again in 2011 – now a slight La Niña.
Global Warming and Water Dynamics

Ontario’s Mississippi R. watershed and discharge at Appleton

Modelling Conducted by Paul Lehman and Sobhalatha Kunjikutty, Mississippi Valley Conservation, 2008
Mississippi River Watershed

Water control structures
Storage reservoirs (shaded waterbodies)
Hydro-electric generating stations
WMP planning area

Appleton

City of Ottawa
FALL AND WINTER DISCHARGE
Mississippi River, Appleton – Sep to Feb

\[ Y_{\text{disch.}} = -366.62 + 0.197 \times X \quad \text{(year)} \]

\[ N = 74 \quad r = 0.450 \quad P = 0.0001 \]

\[ \text{Mean} = 21.3 \, \text{m}^3 \cdot \text{s}^{-1} \]
Mean Daily Stream Flow Comparison

Modelling Change

Mississippi River at Appleton (WSC 02KF006)
Mean Daily Stream Flow Comparison

Modelling Change

*Mississippi River at Appleton (WSC 02KF006)*

Fall and winter – flows 70% higher
Spring flows – 33% lower and peak 6-7 weeks earlier
Summer – flows 44% lower and lasting 28% longer
Summary

Fish, Fisheries, and Water Power

• Environmental and fish changes have generally been negative; water-level stabilization and alterations have resulted in habitat alteration and generally reduced fish production

• Direct effects have been considerable: species and genetic diversity, mobility and migratory behaviour, and unique ecotypes

• Upstream passage for some migratory species (e.g., eels) can be, and have been, facilitated; however, safe downstream passage remains unresolved and needs research
Climate change is a new and compounding problem.

Science is now accumulating to give us a better understanding of how to address these alterations and, where possible, to mitigate these two naturally integrated and sometimes conflicting renewable resources.

Fish resources are greatly under-valued, particularly as local recreation and food (i.e., for food security and a more environmentally sustainable 100-mile diet, preferably from certified sustainable fisheries).
Summary

We should . . .

• acquire more and better assessment information to evaluate environmental and habitat alterations so that fish resources are sustainable and enhanced where possible

• appreciate the real and increasing value of fish and fish resources, important indicators of environmental change, and work together to mitigate and manage to sustain and enhance fish resources and fisheries

• work cooperatively to ensure that water power is truly a green energy resource by taking fish into consideration; they can be an equally important renewable resource
Thank you!