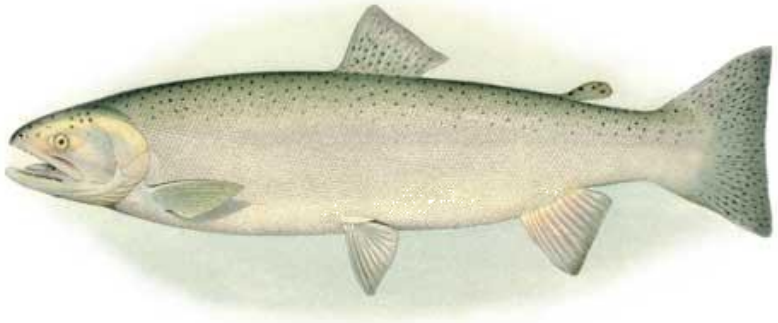
# Proposed viability criteria for Puget Sound steelhead



STEELHEAD TROUT


The Puget Sound Steelhead Technical Recovery Team

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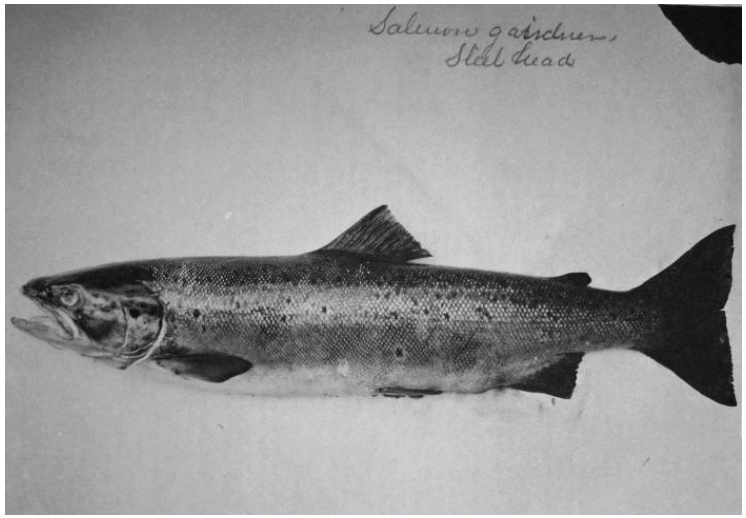
Puget Sound Steelhead Recovery Science Workshop

