# Fisheries Studies:
# Beyond the Guidelines

(for Hydroelectric & Mining Projects)


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**&**

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EMA of BC Workshop - February 21, 2013


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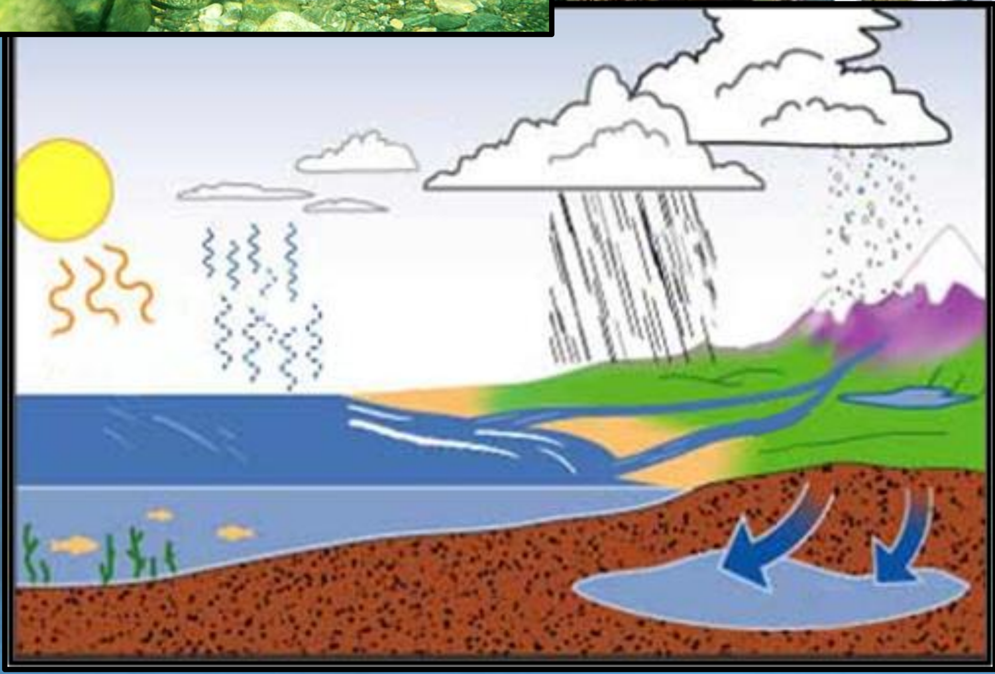
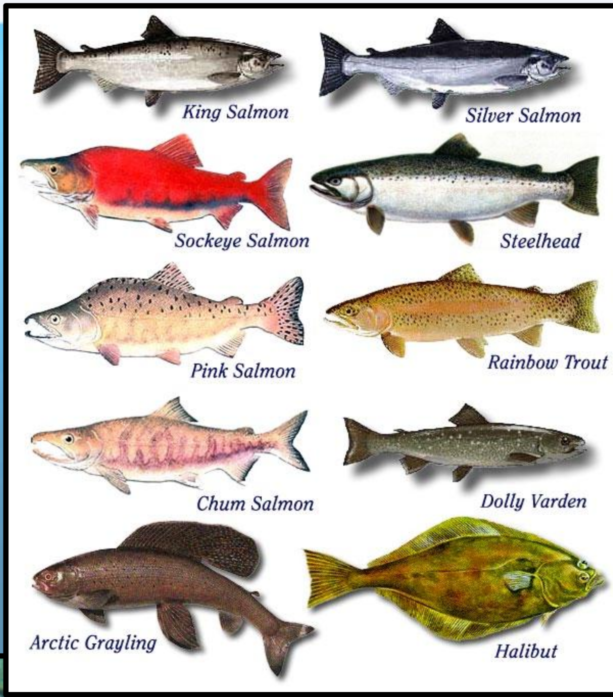
# Components of EA Studies

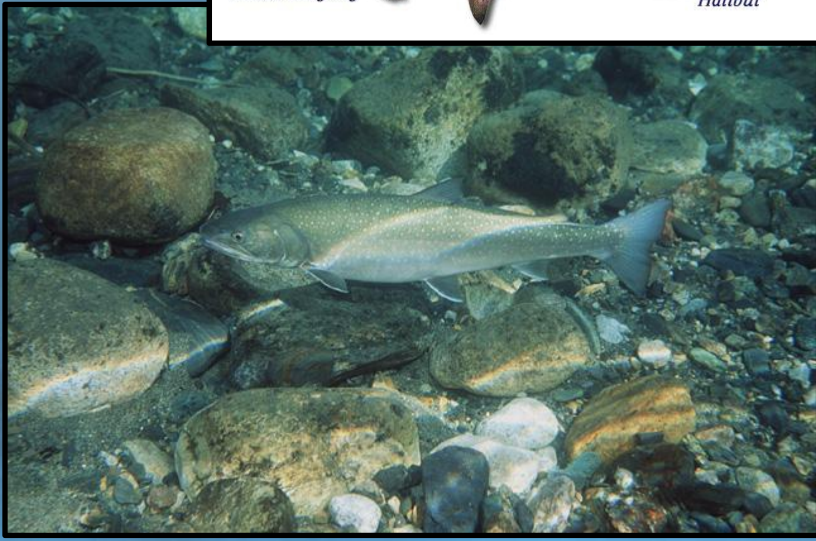
- Baseline studies
- Impact Assessment
  - Fisheries
  - Other aquatic life
  - Geology
  - Hydrology
  - Hydrogeology
  - Water Quality
  - Climate
  - Air Quality
  - Etc.



# Components of Fisheries Studies

- Species diversity
- Abundance
- Species at risk
- Life history strategies
- Distribution
- Population dynamics
- Habitat quality & quantity
- Instream Flow Needs (IFN)
- Etc.



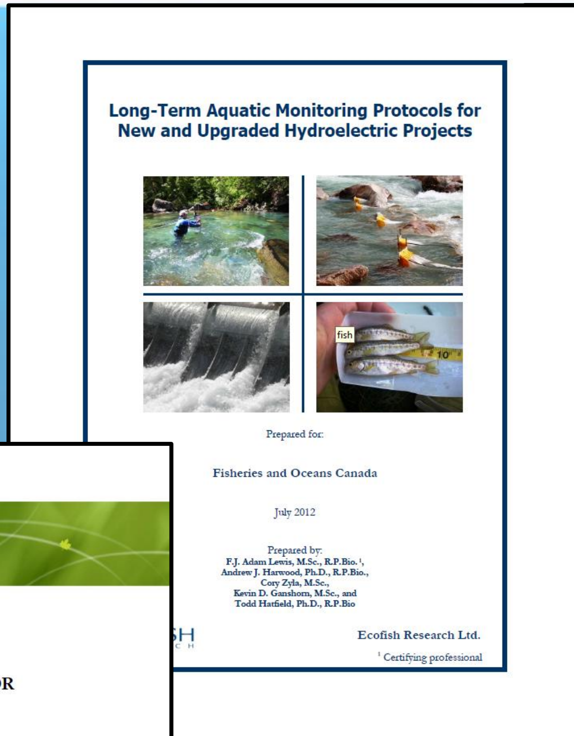
# Guidelines

- There are numerous provincial and federal guidelines that are used in British Columbia to guide fisheries studies related to EIAs

Why are guidelines needed?

- Impose specific criteria
- Increase scientific rigor
- Standardize methodology and results for comparison purposes

# Federal Guidelines


Long-Term Aquatic Monitoring Protocols for New and Upgraded Hydroelectric Projects

Prepared for:

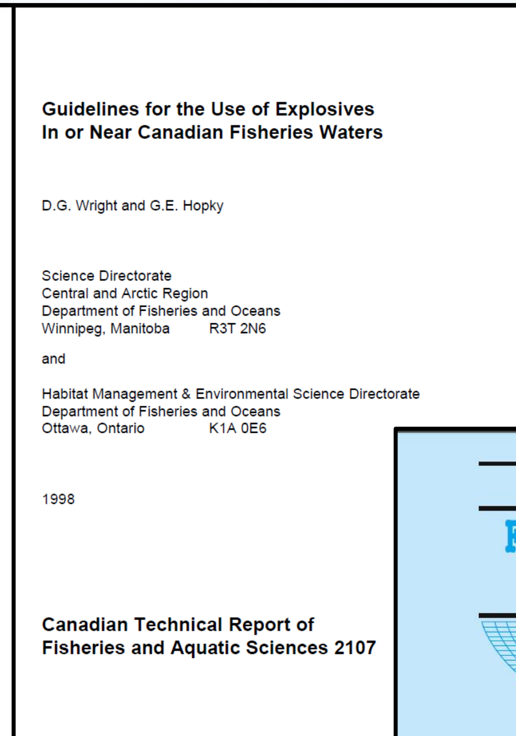
Fisheries and Oceans Canada

July 2012

Prepared by:
F.J. Adam Lewis, M.Sc., R.P.Bio.[1],
Andrew J. Harwood, Ph.D., R.P.Bio.,
Cory Zyla, M.Sc.,
Kevin D. Ganshorn, M.Sc., and
Todd Hatfield, Ph.D., R.P.Bio

Ecofish Research Ltd.

[1] Certifying professional


Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters

D.G. Wright and G.E. Hopky

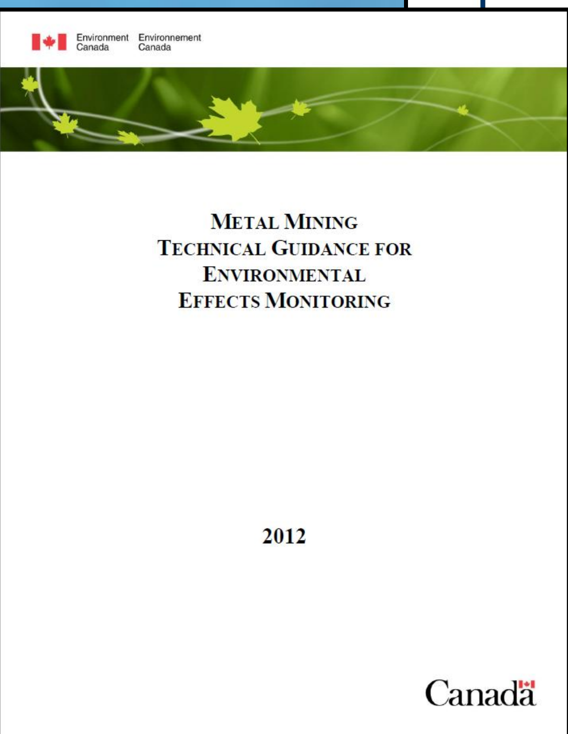
Science Directorate
Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

and

Habitat Management & Environmental Science Directorate
Department of Fisheries and Oceans
Ottawa, Ontario K1A 0E6

1998

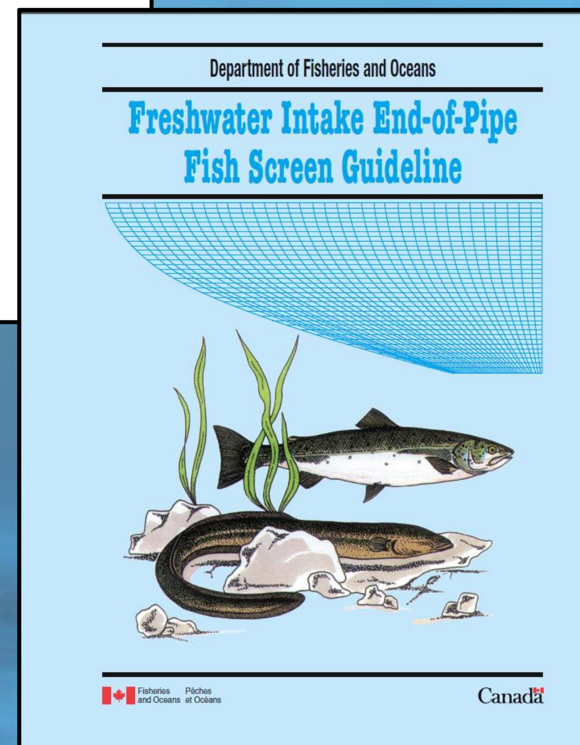
Canadian Technical Report of Fisheries and Aquatic Sciences 2107


Environment Canada Environnement Canada

METAL MINING TECHNICAL GUIDANCE FOR ENVIRONMENTAL EFFECTS MONITORING

2012

Canada

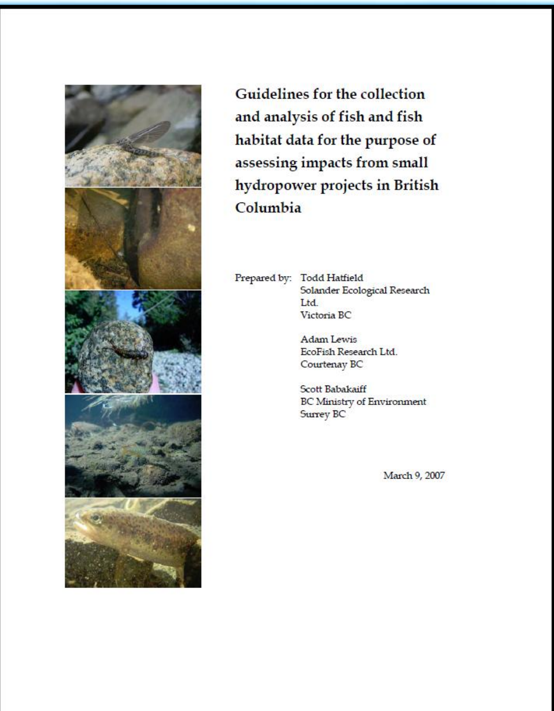

Department of Fisheries and Oceans

Freshwater Intake End-of-Pipe Fish Screen Guideline

Fisheries and Oceans Pêches et Océans

Canada

# Provincial Guidelines



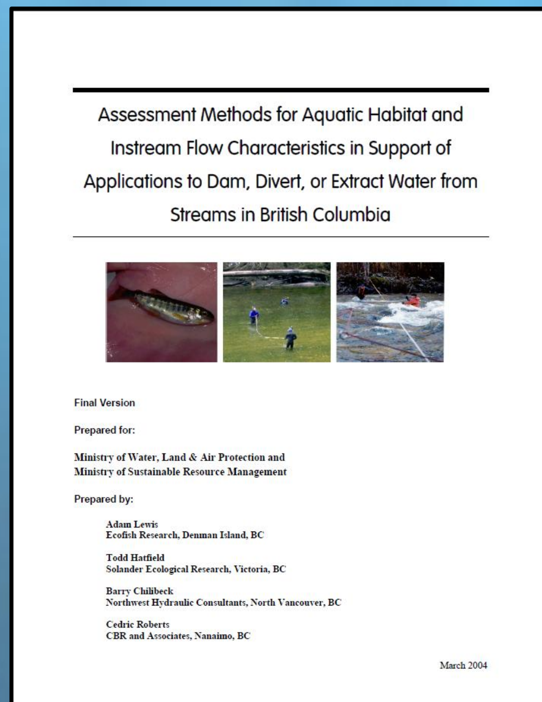
Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia

Prepared by: Todd Hatfield
Solander Ecological Research Ltd.
Victoria BC

Adam Lewis
EcoFish Research Ltd.
Courtenay BC

Scott Babakaiff
BC Ministry of Environment
Surrey BC

March 9, 2007



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Final Version

Prepared for:

Ministry of Water, Land & Air Protection and
Ministry of Sustainable Resource Management

Prepared by:

Adam Lewis
Ecofish Research, Denman Island, BC

Todd Hatfield
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Barry Chilibeck
Northwest Hydraulic Consultants, North Vancouver, BC

Cedric Roberts
CBR and Associates, Nanaimo, BC

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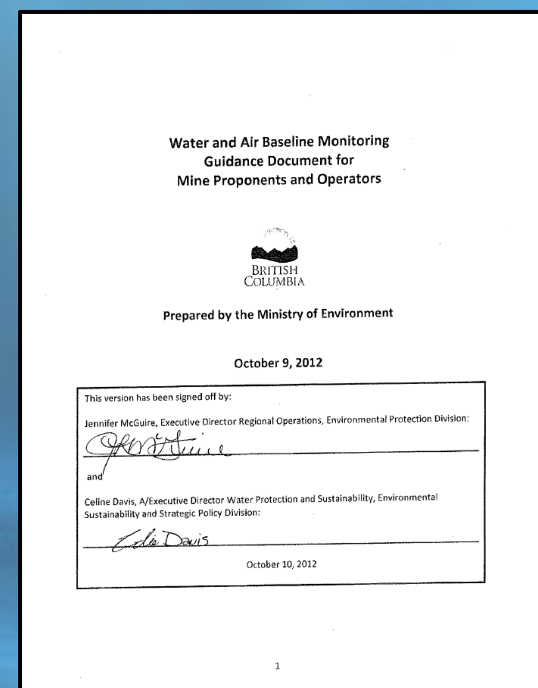

Water and Air Baseline Monitoring
Guidance Document for
Mine Proponents and Operators

BRITISH COLUMBIA

Prepared by the Ministry of Environment

October 9, 2012

This version has been signed off by:

Jennifer McGuire, Executive Director Regional Operations, Environmental Protection Division:

and

Celine Davis, A/Executive Director Water Protection and Sustainability, Environmental Sustainability and Strategic Policy Division:

October 10, 2012

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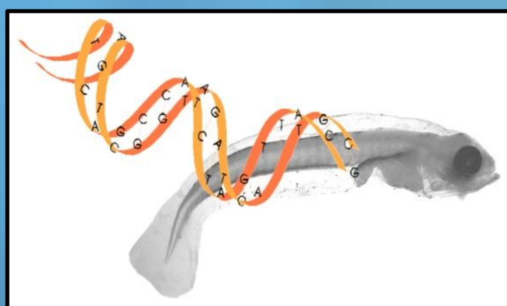
# The "Perception" of Guidelines

- Viewed as status quo


- Best science available



- Provide all the data necessary for approval

| Site Name | Trap No. | Date Set (dd/mm/yy) | Time Set (HH:MM) | Date Lifted (dd/mm/yy) | Time Lifted (HH:MM) | Water depth (m) | Latitude | Longitude | Sample # | Species | TL (mm) | Weight (g) | Sacrificed (Y/N) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rive1 | 1 | 07/31/2011 | 14:30 | 2011/08/01 | 15:15 | 0.80 | 15 W 572791 | 7392766 | 1 | Slimy Sculpin | 102 | 9.1 | N |
| Rive1 | 1 | 07/31/2011 | 14:30 | 2011/08/01 | 15:15 | 0.80 | 15 W 572791 | 7392766 | 2 | Slimy Sculpin | 107 | 10.2 | N |
| Rive1 | 2 | 07/31/2011 | 14:30 | 2011/08/01 | 15:15 | 0.80 | 15 W 572791 | 7392766 | 3 | Slimy Sculpin | 105 | 8.8 | N |
| Rive1 | 2 | 07/31/2011 | 14:30 | 2011/08/01 | 15:15 | 0.80 | 15 W 572791 | 7392766 | 4 | Slimy Sculpin | 91 | 5.5 | N |
| Rive1 | 3 | 07/31/2011 | 14:30 | 2011/08/01 | 15:15 | 0.80 | 15 W 572791 | 7392766 | 5 | Slimy Sculpin | 67 | 2.1 | N |
| …. | …. | …. | …. | …. | …. | …. | …. | …. | …. | …. | …. | …. | …. |

# The "Reality" of Guidelines

- Living documents (must be updated continually)
- Based on science that has inherent assumptions and limitations
- May not address all data needs for all projects
- Should be flexible in their current state based on project footprint, study objectives, stakeholder issues, and environmental conditions
- New ideas should be encouraged and embraced

e.g. "*Data collected to support a water license application should meet or exceed existing inventory standards*" (Lewis et al. 2004)

# Use of Guidelines

- Professional accountability

e.g. "*Data collected to support a water license application…should be signed off by a fisheries biologist with a professional designation of R.P.Bio. and demonstrated experience with instream flow assessments*" (Lewis et al. 2004)

- Consultants hired by proponents

- Regulators reviewing the EIAs

# Risks associated with verbatim use or misuse of Guidelines

- Insufficient baseline data
- Unacceptable accuracy and precision of baseline data
- Inappropriate or incomplete methodology
- Errors with interpretation of baseline results
- Misinterpretation of impact assessment findings
- Stumbling blocks in receiving project permits
- Increase in project timelines and cost

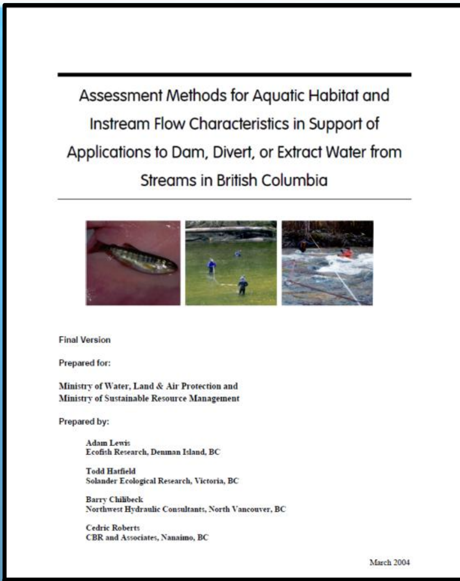
# "Going Beyond" the Guidelines

Example 1

- Fish habitat models within provincial hydroelectric guidelines

Example 2

- Genetic studies within provincial hydroelectric and mining guidelines



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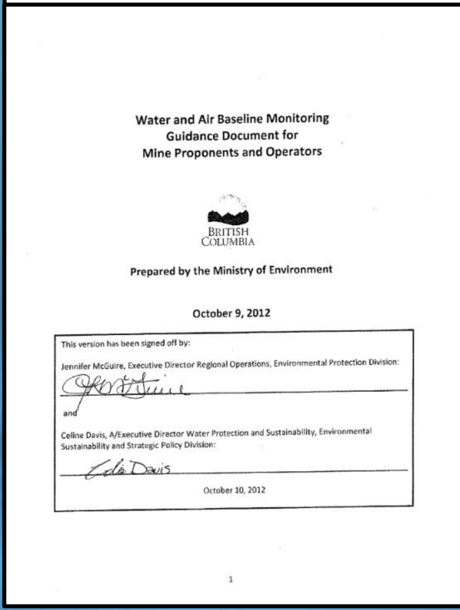

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October 10, 2012

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# Questions?

# Example 1

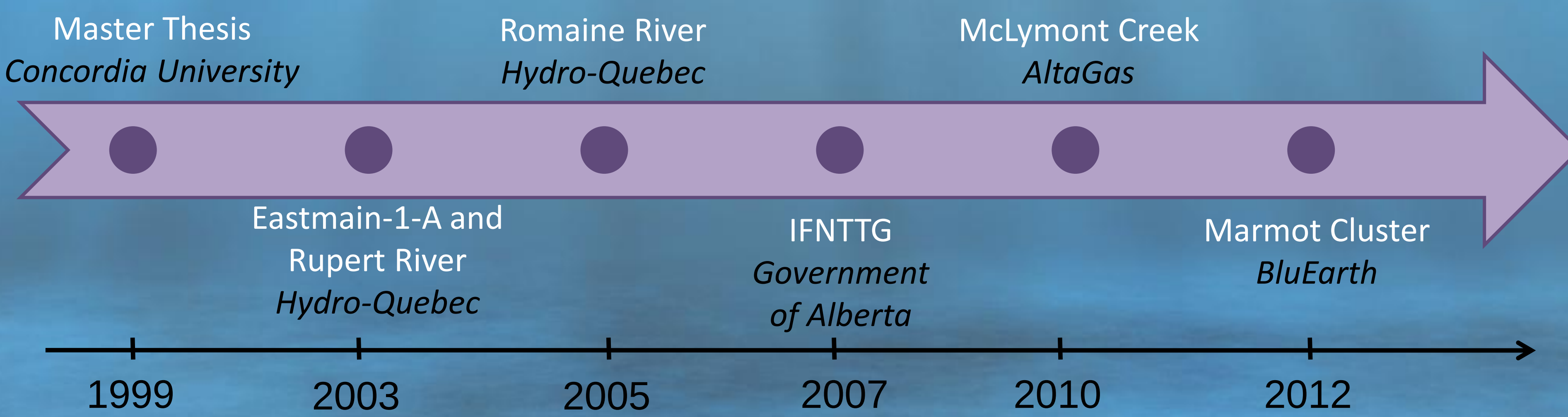
## Fish Habitat Models within the Provincial Hydroelectric Guidelines

**Isabelle Girard, M.Sc., R.P.Bio., CFP***

* Certified Fisheries Professional, American Fisheries Society

# Professional Experience

- B.Sc. and M.Sc., Concordia University, Qc
- Master's thesis: Fish habitat modeling of Atlantic Salmon in a New Brunswick stream
- Numerous studies related to fish habitat modeling and IFN



# Instream Flow Needs (IFN)

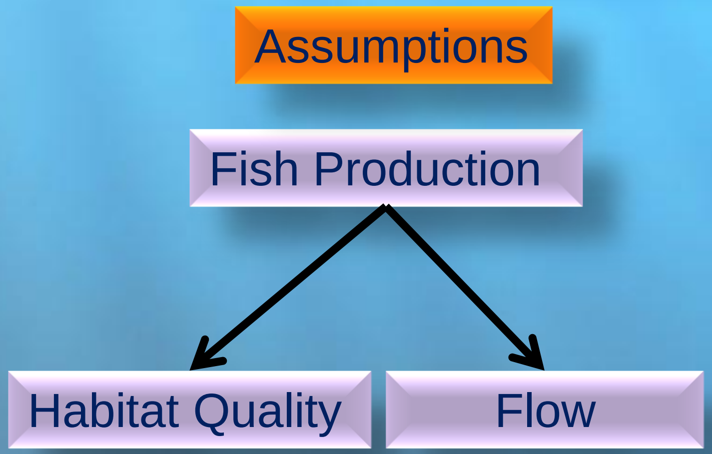
*"Amount of water needed in a stream/river to adequately provide for downstream uses occurring within the stream channel (e.g., aquatic resources, navigation, human consumption)"*

- Typical run-of-river hydroelectric project

# IFN Assessments

**Standard-Setting Methods**

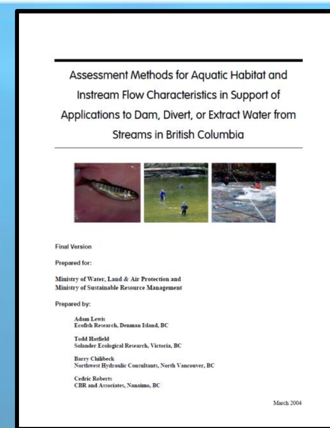
- e.g., Tennant, Wetted Perimeter
- Simpler
- Requires little data
- Desktop




**Incremental Methods**

- Instream Flow Incremental Methodology (IFIM)
- e.g., PHABSIM, MESOHABSIM
- More complex
- Data intensive (e.g., hydrology and fish habitat data)
- Field and Desktop

# IFN Assessments in BC – Current Guidelines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March 2004

**Standard-Setting Method**
Based on Historic Flows

↓

**Instream Flow Thresholds**
(Minimum flow in diversion section at all times of year)

**Accept** ↓

**No Expected Impacts to Fish**

↓

**Submit Application**

**Reject** →

**Incremental Method**
**BC Instream Flow Methodology**

↓

**Instream Flow Requirements (IFR)**
(Minimum flow in diversion section at different times of year)

↓

**No Expected Impacts to Fish**
**or**
**Proposed Compensation**

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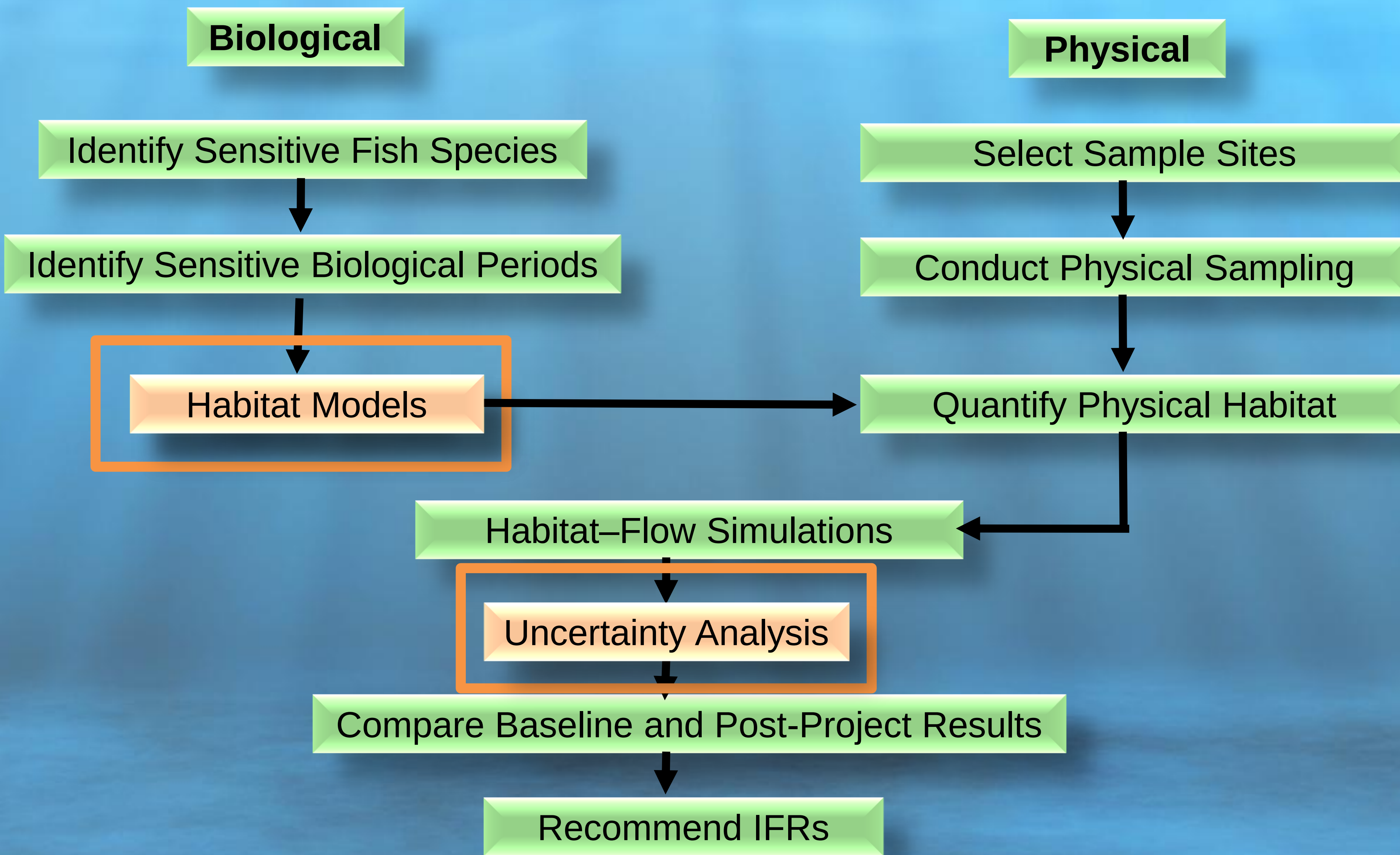
# BC Instream Flow Methodology



# What is a Habitat Model?

A mathematical equation that allows scientists to "represent animal habitat quality in relation to animal presence or reproductive success" (USGS, 2012)

$$\ln(1 + 1000\, d_k) = a + \sum_{j=1}^{j=5} a_{1j} \cdot w_{1jk} + \sum_{j=1}^{j=4} a_{2j} \cdot w_{2jk}$$

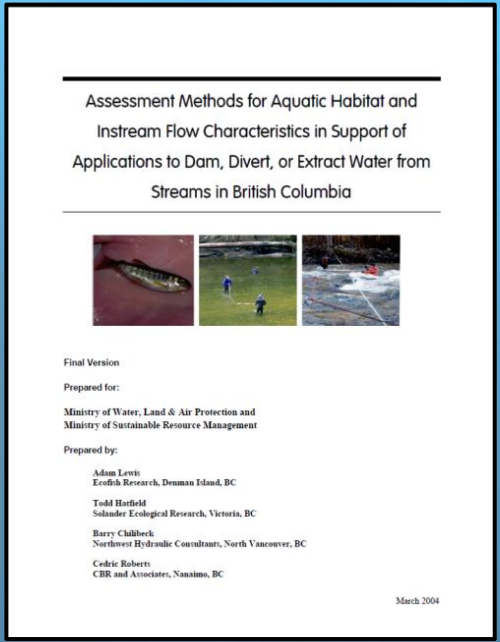
Table I. Habitat use model coefficients derived using Equation (7) for barbel and chub

| Species | $a$ | $a_{11}$ | $a_{12}$ | $a_{13}$ | $a_{14}$ | $a_{15}$ | $a_{21}$ | $a_{22}$ | $a_{23}$ | $a_{24}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Barbel | −0.22 | 0 | 1.09 | 1.52 | 1.78 | 1.31 | 0.12 | 0.39 | 0.73 | 0.44 |
| Chub | 3.37 | 0 | −0.99 | −0.86 | −2.68 | −3.36 | 0.20 | 0.48 | 0.47 | 0.26 |

Lamoureux et al. 1998

# Habitat Models – Current Guidelines

- Primarily endorse the use of existing Habitat Suitability Index (HSI) models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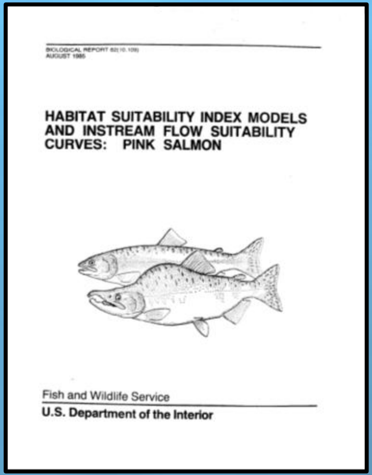
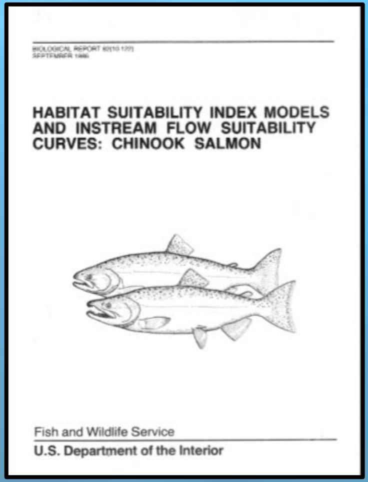
- Positives
  - Simpler mathematics
  - Used for decades
  - No collection of biological data
- Negatives
  - Assume that HSI models are correct in their predictions of fish distribution in the streams under study
  - Assume that models can be used indiscriminately among streams in BC

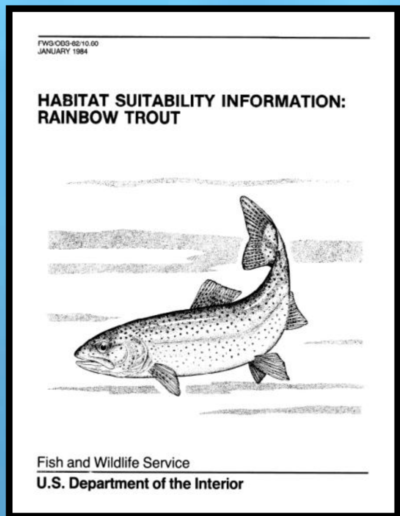
# Habitat Models – Current Guildelines




- 57 HSI models developed by the U.S. Fish and Wildlife Service in the early 1980s
- Available on the National Wetlands Research Center (NWRC) of the U.S. Geological Survey (USGS) Website
- Models for some species have been refined for BC (available through MoE)

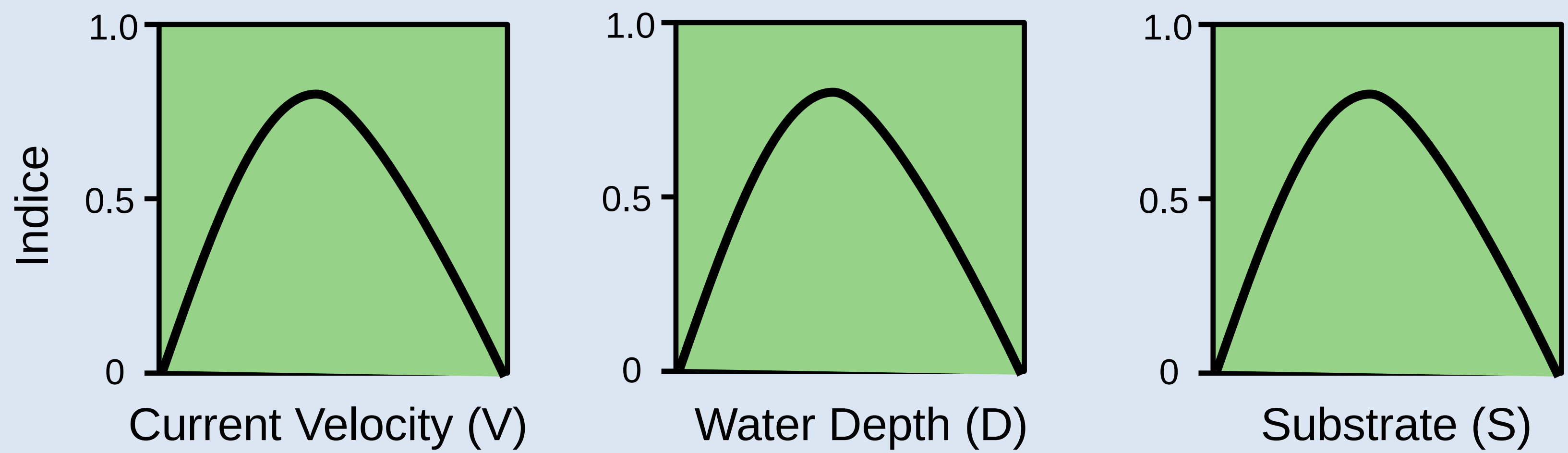
# What is an HSI Model?