Seattle, WA

30 May 2013

†Deceased

# Acknowledgments

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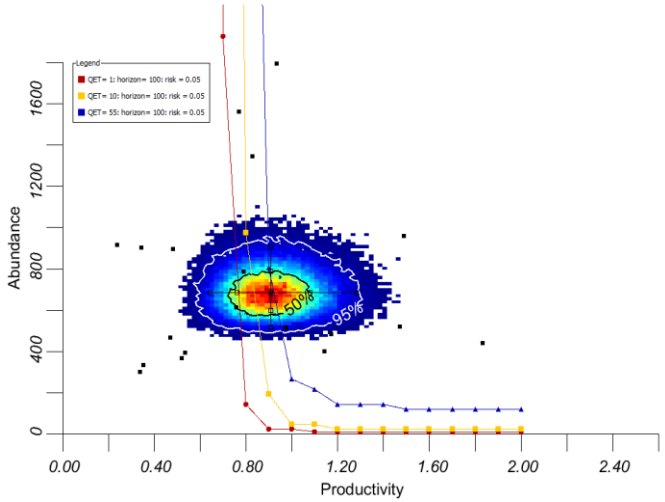
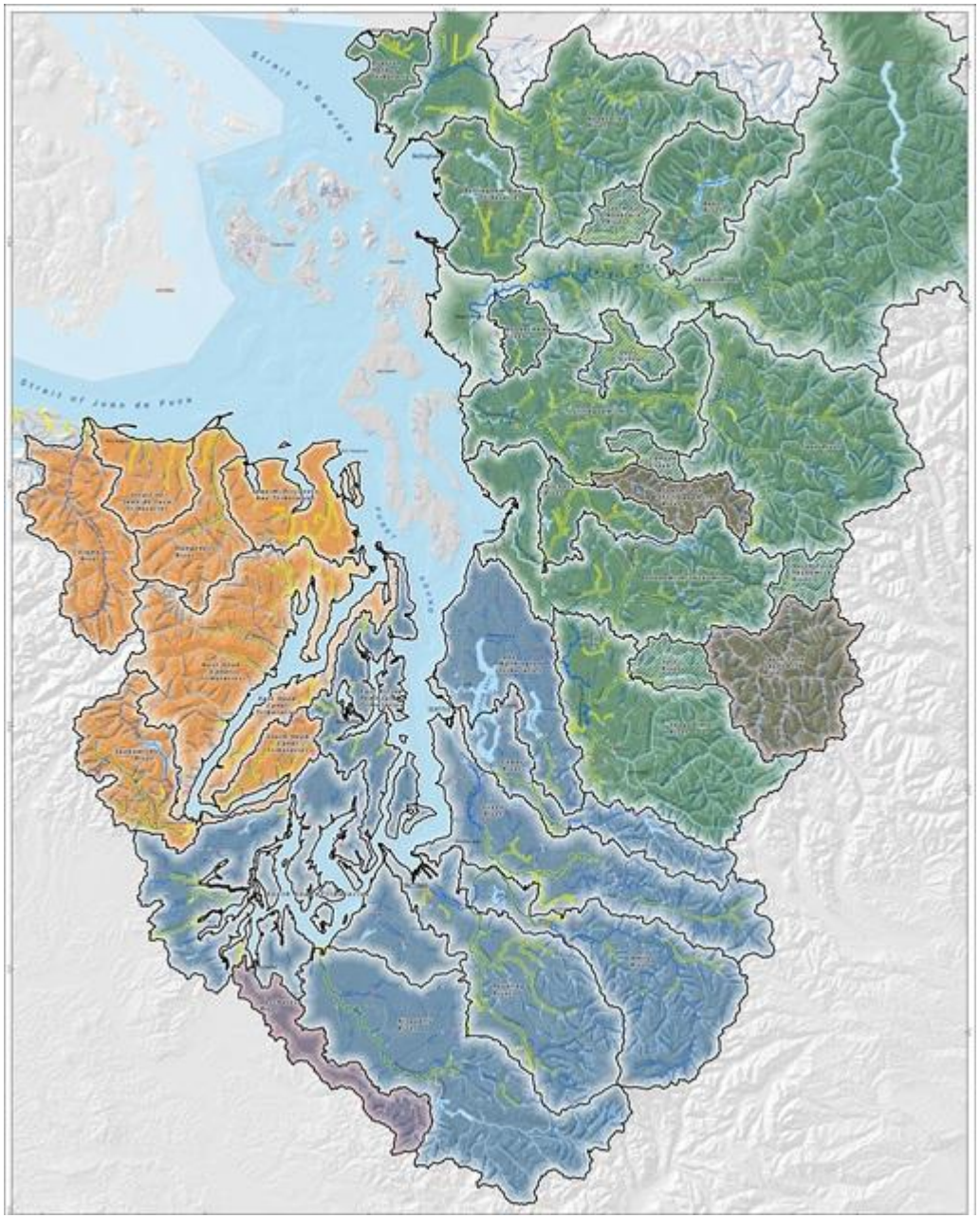


# Outline

- ✓ Describe status of Puget Sound steelhead
- ✓ Introduce a framework to assess viability
- ✓ Summarize key findings
- ✓ Outline proposed criteria
- ✓ *Objectives:*
  - *Stimulate recovery process*
  - *Promote data collection and M & E*



# Puget Sound steelhead status

- ✓ 2007 BRT review → T listing under ESA
- ✓ Declines widespread despite ↓ harvest
- ✓ Declines acute in S and W parts of DPS
- ✓ Low productivity; poor marine survival; hatchery production; ↓ diversity