FWS/OBS-82/10.60
JANUARY 1984

HABITAT SUITABILITY INFORMATION:
RAINBOW TROUT

Fish and Wildlife Service
U.S. Department of the Interior

$$HSI = I_V^a * I_D^b * I_S^c$$

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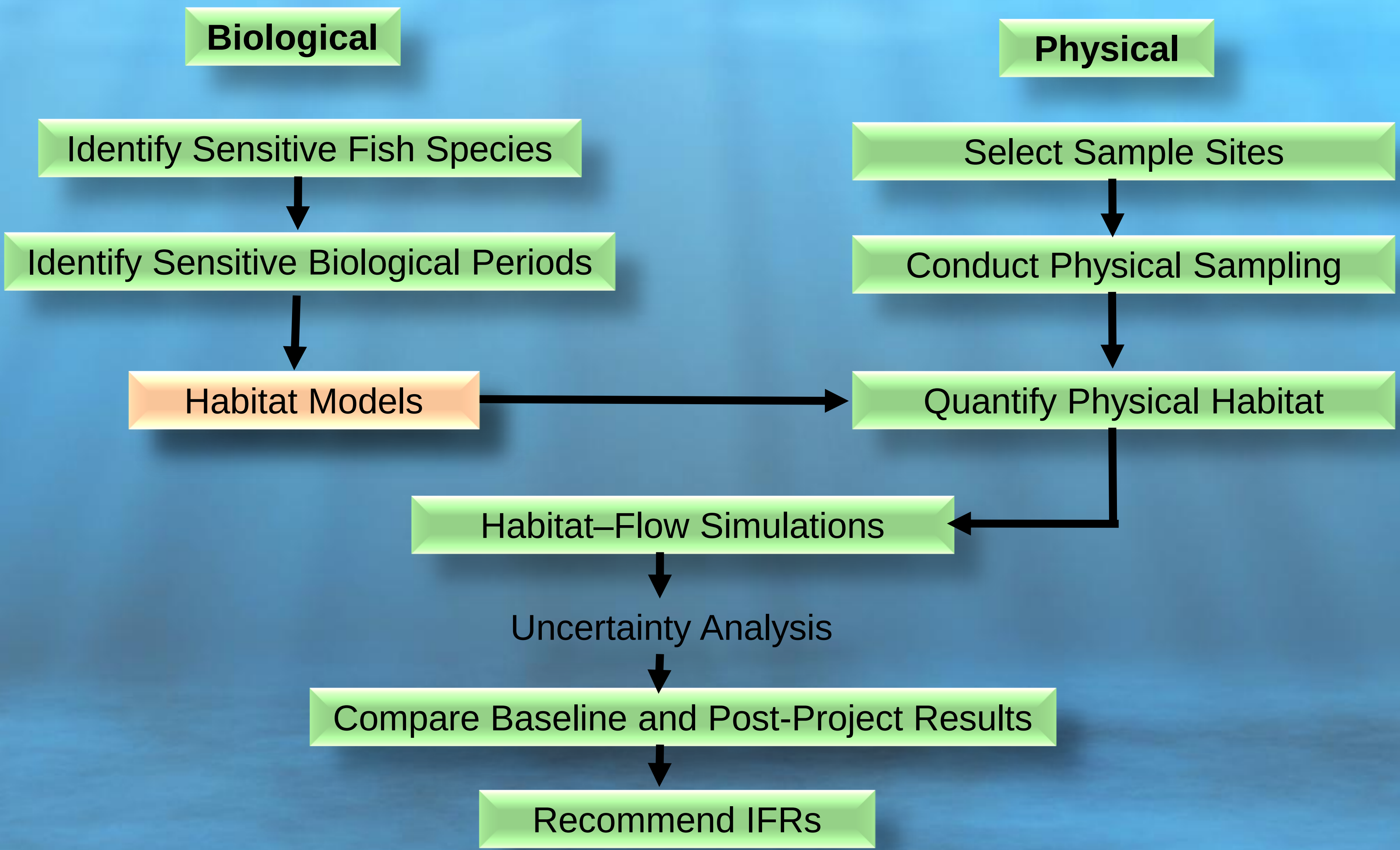
# “Going Beyond” the Guidelines

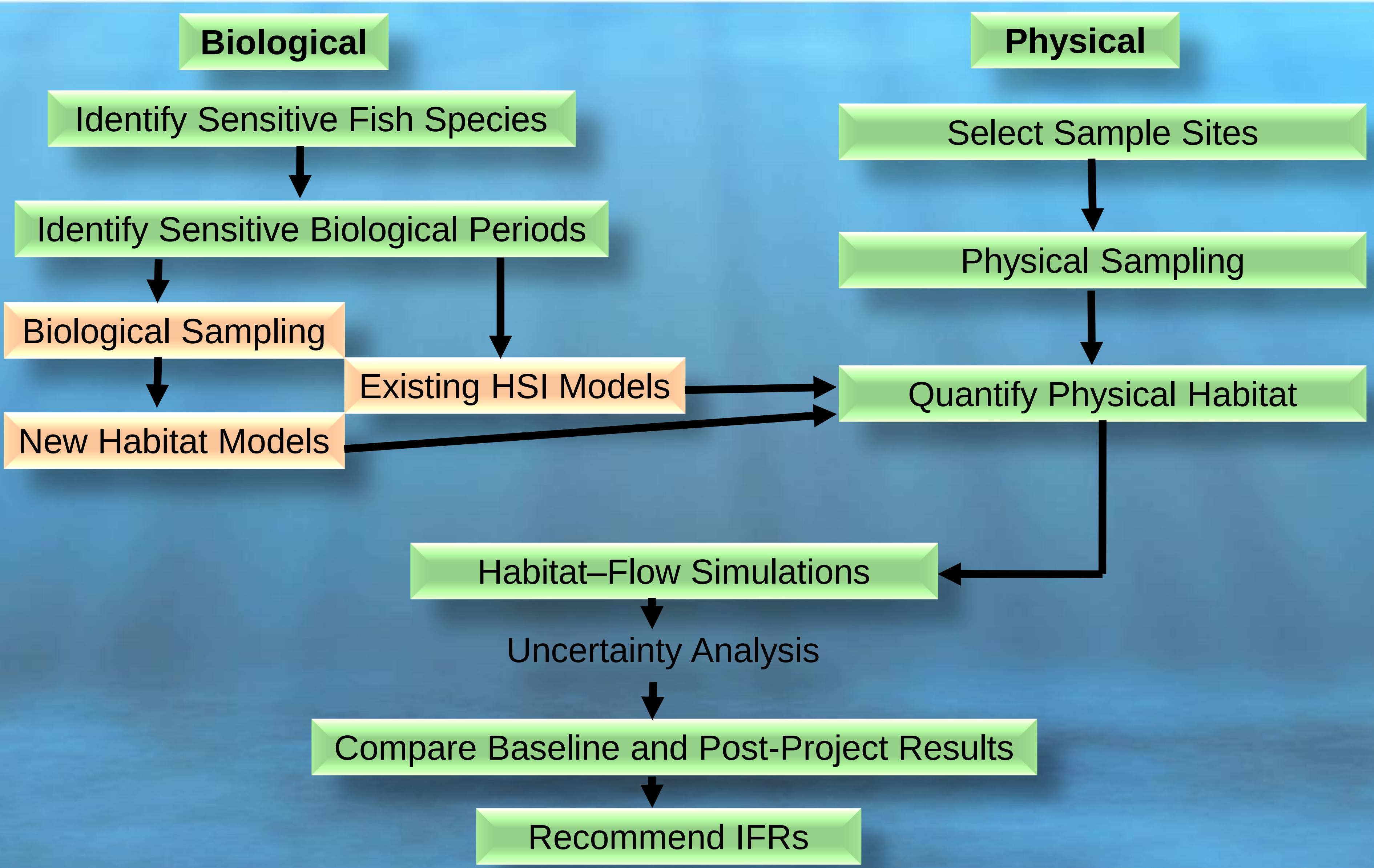
Our Recommendations

- Use existing HSI fish habitat models
- Develop new site-specific fish habitat models
- Explore the use of other types of habitat models (e.g., HPI)
- Compare the results of IFN between existing HSI models and new models

# BC Instream Flow Methodology



# Improved BC Instream Flow Methodology

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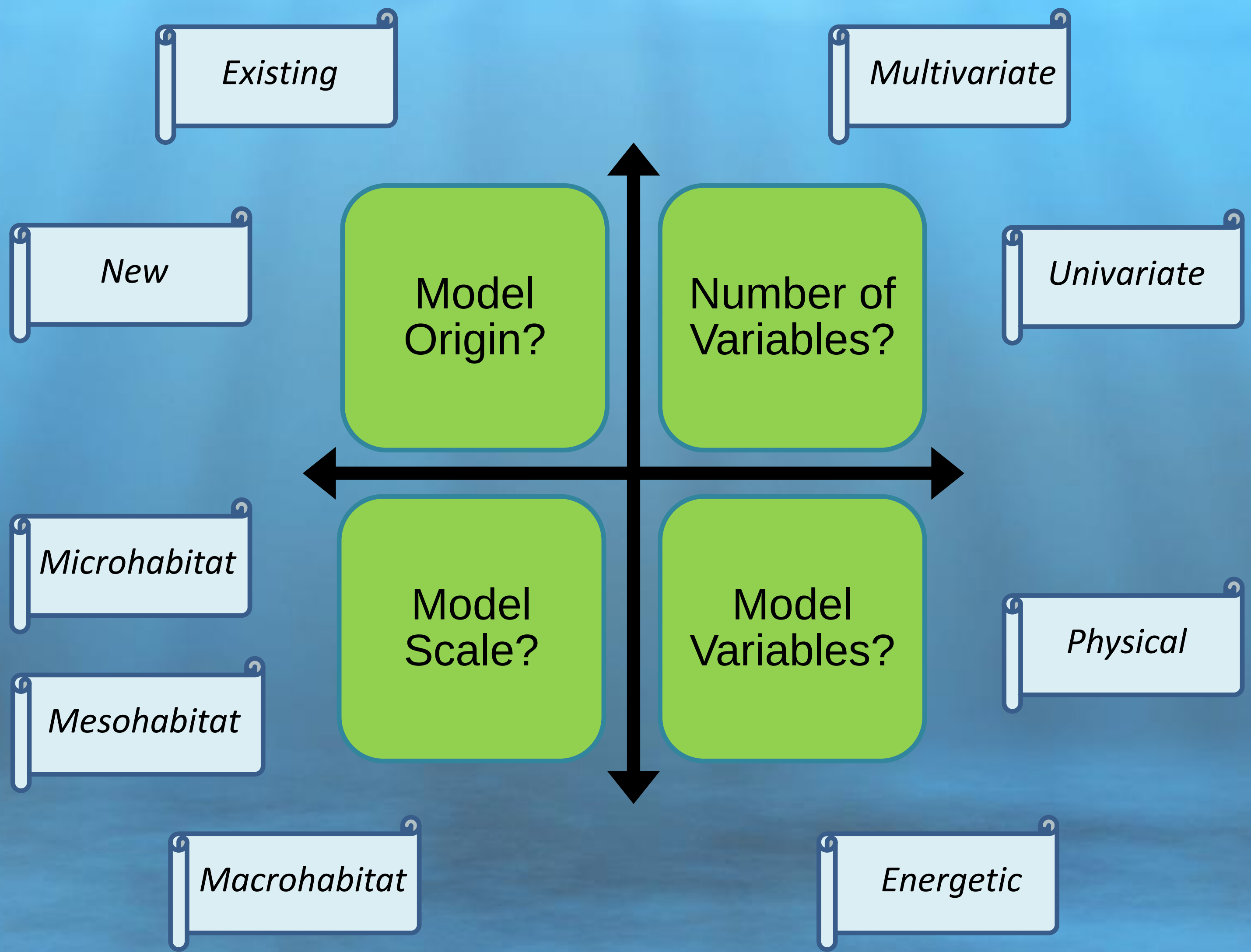
# Why?

1. Several habitat modeling methods are available

# Fish Habitat Models – Other Possibilities



# Fish Habitat Models – Other Possibilities

- Abundance Exchange Model
- Discrete Choice Model
- Habitat Suitability Index (HSI) Model
- Classification Tree (CT) Model
- Discriminant Function Analysis Model
- Foraging Model
- Principal Component Analysis (PCA) Model
- Isodar Model
- Habitat Probabilistic Index (HPI) Model
- Fuzzy Model
- Individual-Based Model (IBM)
- Artificial Neural Network (ANN) Model
- Generalized Linear Model
- Bioenergetics Model
- Multiple Regression Model
- Energetic HSI Model

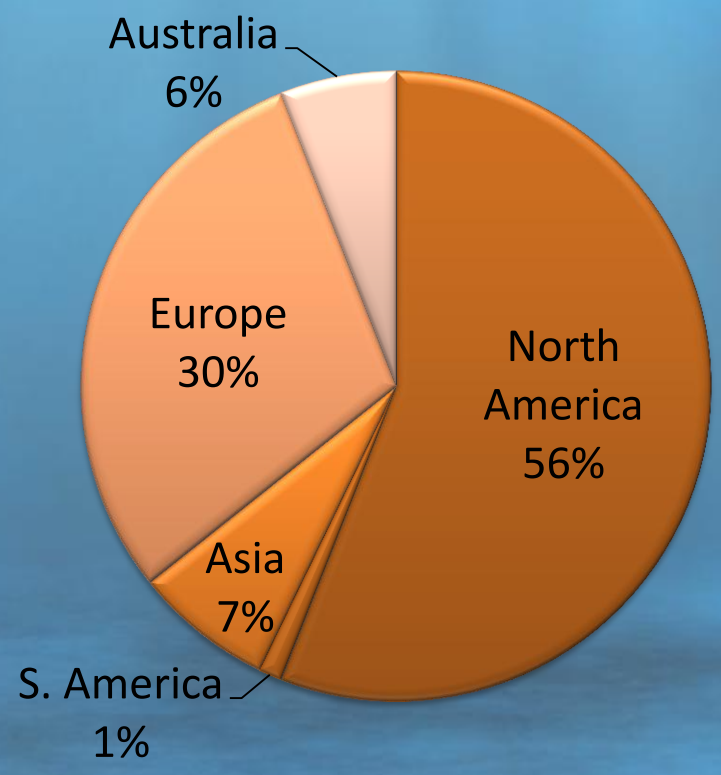
- Some are official names for a modeling method
- Others are tools or statistical methods used to create habitat models

# Why?

2. Other habitat models have increased in popularity

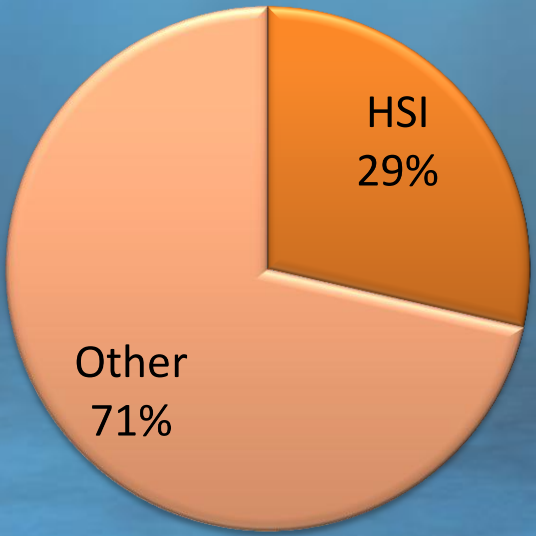
# Habitat Models in Literature

- What models are use predominantly in literature?
- Literature review of 84 published and/or professional documents



# Habitat Models in Literature

- Only 29% of studies used exclusively HSI
- Decrease in exclusive use of HSI models
- Potential explanations:
  - Increase in mathematical abilities among biologists
  - HSI model performance issues



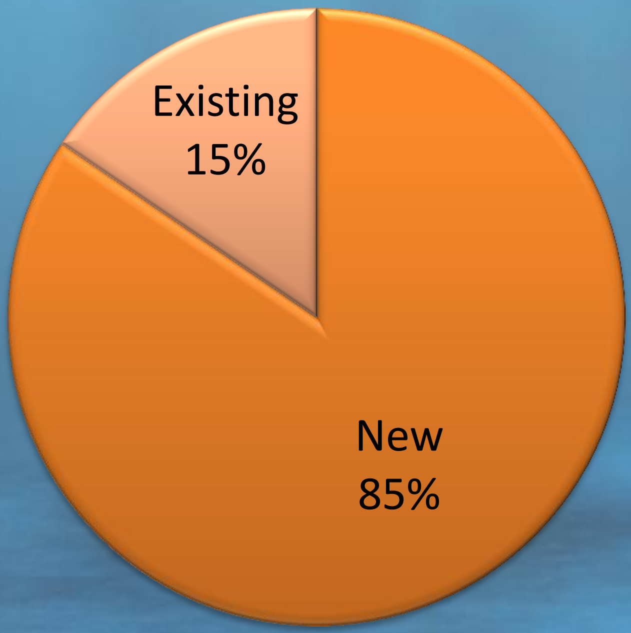

| Time Period | HSI (%) | Other (%) |
|---|---|---|
| 1991-2002 | 35 | 65 |
| 2003-2012 | 26 | 74 |

# Why?

3. New habitat models are more prevalent

# Existing Versus New Habitat Models

- Only 15% of studies used existing models
- Potential explanations:
  - Existing models may not transfer well from one geographical location to another

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# Why?

4. Other habitat models can outperform HSI models

# Example – Guay et al. 2000

- Developed new habitat models (HSI and HPI) for juvenile Atlantic Salmon
- Sainte-Marguerite River, Quebec

HSI Model

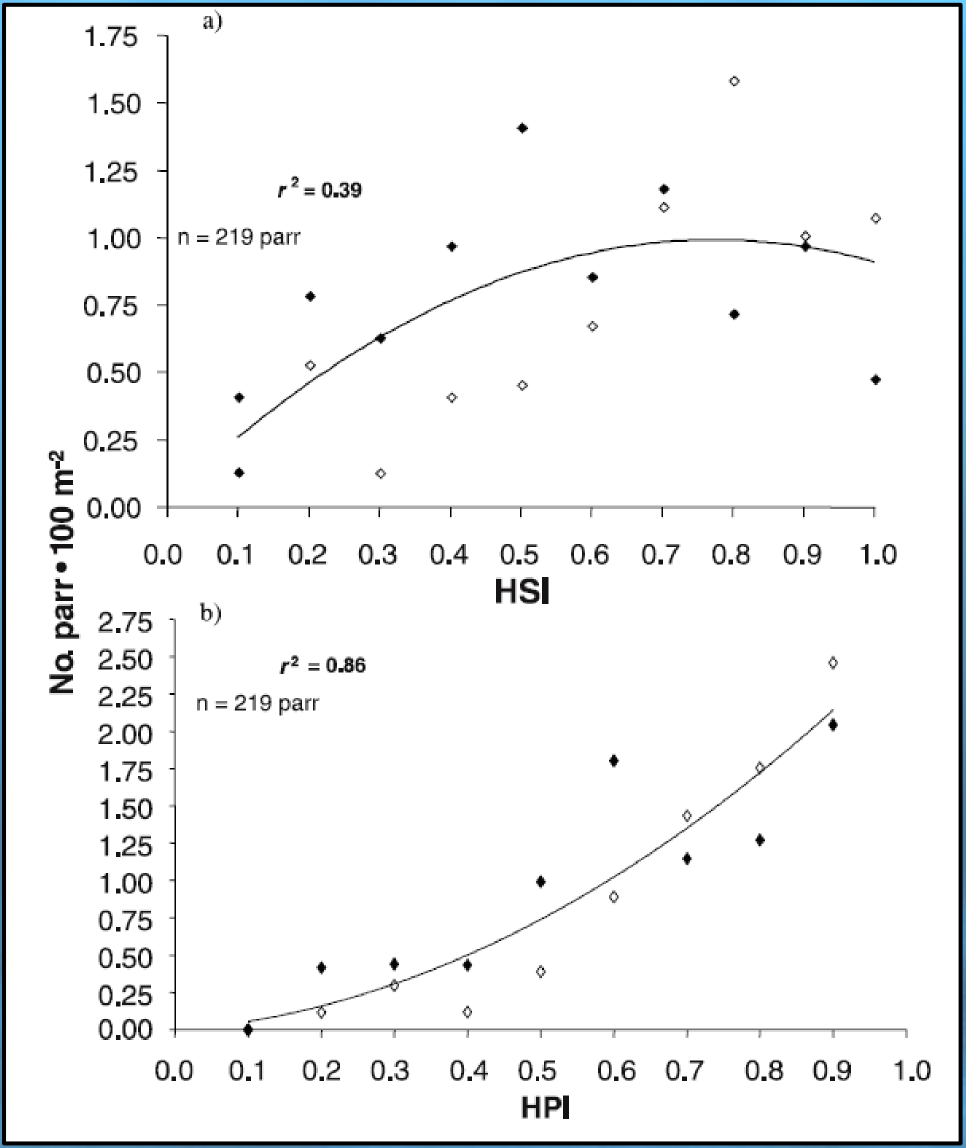
$$HSI = I_V^{0.38} * I_D^{0.30} * I_S^{0.32}$$

HPI Model

$$HPI = 1/(1+e^{-\lambda})$$

$$\lambda = (-3.067 + 8.461*D + 2.86*V + 0.093*S - 6.203*D^2)$$

# HPI Outperformed the HSI Model



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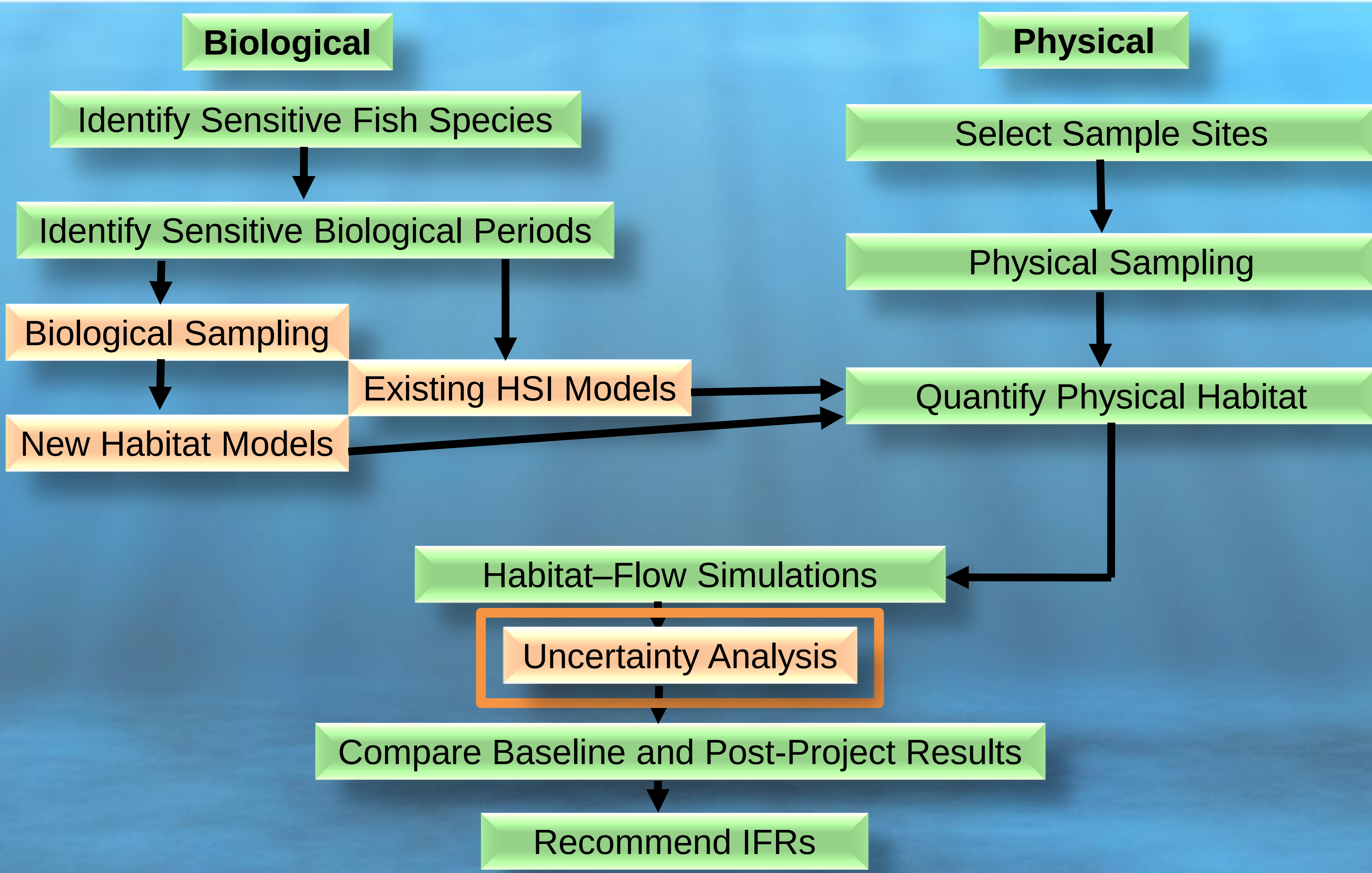


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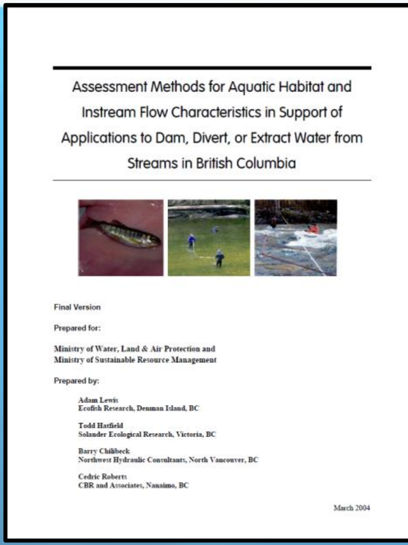
# Uncertainty Analysis – Current Guidelines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March 2004

- Accuracy and precision of habitat models are not addressed
- Impacts of habitat modeling uncertainty on instream flow needs are not estimated
- Positives
  - Less intensive analysis
  - No collection of biological data
- Negatives
  - Assume that HSI models are correct in their predictions of fish distribution in the streams under study
  - Assume that models can be used indiscriminately among streams in BC

# Accuracy

"Degree of closeness of measurements of a quantity to that quantity's actual true value" (NDT, 2011)

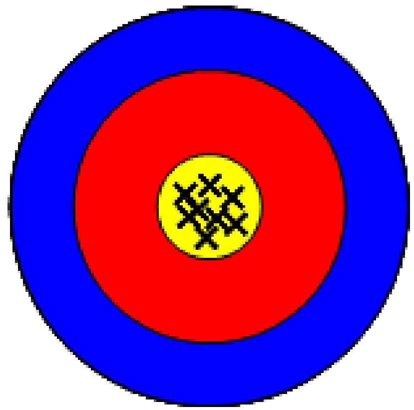
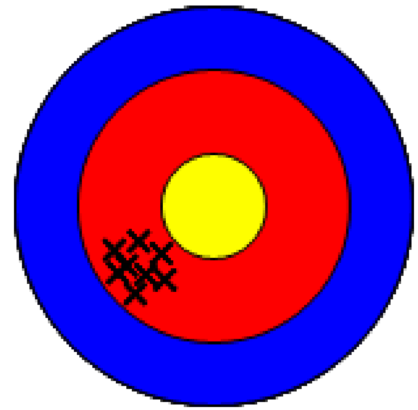
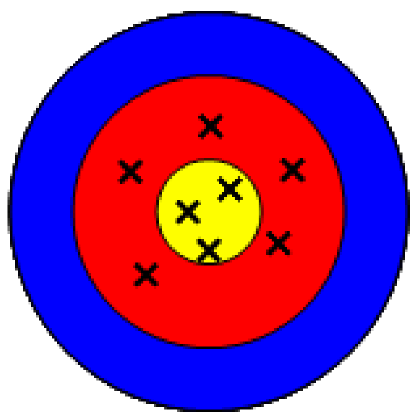
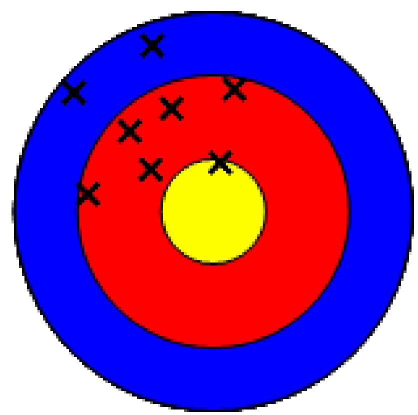
- "Validation" of habitat models
- Determine the success of models in predicting fish distribution
- Should be a crucial element of all modeling work

# Precision

"Degree to which repeated measurements under changed conditions (e.g., observer, settings) show the same results" (NDT, 2011)"

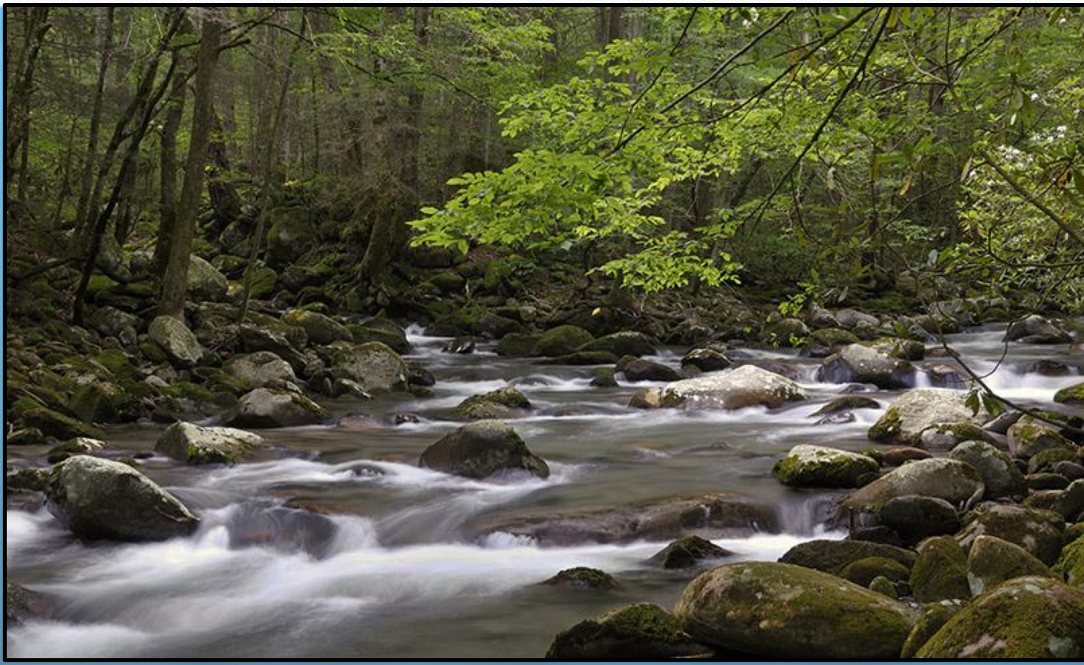
- Also called "Repeatability"
- Different ways to estimate precision
- E.g., Sensitivity analysis
  - Reshuffling original dataset into numerous new datasets
  - Rerun analyses on new datasets
  - Compare results of original dataset with results of new datasets

# Accuracy & Precision

| | Accurate | Inaccurate |
|---|---|---|
| Precise |  |  |
| Imprecise |  |  |

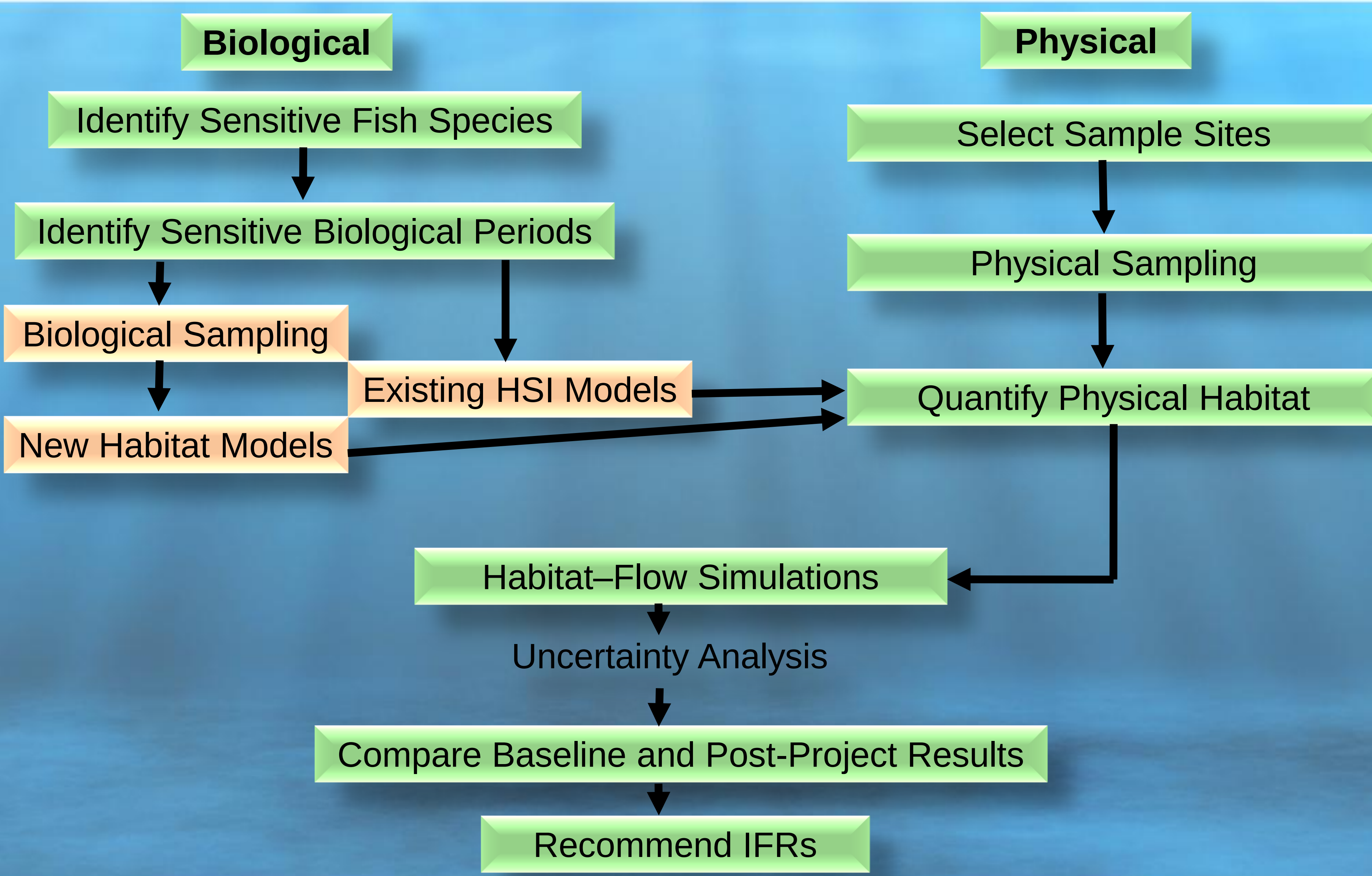
# "Going Beyond" the Guidelines

Our Recommendations



- Determine the accuracy and precision of all habitat models used within the BC IFN methodology
- Determine the impact of habitat modeling uncertainty on instream flow needs

# Improved BC Instream Flow Methodology

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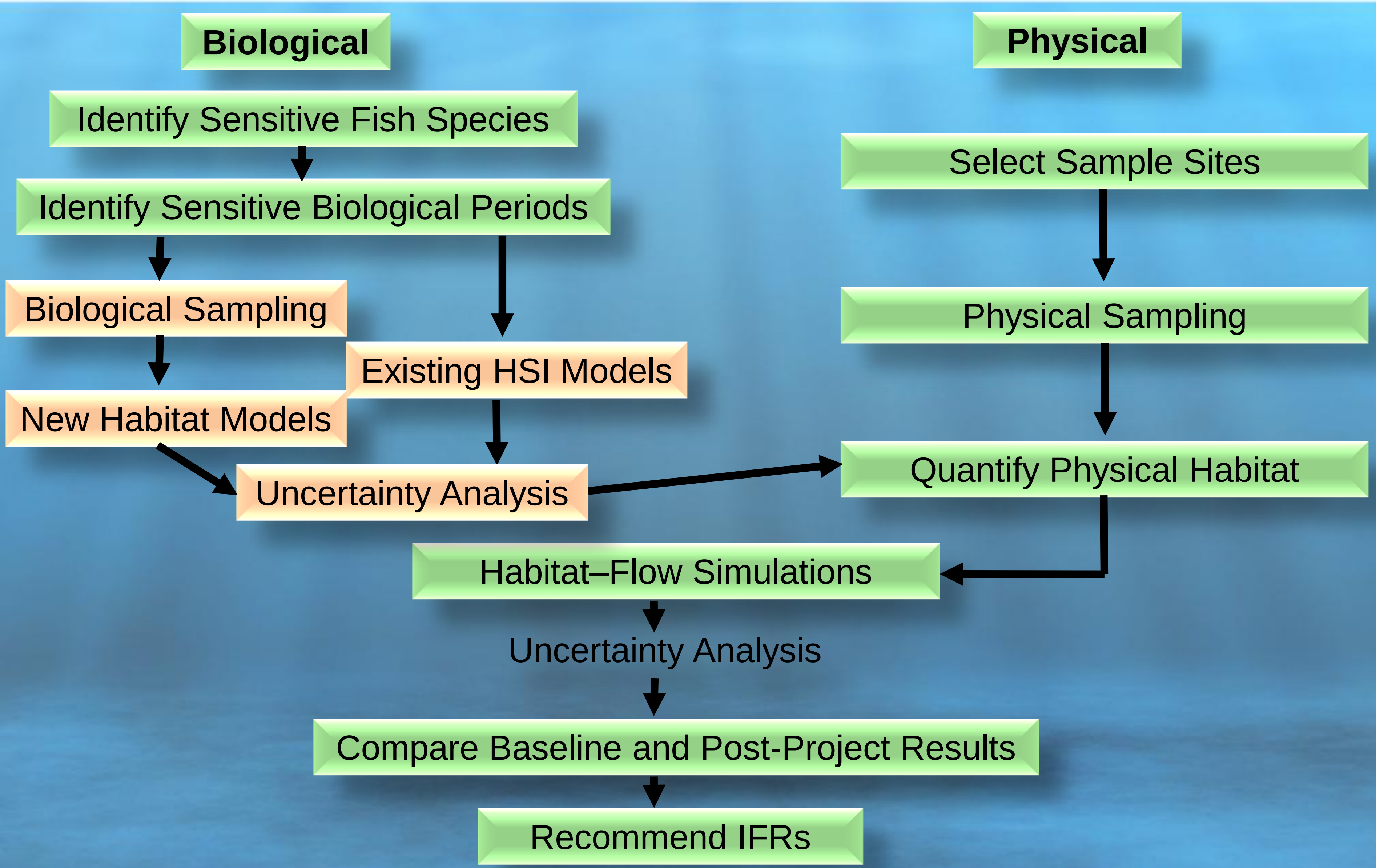
# Our Recommendation

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# Why?

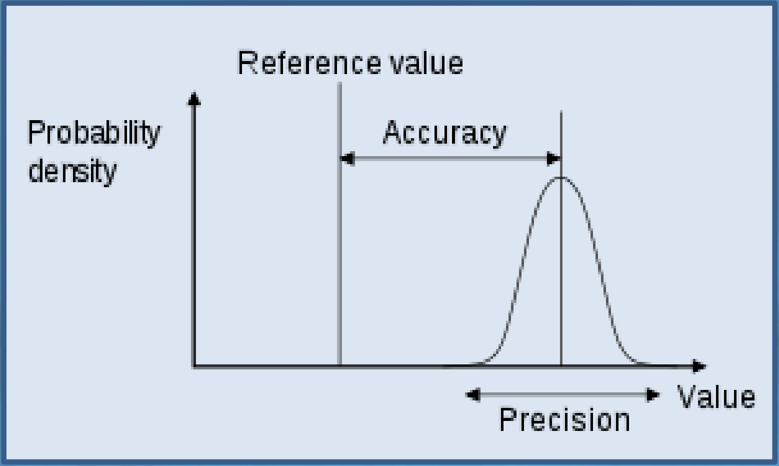
1. To adhere to good mathematical practices

# Good mathematical practices

- When interpreting data and drawing conclusions, one should always provide measures of the uncertainty associated with the data

e.g. "The greatest single constraint to the proper implementation of IFN analysis is the use of accurately derived habitat models. Use of models that do not accurately characterize the utilized or preferred habitat for a species can cause significant error" in predictions (Hudson et al. 2003)"

- Goal is to obtain high precision and accuracy of results



# Why?

2. Accuracy estimates are prevalent in numerous fish habitat modeling studies

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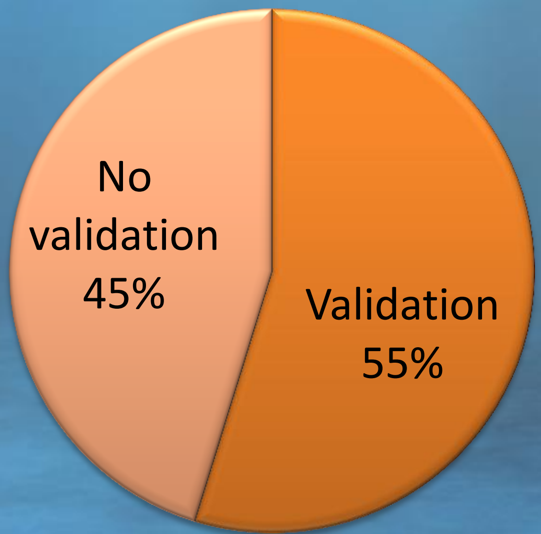
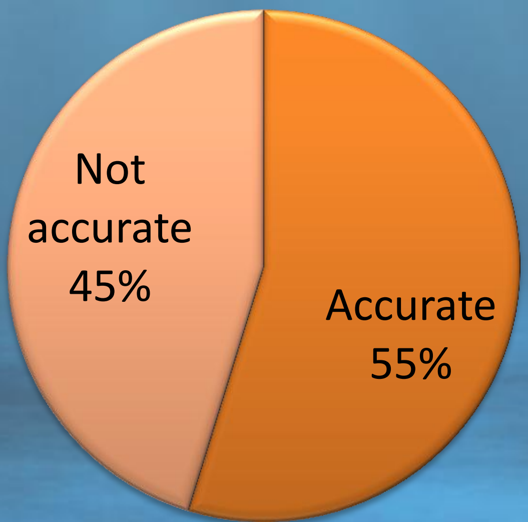
# Accuracy of Habitat Models in Literature

- Over 55% of studies conducted a validation of fish habitat models
- Around 45% of models do not validate (are not accurate in predicting fish distribution)
- Potential explanations:
  - Other variables may be responsible for habitat selection



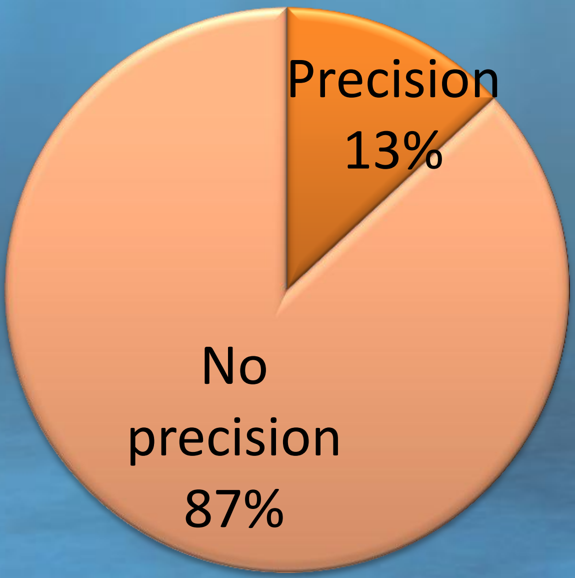



# Why?

2. Precision estimates, although rare, are increasing in popularity

# Precision of Habitat Models in Literature

- Only 13% of studies estimated the precision of fish habitat models
- Potential explanations:
  - Complex mathematics involved
  - Timing and budget constraint
- Slight increase in reporting of precision for fish habitat modeling studies




| Time Period | Precision (%) | No Precision (%) |
|---|---|---|
| 1991-2002 | 10 | 90 |
| 2003-2012 | 15 | 85 |

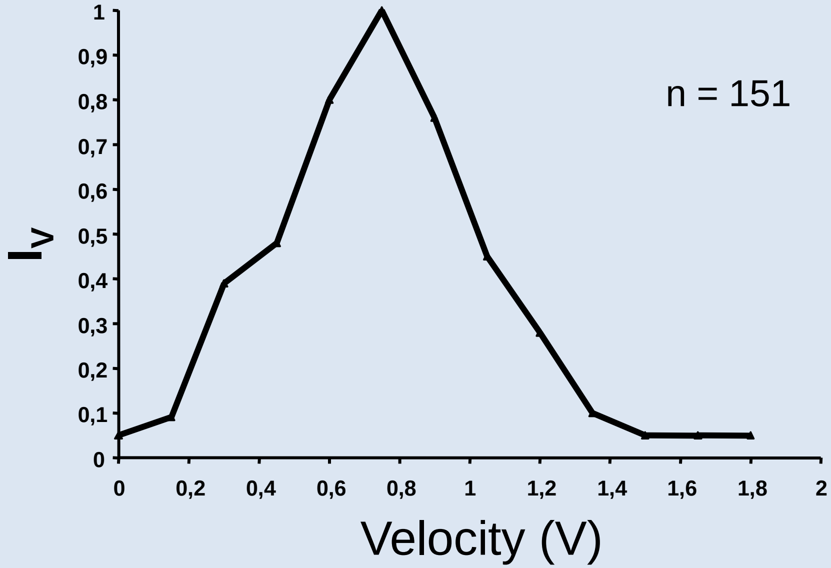
# Why?

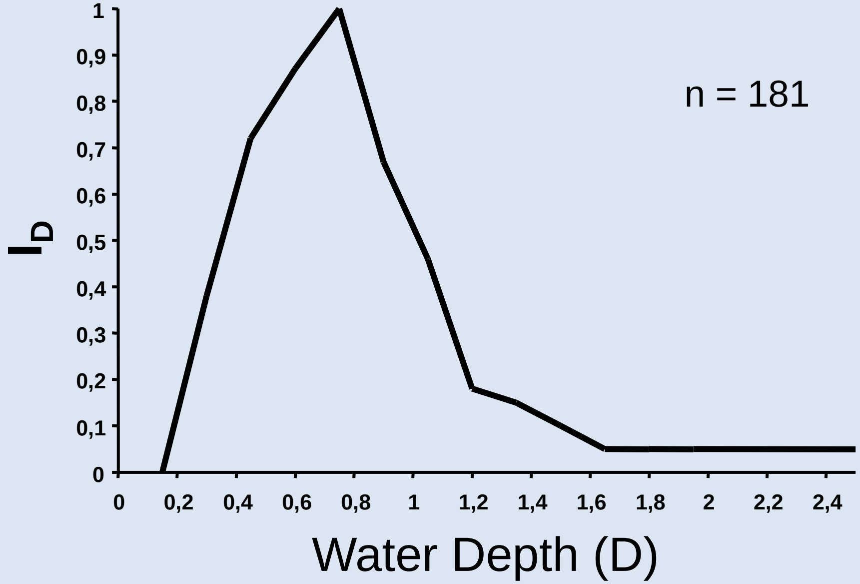
4. Precision and accuracy can show which habitat models should be used for IFN assessments

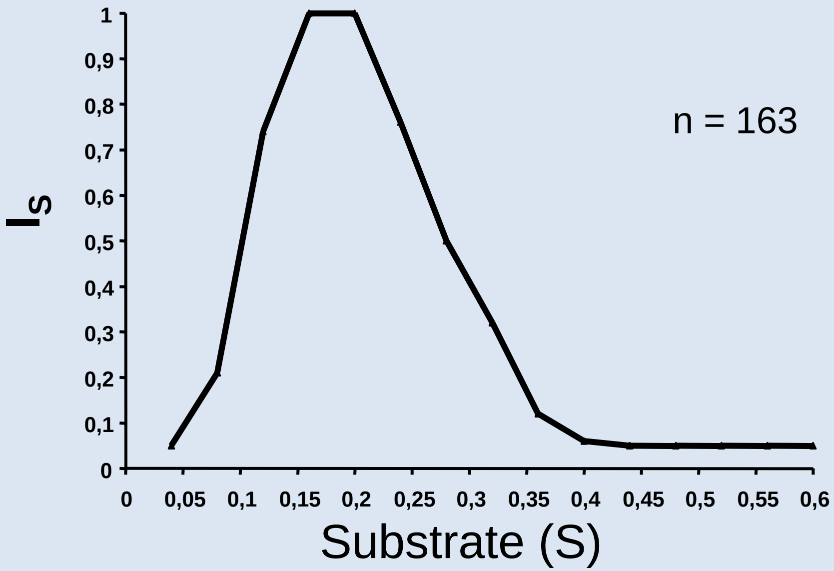
# Example – Uncertainty of Habitat Models in an EIA

- James Bay, Quebec
- 918 MW hydroelectric Project on the Rupert River
- IFN used to determine ecological minimal flows downstream of the dam
- Developed new HSI and HPI habitat models for numerous fish species
- Conducted a validation on all habitat models
- Estimated the Precision of all habitat models and the impact of that uncertainty on the Instream Flow Needs

# New HSI Models




$$HSI = I_V^{0,35} * I_D^{0,29} * I_S^{0,36}$$

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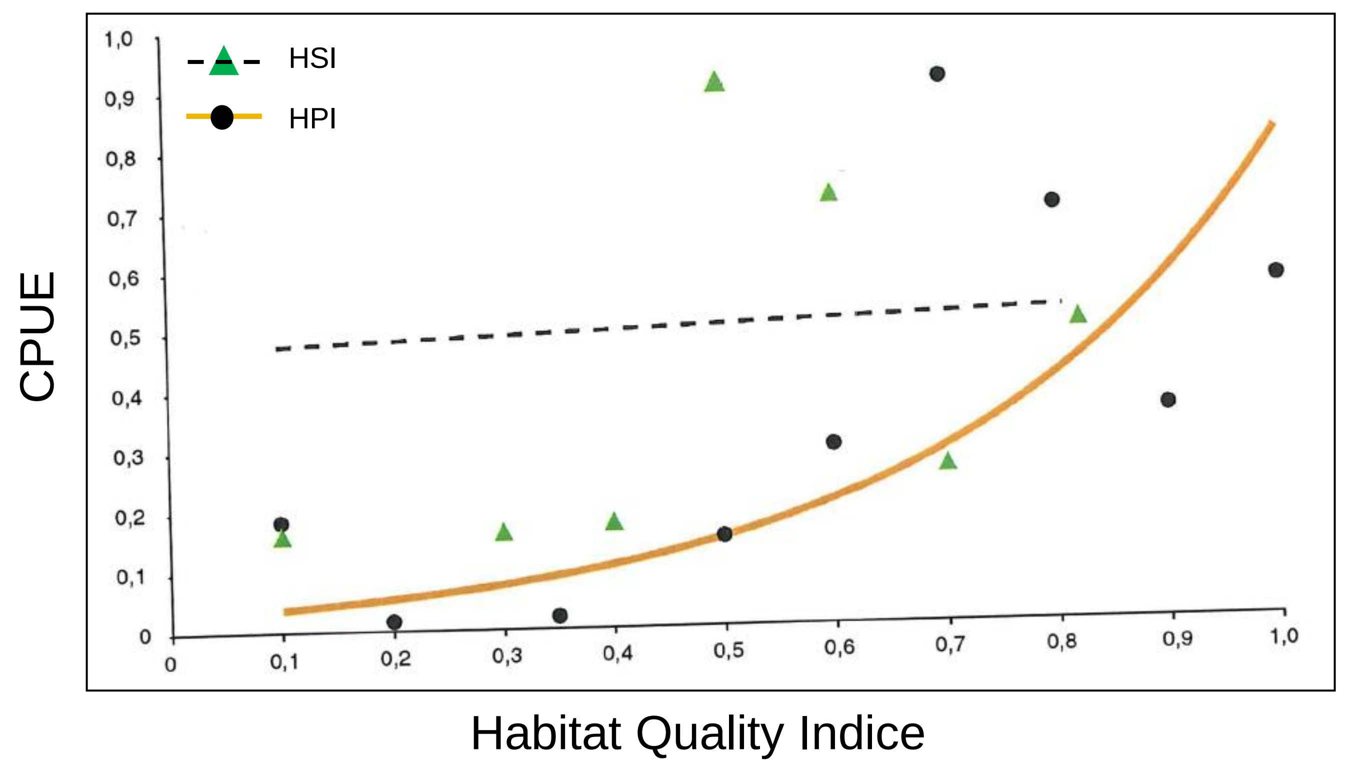
# New HPI Models

$$HPI = 1/\,(1 + e^{-\lambda})$$

$$\lambda = (-2{,}30 + 2{,}24*D - 0{,}30*D^2 - 3{,}82*V + 15{,}46*F - 0{,}02*\%Cobble + 0{,}02*\%Gravel)$$

| Variable | HPI |
|---|---|
| Depth (D) | + |
| $Depth^2$ ($D^2$) | – |
| Velocity (V) | – |
| $Velocity^2$ | N/A |
| % Boulder | N/A |
| % Cobble | – |
| % Pebble | N/A |
| % Gravel | + |
| % Sand | N/A |
| % Silt | N/A |
| Froude (F) | + |
| Precision of predictions (%) | 66.4 |

# Accuracy of Fish Habitat Models




- HPI models outperformed all the HSI models
- HPI models were retained for all fish species within the IFN

| Regression Type | HSI | | HPI | |
|---|---|---|---|---|
| | $r^2$ | P | $r^2$ | P |
| Linear | 0.33 | 0.13 | 0.77 | 0.002 |
| Quadratic | 0.36 | 0.33 | 0.85 | 0.004 |
| Exponential | 0.43 | 0.08 | 0.67 | 0.007 |

# Precision of Retained Fish Habitat Models

- Bootstrap Technique: Random resampling of 80% of the data to create 15 new datasets
- Create 15 HPI sub models

| Sub Model | $HPI_\lambda$ = 1 / (1+e) where λ is equal to | $\chi^2$ | *ddl* | *P* |
|---|---|---|---|---|
| 1 | λ = [-2,559 + (2,522 * P) - (0,325* $P^2$) - (4,383 * V) + (16,466* F) - (0,015 * % galet) + (0,025 * % gravier)] | 31,21 | 6 | < 0,001 |
| 2 | λ = [-2,393 + (2,587 * P) - (0,346* $P^2$) - (4,616 * V) + (17,591* F) - (0,018 * % galet) + (0,014 * % gravier)] | 25,69 | 6 | < 0,001 |
| 3 | λ = [-2,013 + (2,161 * P) - (0,316* $P^2$) - (2,702 * V) + (11,382* F) - (0,018 * % galet) + (0,019 * % gravier)] | 22,75 | 6 | 0,001 |
| 4 | λ = [-1,724 + (1,754 * P) - (0,239* $P^2$) - (2,138 * V) + (9,795* F) - (0,021 * % galet) + (0,025 * % gravier)] | 26,72 | 6 | < 0,001 |
| 5 | λ = [-2,502 + (2,154 * P) - (0,277* $P^2$) - (3,501 * V) + (16,238* F) - (0,019 * % galet) + (0,02 * % gravier)] | 33,49 | 6 | < 0,001 |
| 6 | λ = [-2,52 + (2,355 * P) - (0,309* $P^2$) - (3,749 * V) + (15,363* F) - (0,017 * % galet) + (0,027 * % gravier)] | 28,01 | 6 | < 0,001 |
| 7 | λ = [-1,89 + (2,172 * P) - (0,317* $P^2$) - (2,848 * V) + (12,385* F) - (0,021 * % galet) + (0,01 * % gravier)] | 22,85 | 6 | 0,001 |
| 8 | λ = [-2,885 + (2,453 * P) - (0,314* $P^2$) - (4,804 * V) + (19,89* F) - (0,012 * % galet) + (0,022 * % gravier)] | 29,65 | 6 | < 0,001 |
| 9 | λ = [-2,354 + (2,463 * P) - (0,323* $P^2$) - (4,668 * V) + (18,643* F) - (0,019 * % galet) + (0,011 * % gravier)] | 27,92 | 6 | < 0,001 |
| 10 | λ = [-2,495 + (2,302 * P) - (0,276* $P^2$) - (4,606 * V) + (17,943* F) - (0,014 * % galet) + (0,02 * % gravier)] | 29,30 | 6 | < 0,001 |
| 11 | λ = [-2,113 + (2,042 * P) - (0,279* $P^2$) - (3,09 * V) + (13,561* F) - (0,02 * % galet) + (0,021 * % gravier)] | 28,07 | 6 | < 0,001 |
| 12 | λ = [-2,424 + (2,352 * P) - (0,304* $P^2$) - (4,244 * V) + (16,749* F) - (0,019 * % galet) + (0,023 * % gravier)] | 33,60 | 6 | < 0,001 |
| 13 | λ = [-2,082 + (2,154 * P) - (0,3* $P^2$) - (2,939 * V) + (11,978* F) - (0,016 * % galet) + (0,019 * % gravier)] | 22,48 | 6 | 0,001 |
| 14 | λ = [-1,659 + (1,861 * P) - (0,247* $P^2$) - (2,757 * V) + (14,182* F) - (0,03 * % galet) + (0,006 * % gravier)] | 27,50 | 6 | < 0,001 |
| 15 | λ = [-2,073 + (2,145 * P) - (0,282* $P^2$) - (3,621 * V) + (15,107* F) - (0,02 * % galet) + (0,013 * % gravier)] | 22,97 | 6 | 0,001 |

| Sub Model | | Absence (Nb.) | Presence (Nb.) | Precision of predictions |
|---|---|---|---|---|
| 1 | Absence ($N^{bre}$ = 88) | 61 | 27[a] | 69,3 |
| | Présence ($N^{bre}$ = 88) | 29[a] | 59 | 67,0 |
| | **Global** | -- | -- | **68,2** |
| 2 | Absence | 60 | 28[a] | 68,2 |
| | Présence | 30[a] | 58 | 65,9 |
| | **Global** | -- | -- | **67,0** |
| 3 | Absence | 53 | 35[a] | 60,2 |
| | Présence | 30[a] | 58 | 65,9 |
| | **Global** | -- | -- | **63,1** |
| 4 | Absence | 57 | 31[a] | 64,8 |
| | Présence | 34[a] | 54 | 61,4 |
| | **Global** | -- | -- | **63,1** |
| 5 | Absence | 59 | 29[a] | 67,0 |
| | Présence | 25[a] | 63 | 71,6 |
| | **Global** | -- | -- | **69,3** |
| 6 | Absence | 58 | 30[a] | 65,9 |
| | Présence | 29[a] | 59 | 67,0 |
| | **Global** | -- | -- | **66,5** |
| 7 | Absence | 52 | 36[a] | 59,1 |
| | Présence | 30[a] | 58 | 65,9 |
| | **Global** | -- | -- | **62,5** |
| 8 | Absence | 61 | 27[a] | 69,3 |
| | Présence | 27[a] | 61 | 69,3 |
| | **Global** | -- | -- | **69,3** |
| 9 | Absence | 58 | 30[a] | 65,9 |
| | Présence | 28[a] | 60 | 68,2 |
| | **Global** | -- | -- | **67,0** |
| 10 | Absence | 64 | 24[a] | 72,7 |
| | Présence | 32[a] | 56 | 63,6 |
| | **Global** | -- | -- | **68,2** |
| 11 | Absence | 55 | 33[a] | 62,5 |
| | Présence | 30[a] | 58 | 65,9 |
| | **Global** | -- | -- | **64,2** |
| 12 | Absence | 62 | 26[a] | 70,5 |
| | Présence | 28[a] | 60 | 68,2 |
| | **Global** | -- | -- | **69,3** |
| 13 | Absence | 55 | 33[a] | 62,5 |
| | Présence | 30[a] | 58 | 65,9 |
| | **Global** | -- | -- | **64,2** |
| 14 | Absence | 52 | 36[a] | 59,1 |
| | Présence | 26[a] | 62 | 70,5 |
| | **Global** | -- | -- | **64,8** |
| 15 | Absence | 55 | 33[a] | 62,5 |
| | Présence | 30[a] | 58 | 65,9 |
| | **Global** | -- | -- | **64,2** |

[a] Erroneous prediction

# Precision of Fish Habitat Models

- Estimate the variance among sub-models using a Coefficient of Variation (CV) on the variables of the sub models

$$CV = \frac{\sigma}{\bar{x}} 100$$

σ is the Standard Deviation and $\bar{x}$ is the average

| Sub Model | D<br>Depth | D [2]<br>Depth | V<br>Velocity | F<br>Froude | %<br>Cobble | %<br>Gravel | Constant |
|---|---|---|---|---|---|---|---|
| 1 | 2,522 | -0,325 | -4,383 | 16,466 | -0,015 | 0,025 | -2,559 |
| 2 | 2,587 | -0,346 | -4,616 | 17,591 | -0,018 | 0,014 | -2,393 |
| 3 | 2,161 | -0,316 | -2,702 | 11,382 | -0,018 | 0,019 | -2,013 |
| 4 | 1,754 | -0,239 | -2,138 | 9,795 | -0,021 | 0,025 | -1,724 |
| 5 | 2,154 | -0,277 | -3,501 | 16,238 | -0,019 | 0,02 | -2,502 |
| 6 | 2,355 | -0,309 | -3,749 | 15,363 | -0,017 | 0,027 | -2,52 |
| 7 | 2,172 | -0,317 | -2,848 | 12,385 | -0,021 | 0,01 | -1,89 |
| 8 | 2,453 | -0,314 | -4,804 | 19,89 | -0,012 | 0,022 | -2,885 |
| 9 | 2,463 | -0,323 | -4,668 | 18,643 | -0,019 | 0,011 | -2,354 |
| 10 | 2,302 | -0,276 | -4,606 | 17,943 | -0,014 | 0,02 | -2,495 |
| 11 | 2,042 | -0,279 | -3,09 | 13,561 | -0,02 | 0,021 | -2,113 |
| 12 | 2,352 | -0,304 | -4,244 | 16,749 | -0,019 | 0,023 | -2,424 |
| 13 | 2,154 | -0,3 | -2,939 | 11,978 | -0,016 | 0,019 | -2,082 |
| 14 | 1,861 | -0,247 | -2,757 | 14,182 | -0,03 | 0,006 | -1,659 |
| 15 | 2,145 | -0,282 | -3,621 | 15,107 | -0,02 | 0,013 | -2,073 |
| **Average** | 2,23 | -0,30 | -3,64 | 15,15 | -0,019 | 0,018 | -2,25 |
| **Standard Deviation** | 0,24 | 0,03 | 0,87 | 2,90 | 0,004 | 0,006 | 0,34 |
| **C.V. (%)** | **10,6** | **10,0** | **23,9** | **19,2** | **22,0** | **33,7** | **15,3** |

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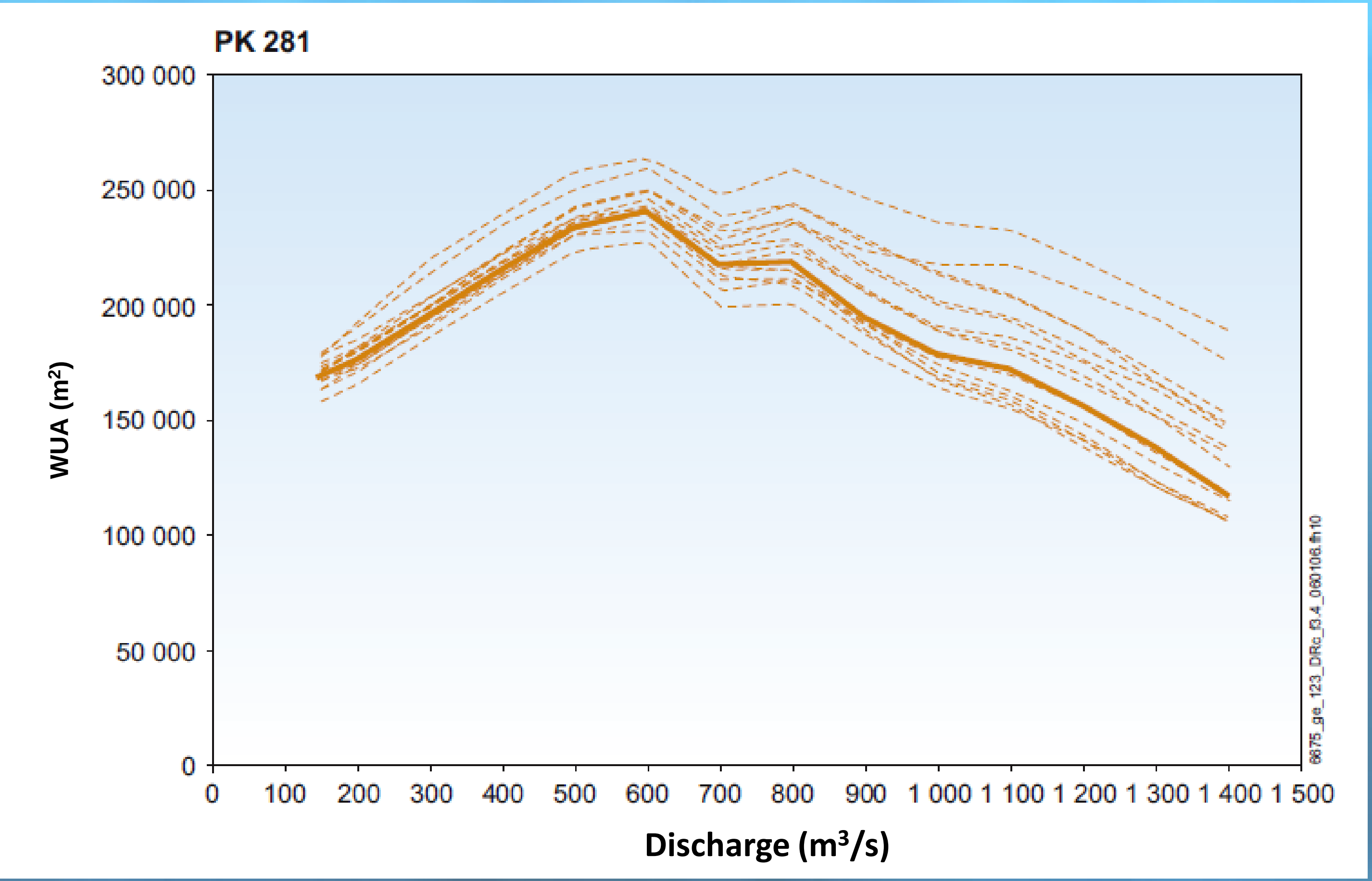
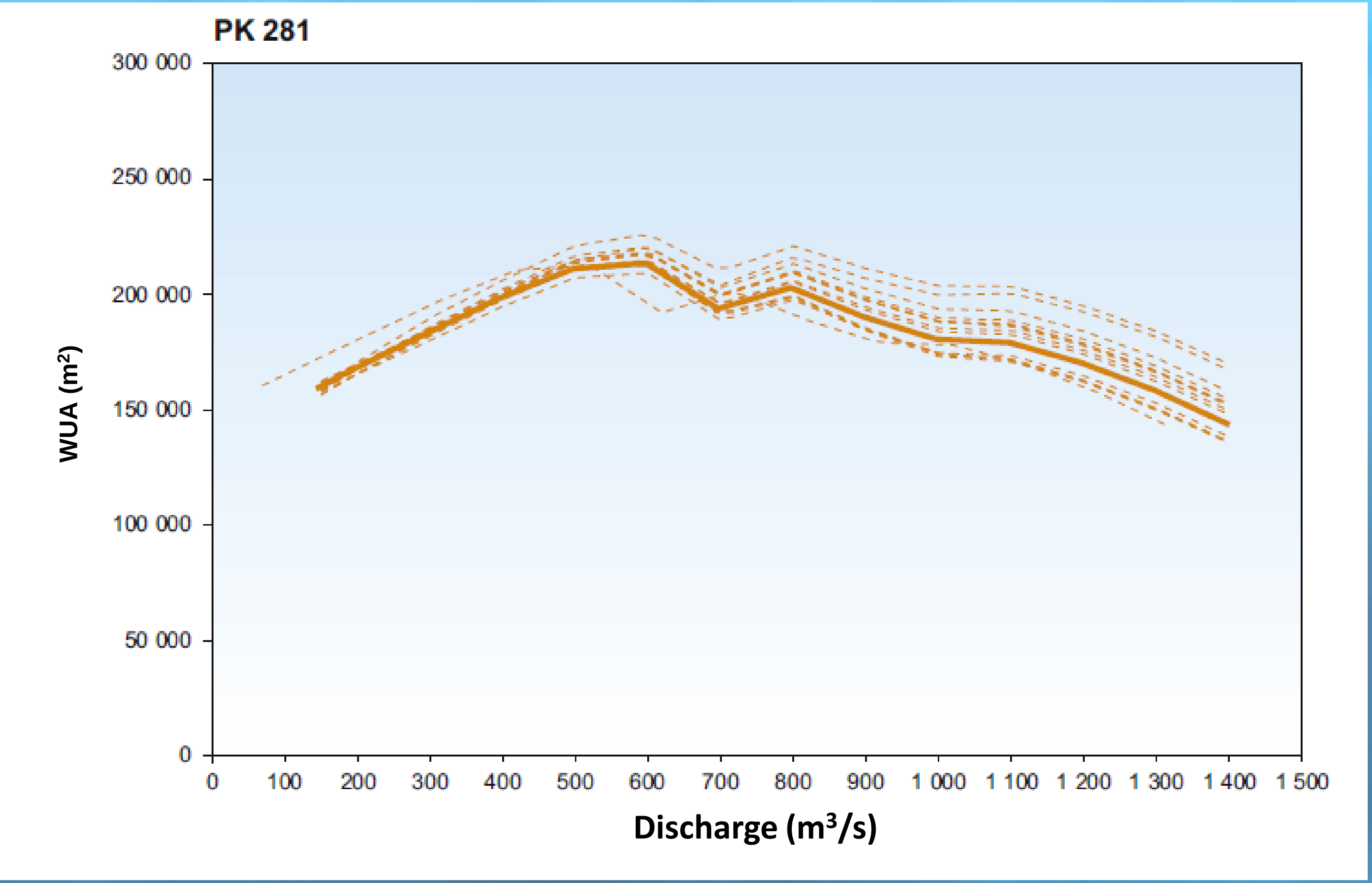
# Impact of Uncertainty of Habitat Models on IFN



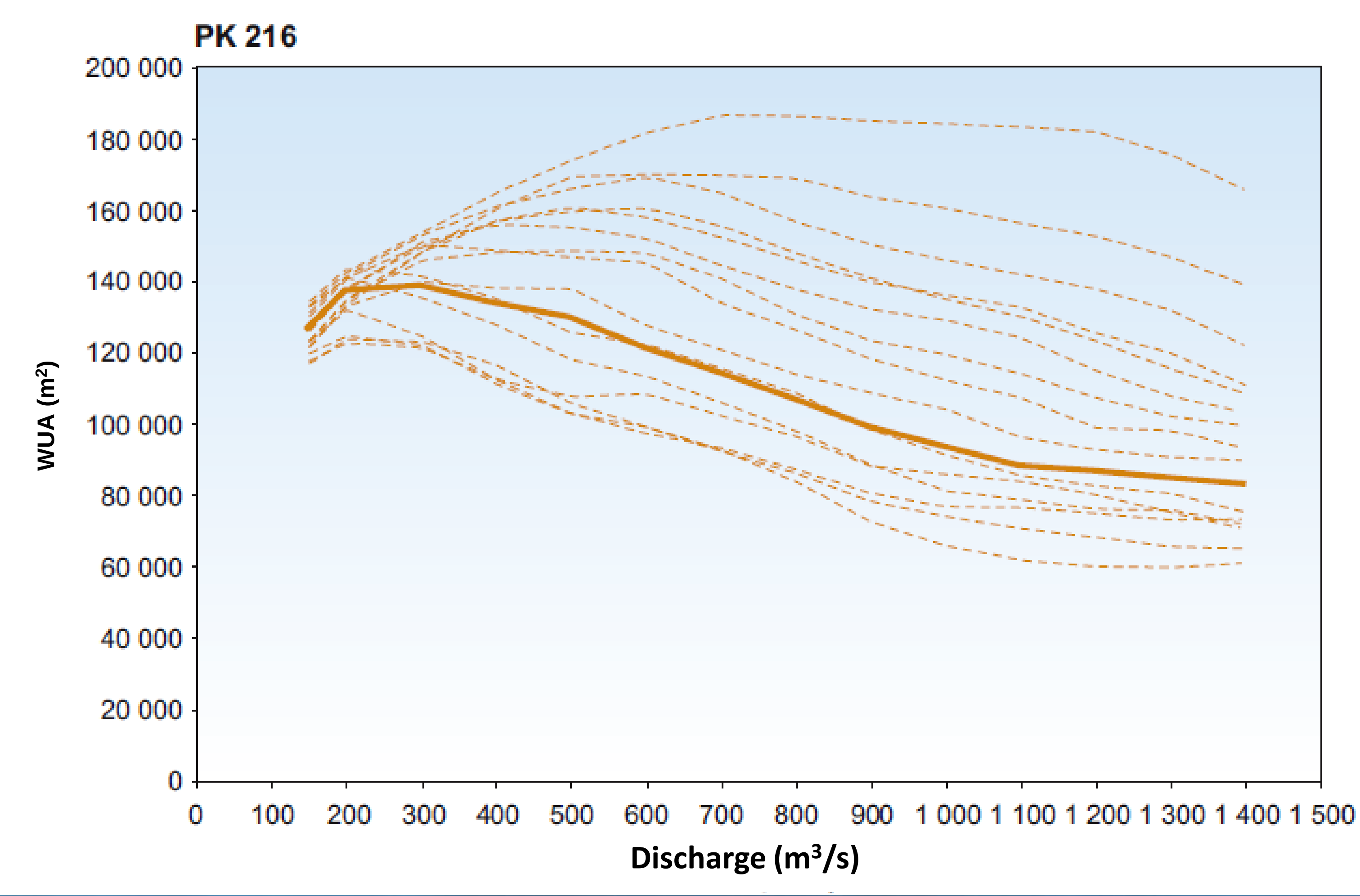

**Good!**

# Impact of Uncertainty of Habitat Models on IFN




**Excellent!**

# Impact of Uncertainty of Habitat Models on IFN




**Unacceptable!**

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# Impact of Uncertainty of Habitat Models on IFN

| Site | Méthode d'interprétation | Méthode de simulation | Débit ($m^3/s$) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Modèle retenu | Sous-modèle | | | | | | | | | | | | | | | Moyenne | Écart type | Min | Max |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | | |
| PK281 | 0,8 $APU_{max}$ | Tous les habitats | 221 | 217 | 202 | 239 | 261 | 247 | 235 | 235 | 210 | 203 | 214 | 235 | 213 | 241 | 253 | 227 | 229 | 18,3 | 202 | 261 |
| PK281 | 0,8 $APU_{max}$ | Habitat >0,5 | 286 | 274 | 257 | 302 | 299 | 282 | 286 | 273 | 264 | 248 | 273 | 303 | 279 | 302 | 267 | 283 | 279 | 16,9 | 248 | 303 |
| PK281 | $APU_{débit\ moyen}$ | Tous les habitats | N/A | 410 | 380 | 420 | 457 | 428 | 423 | 412 | 379 | 377 | 407 | 418 | 399 | 429 | 439 | 412 | 413 | 22,4 | 377 | 457 |
| PK281 | $APU_{débit\ moyen}$ | Habitat >0,5 | N/A | 388 | 336 | 455 | 490 | 505 | 441 | 446 | 367 | 348 | 379 | 454 | 361 | 463 | 496 | 436 | 424 | 56,4 | 336 | 505 |
| PK216 | 0,8 $APU_{max}$ | Tous les habitats | 149 | 144 | 139 | 202 | 260 | 217 | 175 | 194 | 145 | 141 | 143 | 196 | 144 | 195 | 243 | 162 | 180 | 39,3 | 139 | 260 |
| PK216 | 0,8 $APU_{max}$ | Habitat >0,5 | 131 | 125 | 127 | 160 | 216 | 172 | 138 | 170 | 129 | 128 | 125 | 145 | 127 | 148 | 259 | 138 | 154 | 38,3 | 125 | 259 |
| PK216 | $APU_{débit\ moyen}$ | Tous les habitats | N/A | 237 | 181 | 368 | 435 | 363 | 319 | 360 | 224 | 197 | 229 | 351 | 237 | 362 | 416 | 309 | 306 | 81,8 | 181 | 435 |
| PK216 | $APU_{débit\ moyen}$ | Habitat >0,5 | N/A | 150 | 150 | 201 | 424 | 229 | 150 | 263 | 150 | 150 | 96 | 150 | 150 | 171 | 662 | 150 | 216 | 145,4 | 96 | 662 |

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# Questions?

# Example 2

## Role of Genetic Studies within Provincial Hydroelectric and Mining Guidelines

**Cory Bettles, M.Sc., R.P.Bio., CFP***

* Certified Fisheries Professional, American Fisheries Society

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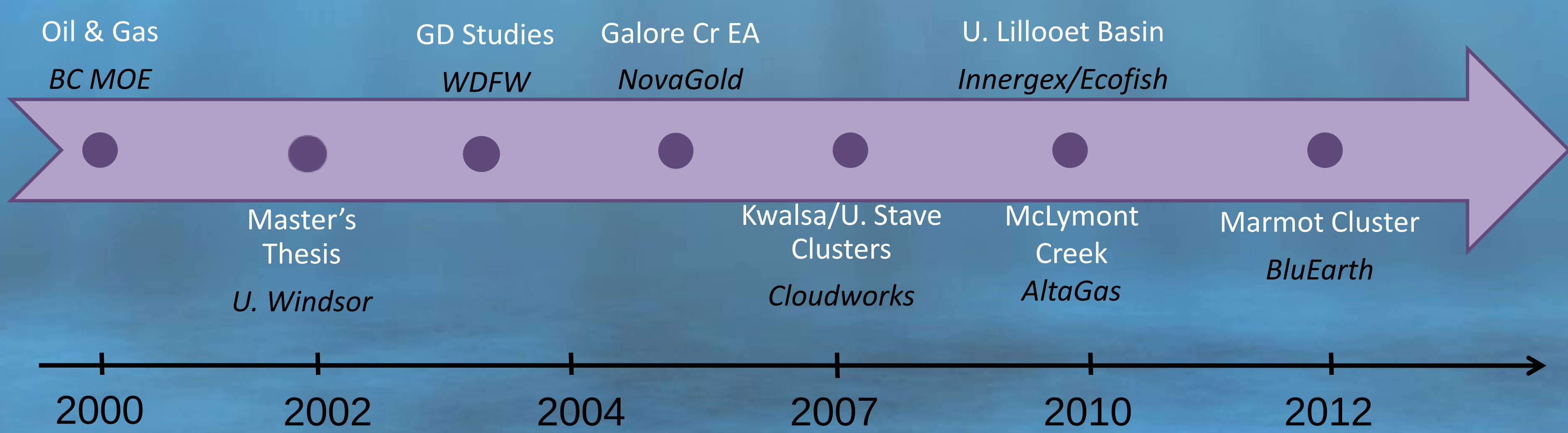
# Genetic Diversity

"Range of heritable differences of a trait or set of traits among individuals of a species, within populations and among different populations" (Bagely et al. 2002)

- Essentially synonymous with 'genetic variation' or 'genetic variance'
- Genetic diversity is considered a trait of populations and species, not of individuals

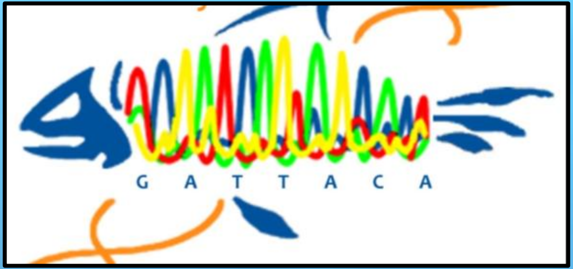
# Professional Experience

- B.Sc. (UNBC) and M.Sc. (GLIER, UWindsor)
- Master's thesis: Hybridization b/t Sympatric CTT and RBT/STD Trout on Van. Island
- Numerous studies specific to fish population structure

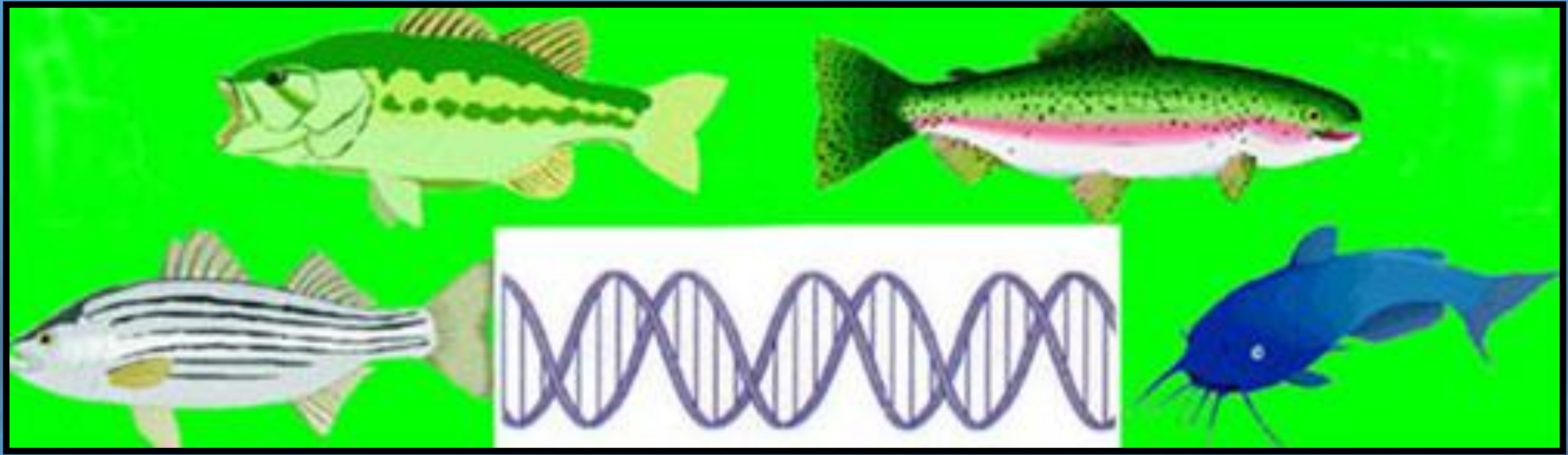


# "Going Beyond" the Guidelines

Current Guidelines




- Genetic Diversity studies are not discussed or included



# “Going Beyond” the Guidelines

## Our Recommendations

- Inclusion of genetic diversity studies in EA when:
  - Species-at-risk (including specifically designated stocks) are present within the study area
  - Species are present that have complex life history strategies (e.g. BT, DV, CTT)
  - Watershed-scale projects where stream networks are potentially affected

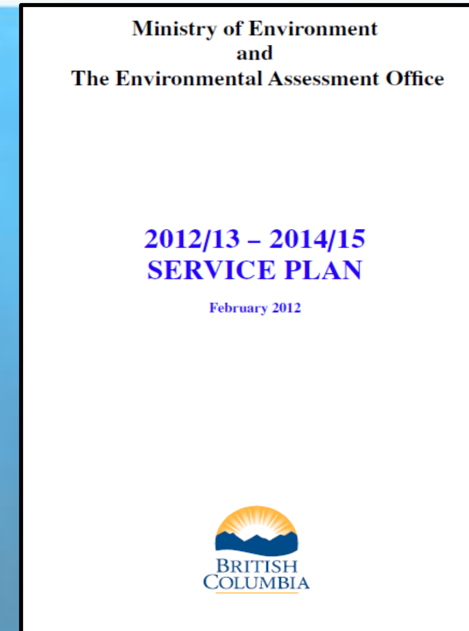
# Why?

1. To adhere to the Provincial Mandate

# BC MoE Service Plan

"Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity" (p.21)

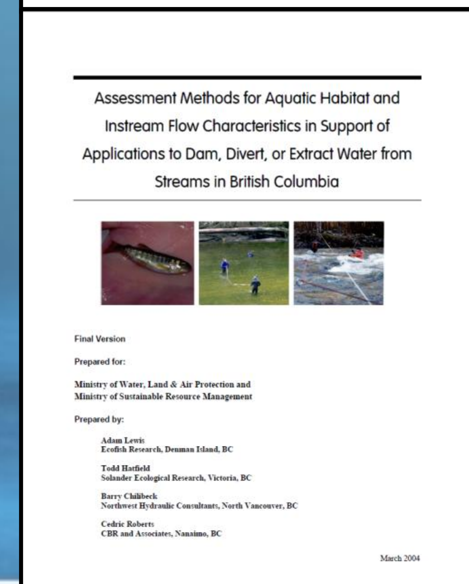
"Fisheries data collected to support a water license application should meet or exceed existing inventory standards" Lewis et al. 2004


Ministry of Environment
and
The Environmental Assessment Office

2012/13 – 2014/15
SERVICE PLAN

February 2012




Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia

Final Version

Prepared for:

Ministry of Water, Land & Air Protection and
Ministry of Sustainable Resource Management

Prepared by:

Adam Lewis
Ecofish Research, Denman Island, BC

Todd Hatfield
Solander Ecological Research, Victoria, BC

Barry Chilibeck
Northwest Hydraulic Consultants, North Vancouver, BC

Cedric Roberts
CBR and Associates, Nanaimo, BC

March 2004

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# Why?

2. To insure the maintenance of <u>biodiversity</u> of fish species

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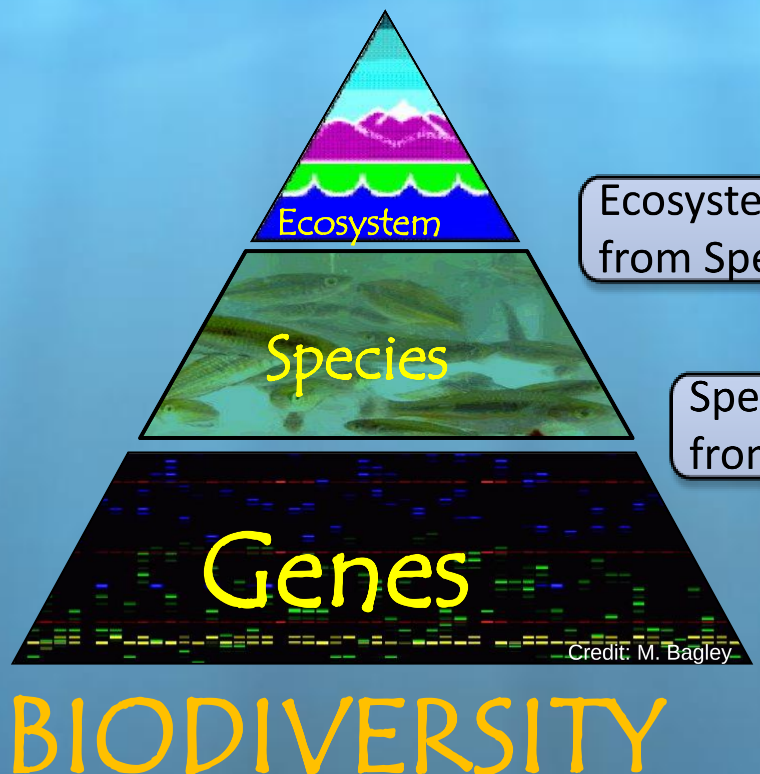
# Importance of Biodiversity




Ecosystem Diversity driven from Species Diversity

Species Diversity driven from Genetic Diversity

- Fundamental organization unit of biodiversity
- Any goal to monitor/maintain biodiversity is incomplete if only considers species & ecosystem component

# Importance of Biodiversity

- The level of development in B.C. has consequences on environmental resources such as fish and wildlife and their habitats, ecosystems and water quality
- Certain species and ecosystems are designated as at risk
- *Nature's Pulse* (2008), an assessment of the state of British Columbia's biodiversity, states that:

"British Columbia's biodiversity is globally significant because of its variety and integrity but without immediate action, it is vulnerable to rapid deterioration, especially in light of climate change... Expanding human settlement and development are the most obvious but not the only threats to biodiversity in B.C. today" (Austin et al. 2008)

# Importance of Biodiversity

- Major Findings on threats to Biodiversity:

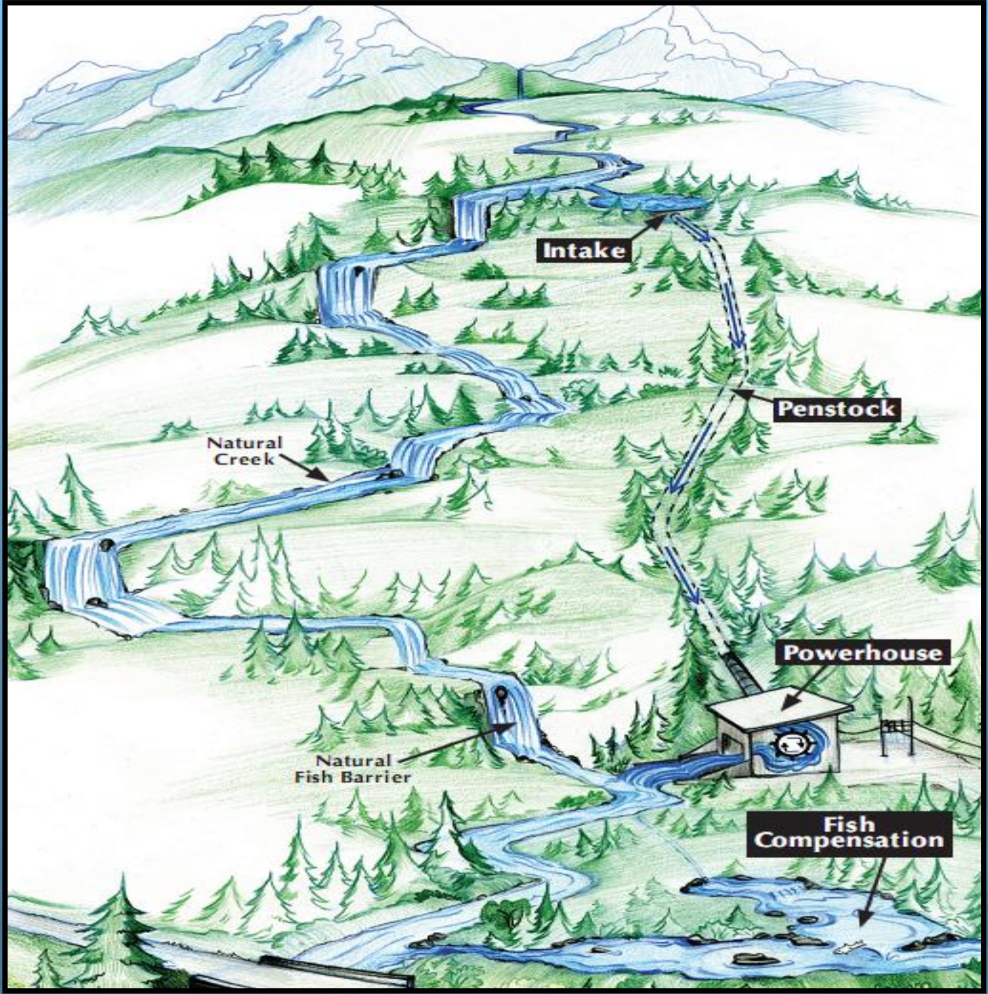
"The cumulative impacts of human activities in British Columbia are increasing and are resulting in the loss of ecosystem resilience. B.C. today" (Nature's Pulse 2008)

"Connectivity of ecosystems in British Columbia is being lost and, among other impacts, this will limit the ability of species to shift their distributions in response to climate change" (Nature's Pulse 2008)

# Why?

3. Genetic studies provide invaluable information for EIA

# Traditional View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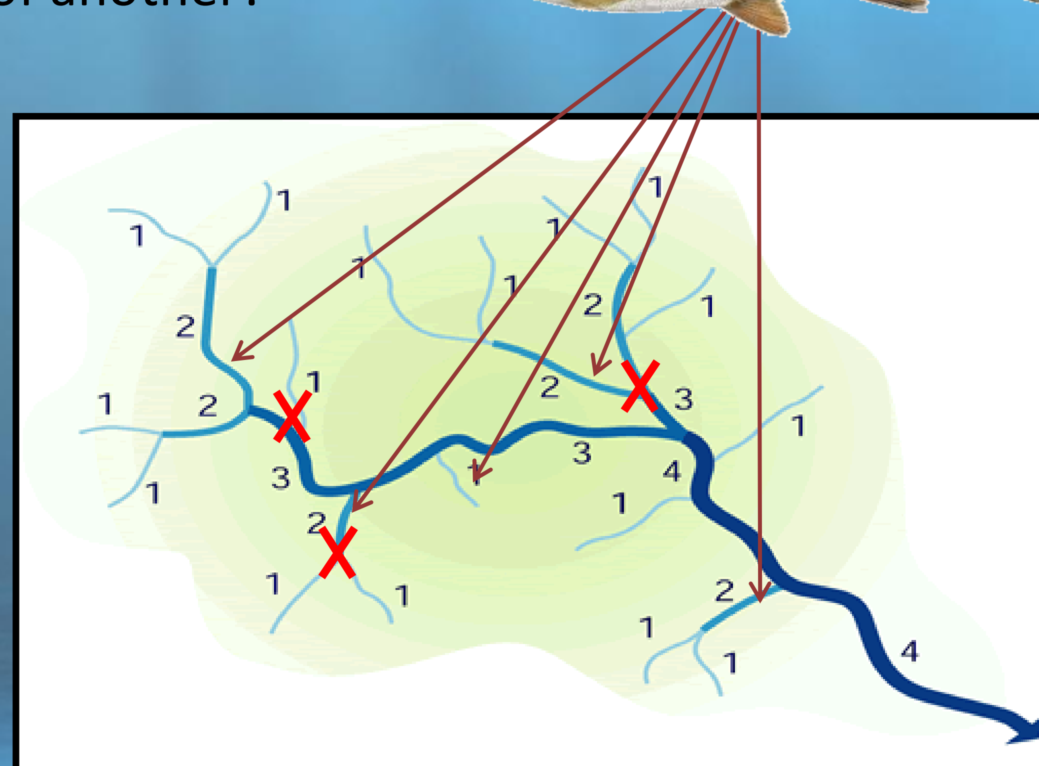
# Genetic Diversity Studies

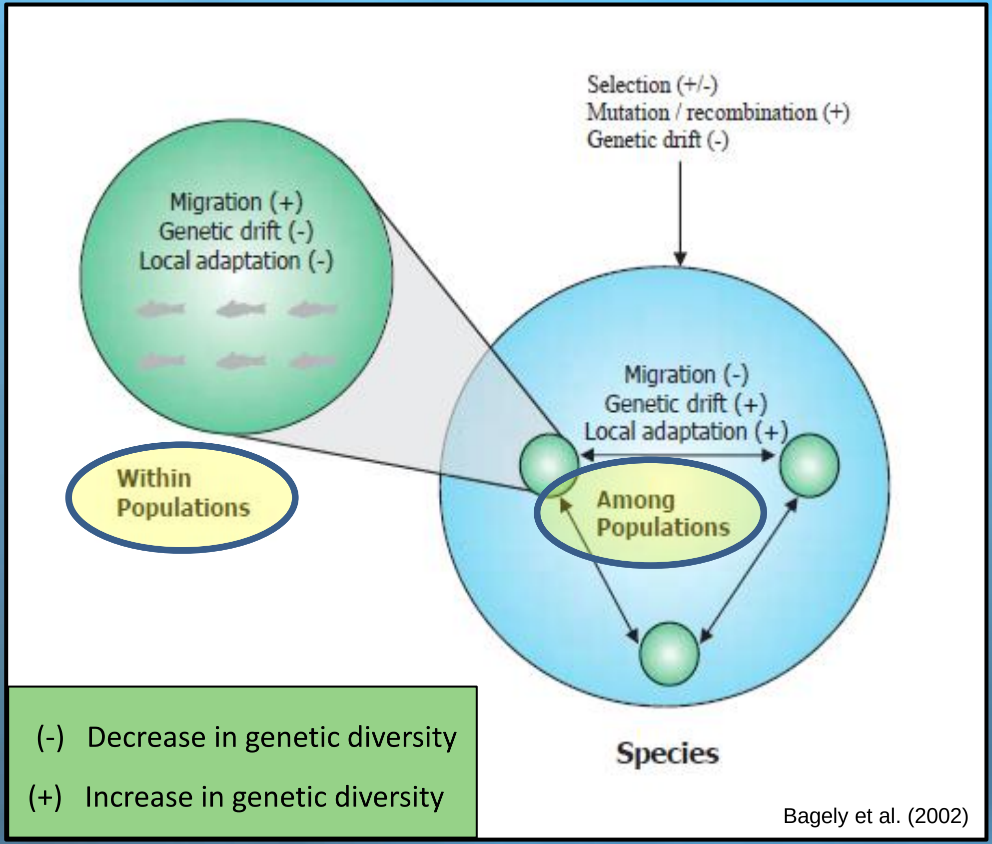
- Majority of indicators: inform little about the biological connectivity of geographic areas
- Will individuals of a species from a given region replace  extirpated populations of another?

- How much evolutionary history of a species will be lost if the habitat of one distinct population is lost/altered through development?



# Genetic Diversity Studies

- To understand long-term effects of environmental change on populations, need to:




- Fundamental Aim:
  - Ensure sufficient diversity is retained to maintain short-term fitness & long-term sustainability
  - Protect populations highly distinct or key evolutionary lineages

# Importance of Genetic Data in EIAs

- Define Population Boundaries of VCs
  - Characterize the natural genetic structure of populations within ecosystems
  - Essential population attributes diagnosed only with genetic data (connectivity, $N_e$)
- Analyze Hierarchical Structure
  - Fish : basic units of measure are populations residing in different stretches of stream/river, which are nested within watersheds, nested within regions etc.
- Measure of Cumulative Effects
  - Current genetic diversity of a population = consequence of effects over many previous generations
- $\Delta$ dynamics of populations: how will they be altered with ongoing environmental change?

# Genetic Assessment & Monitoring

## Genetic Assessment

- Snapshot of population characteristics at a single point in time

## Genetic Monitoring

- Quantifying temporal changes in population genetic metrics

# Population Parameters

## Genetic Variation

- Low variation→ reduced fitness, unable to cope with changes to environment

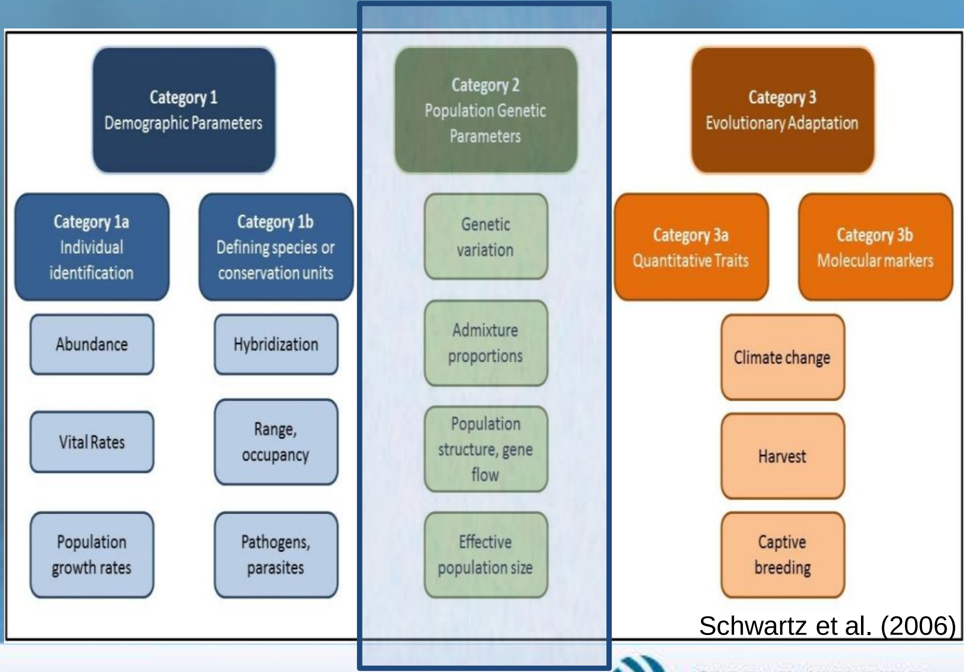
## Population Structure/Gene Flow

- ID of management units (population structure) & knowledge of gene flow b/t populations →detect changes in differentiation

## Population Mixtures

- Mixed-stock analysis

## Effective Population Size



Schwartz et al. (2006)

# Genetic Diversity in EIAs

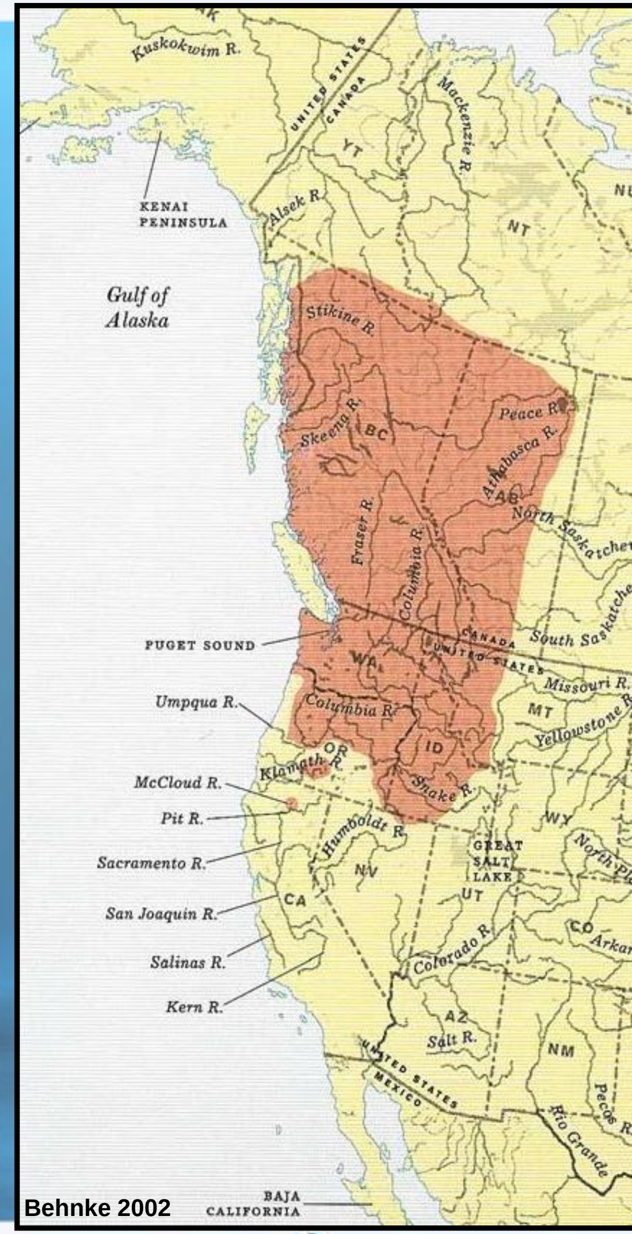
- Typical genetics studies used in EAs: Species ID
- Examples
  - Galore Creek Mine EA (2005): Bull Trout/Dolly Varden Species ID
  - Prosperity Mine EA (2011): Fish Lake & RBT
  - Morrison Copper/Gold Mine EA (2012): Rejected by Minister Terry Lake

> "Morrison Lake is an important ecosystem, in that it supports genetically unique populations of sockeye salmon, which are one of the largest stocks of non-hatchery sockeye. These stocks are important for their genetic diversity, and cannot be replaced if they are lost" (EAO 2012)

  - BC Hydro Site C – Project Description (2011): "Ongoing work will provide further information regarding species genetic diversity, aquatic productivity…"

# Genetics in an EIA in BC

- Bull Trout (*Salvelinus confluentus*)
- Priority sportfish species of conservation concern
- British Columbia
  - Blue Listed,
  - Provincial Management Plan
  - CuFX Tool
- Alberta
  - Special concern
  - Provincial Management Plan
- Canada
  - COSEWIC
- USA
  - Threatened
  - Endangered Species Act 1999
- Key Features
  - Species very sensitive to habitat alterations/loss
  - Life History Types (resident, fluvial, adfluvial)



Behnke 2002

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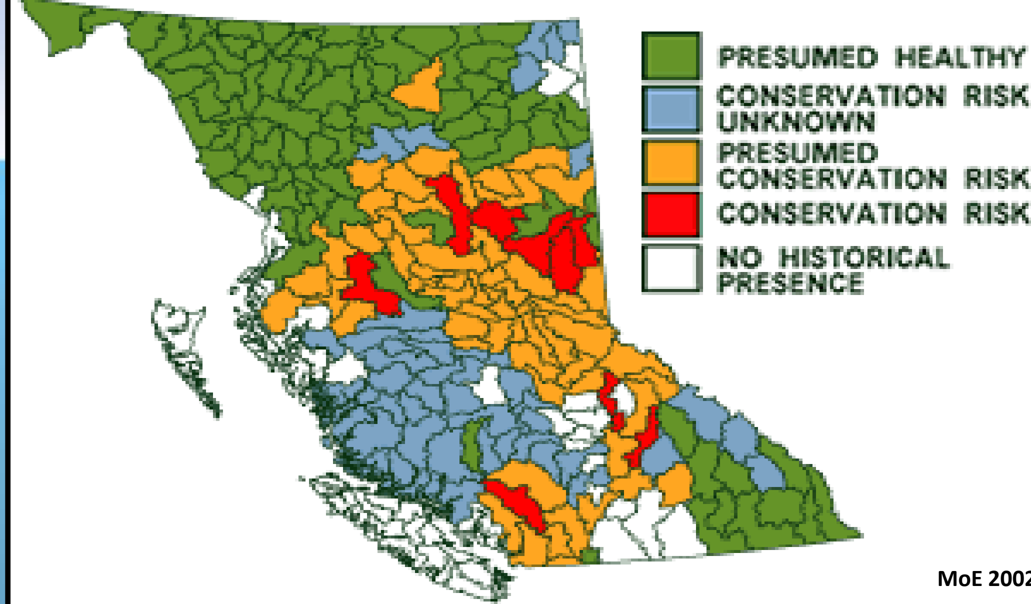
# Genetic Assessment of Upper Lillooet Bull Trout

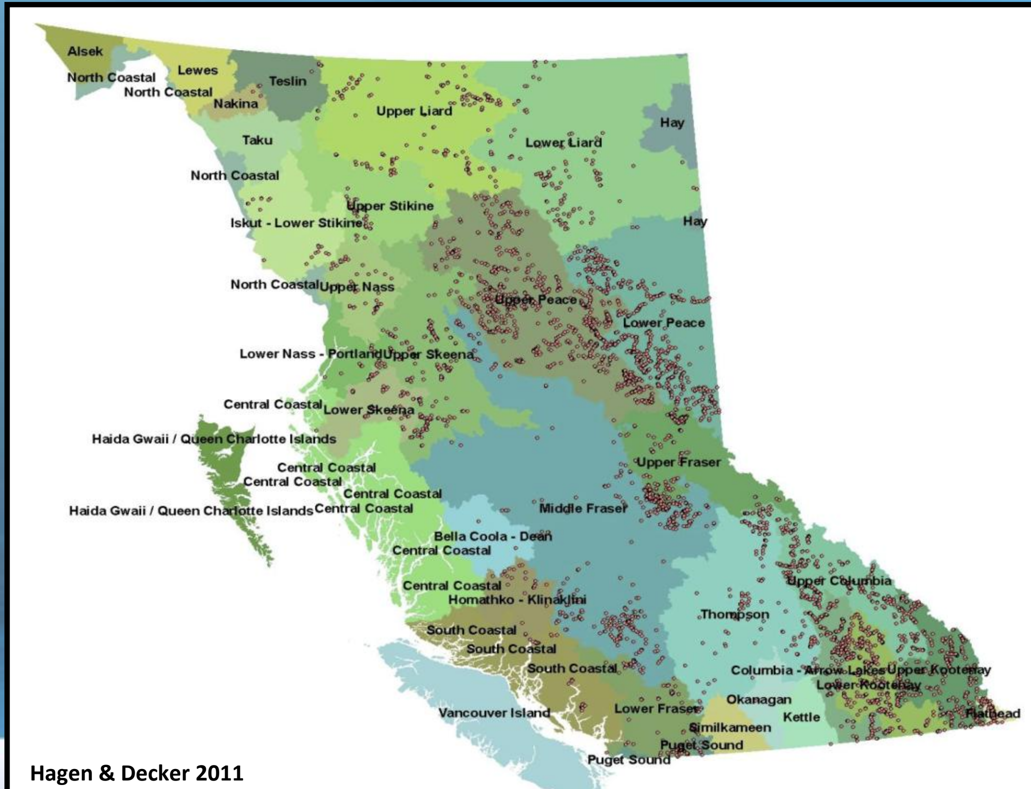
- Costello et al. (2003)
  - High levels of population subdivision at basin level
  - Above-barrier populations contain locally rare alleles
- Hagen & Decker (2011)
  - Lillooet Core Area
- U. Lillooet, Ryan, Birkenhead
  - High threat
  - Status unknown
- Need for better understanding of population demographics
  - Population structure
  - Population size
  - Level of inter-locality dispersal
  - Connectivity
- Genetic assays
  - Monitor long term persistence of populations

# Objectives

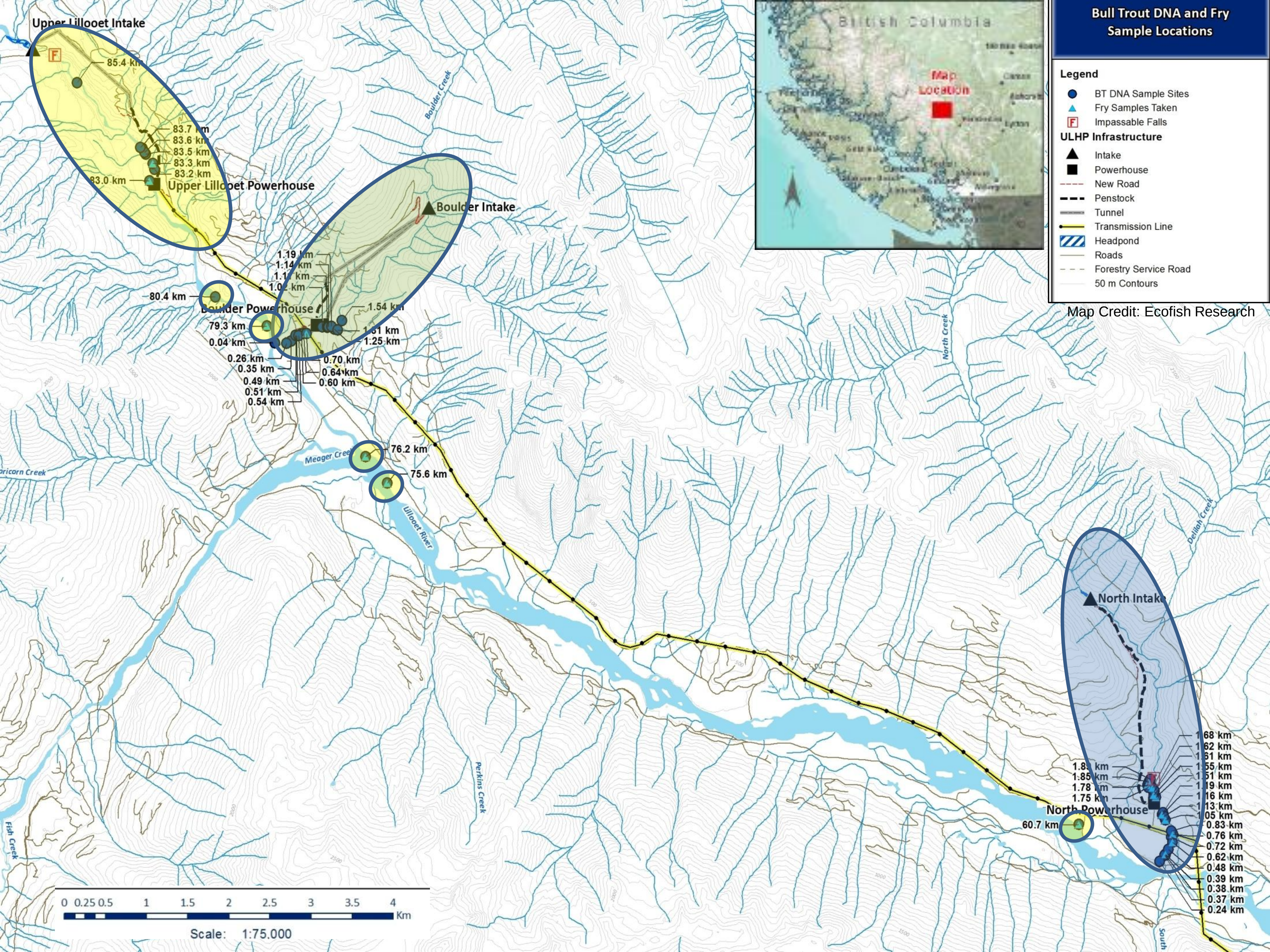
- Characterize Bull Trout collections in terms of genetic diversity
- Determine genetic relationships among sample localities & infer levels of interconnectedness amongst localities
- Integrate (1) and (2) into baseline data to assist in the assessment & monitoring of population structure over time



MoE 2002

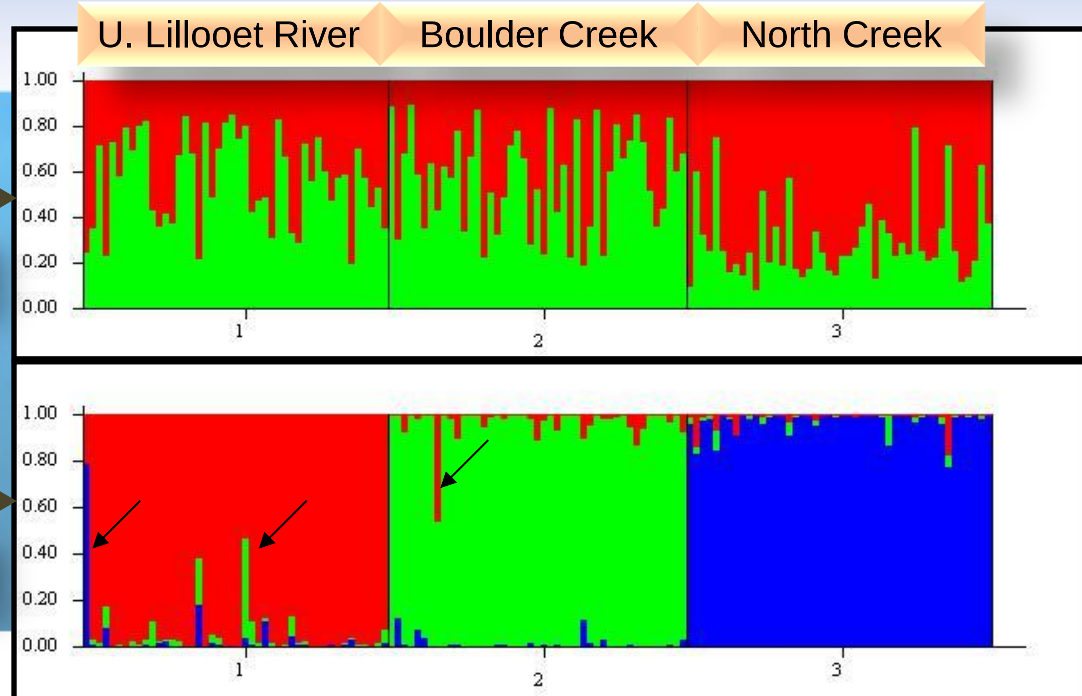


Hagen & Decker 2011



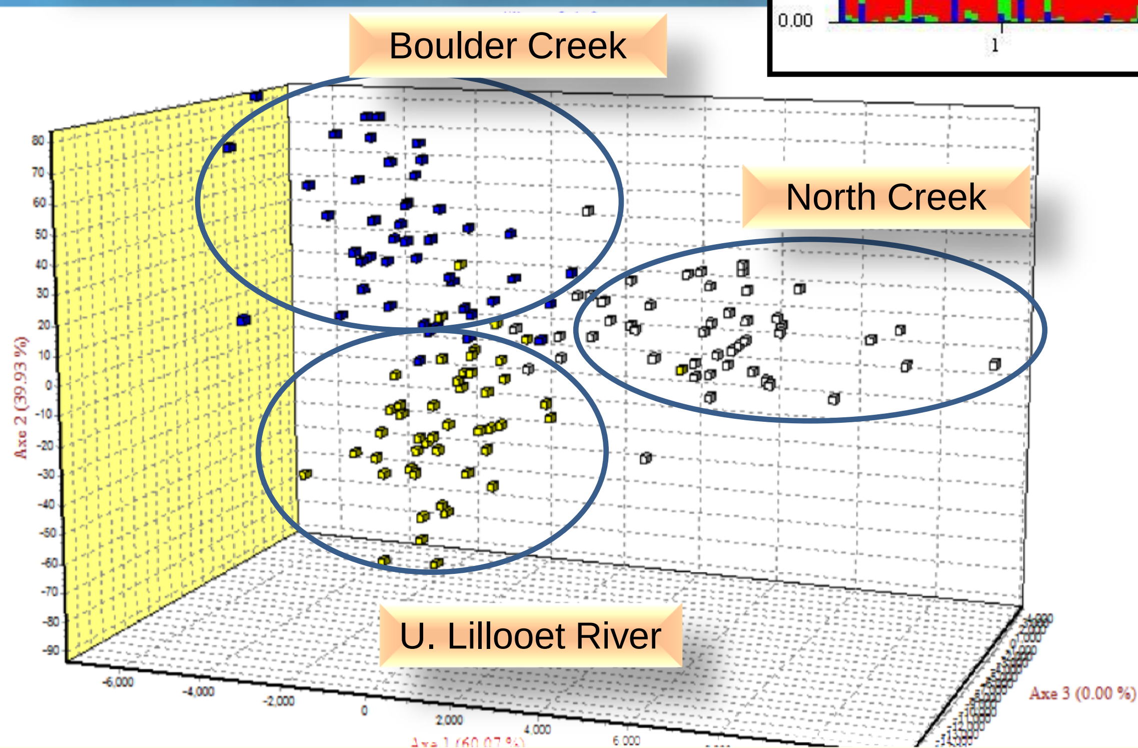
Bull Trout DNA and Fry Sample Locations
Legend
BT DNA Sample Sites
Fry Samples Taken
Impassable Falls
ULHP Infrastructure
Intake
Powerhouse
New Road
Penstock
Tunnel
Transmission Line
Headpond
Roads
Forestry Service Road
50 m Contours
Map Credit: Ecofish Research
British Columbia
Map Location
Upper Lillooet Intake
85.4 km
83.7 km
83.6 km
83.5 km
83.3 km
83.2 km
83.0 km
Upper Lillooet Powerhouse
Boulder Intake
Boulder Creek
80.4 km
Boulder Powerhouse
79.3 km
0.04 km
0.26 km
0.35 km
0.49 km
0.51 km
0.54 km
0.60 km
0.64 km
0.70 km
1.25 km
1.54 km
76.2 km
75.6 km
Meager Creek
Lillooet River
Perkins Creek
Fish Creek
North Creek
Delilah Creek
North Intake
North Powerhouse
60.7 km
1.85 km
1.78 km
1.75 km
0.83 km
0.76 km
0.72 km
0.62 km
0.48 km
0.39 km
0.38 km
0.37 km
0.24 km
0 0.25 0.5 1 1.5 2 2.5 3 3.5 4 Km
Scale: 1:75.000

# Results




No knowledge of sample localities

Knowledge of sample localities

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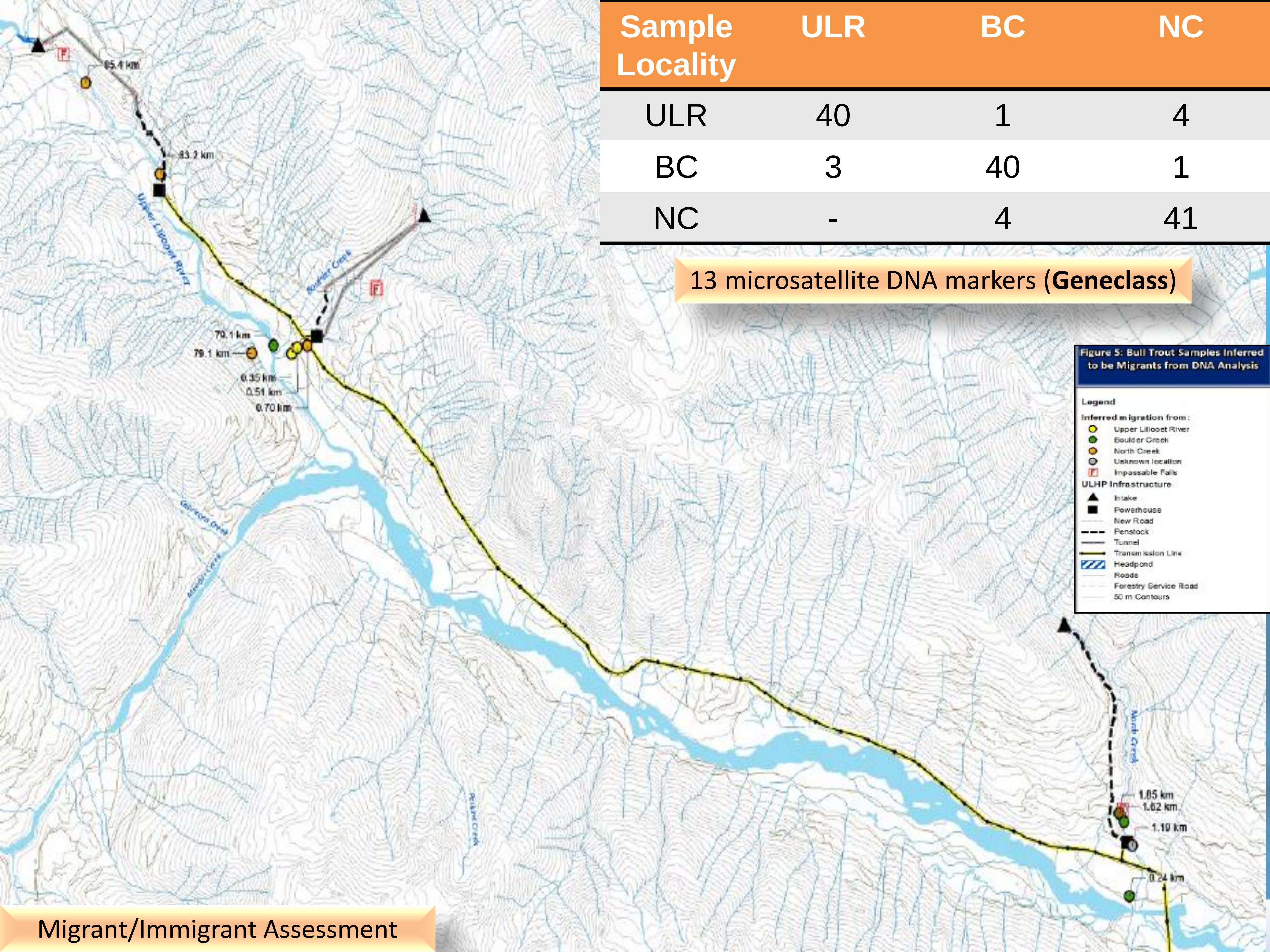
| Sample Locality | ULR | BC | NC |
|---|---|---|---|
| ULR | 40 | 1 | 4 |
| BC | 3 | 40 | 1 |
| NC | - | 4 | 41 |

13 microsatellite DNA markers (**Geneclass**)




Migrant/Immigrant Assessment

# Effective Population Size

- $N_B$: effective number of breeders: related statistic to $N_e$.

| | Upper Lillooet River | Boulder Creek | North Creek |
|---|---|---|---|
| LD | 165 (106 – 348) | 46 (38 - 56) | 79 (59 - 112) |
| SA | 58 (39 – 90) | 60 (38 - 95) | 58 (37 - 91) |

Notes: Confidence limits (95%) derived by jackknifing over loci are provided in parenthesis.

- Low $N_B$: vulnerable to inbreeding (if gene flow low)

- Genetics in Population Viability Analysis (PVA)

  "50/500" Rule

- Genetic monitoring

# Value of Genetic Diversity Data in EA

- Essential tool for filling critical data gaps on Projects that are at a watershed-scale (e.g. mining, hydroelectric)
- Population-level measure (of VC) rather than individual-level measure
- Measure of cumulative impact on population VCs
- May identify problems within species before species assemblage indicators become significant
- Well-defined relationships between genetic data and the size/connectivity of populations
- Highly complementary to species assemblage and landscape/ecosystem data typically collected for impact assessments
- Important indicator of population trends through temporal monitoring
- Data Value vs. Cost

# Conclusion

- Guidelines are not “Status Quo”
- Guidelines are living documents – Need continuous improvement
- Need to be open to enhancing guidelines
- Knowledge to ‘think outside the box’ with respect to other methodologies
- Consult experts
- Use of other habitat models, determining accuracy and precision of models used, and application of genetic diversity studies are just a few examples

# Questions?