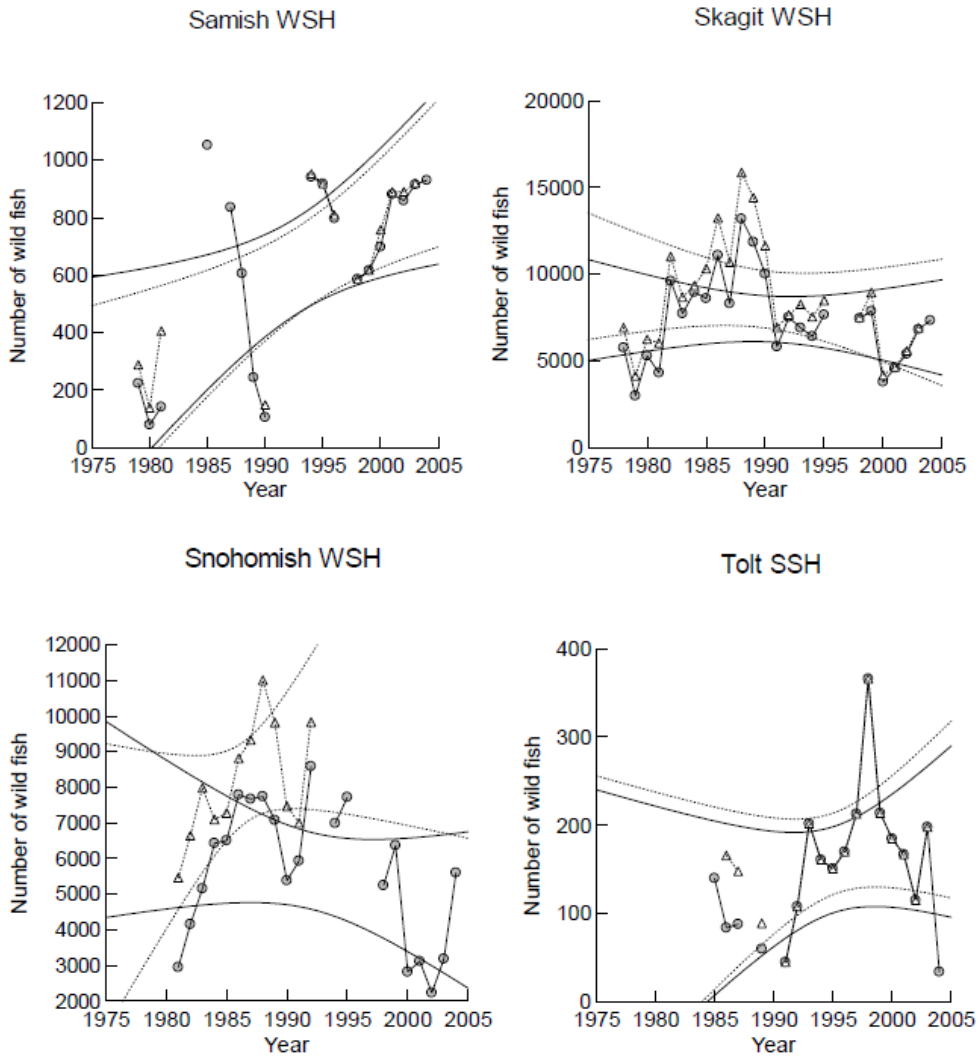
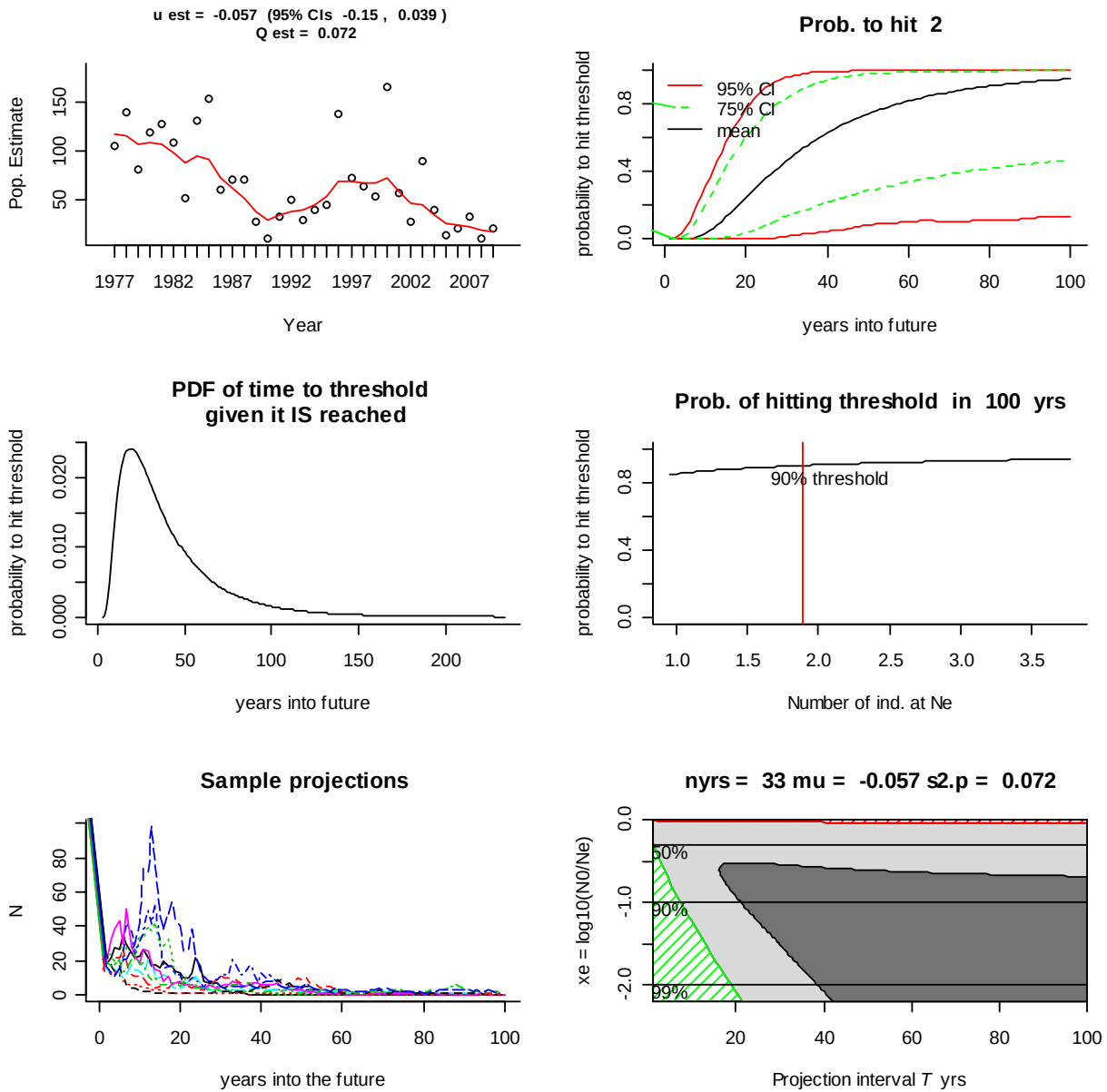



Figure 6. Trends in natural escapement and run size for steelhead in the northern Puget Sound region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–), run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish. Note that the Tolt population is a summer run population; all others are winter run populations. SSH = summer run steelhead, WSH = winter run steelhead.

# Puget Sound steelhead status

- ✓ PVAs for most populations indicate:
  - ✓ ↓ abundance
  - ✓ Uncertainty in projecting trends
  - ✓ Generally, ↓s NGT 50% to 99% within 10-30 years

Snow Creek



# RoE patterns for Puget Sound steelhead

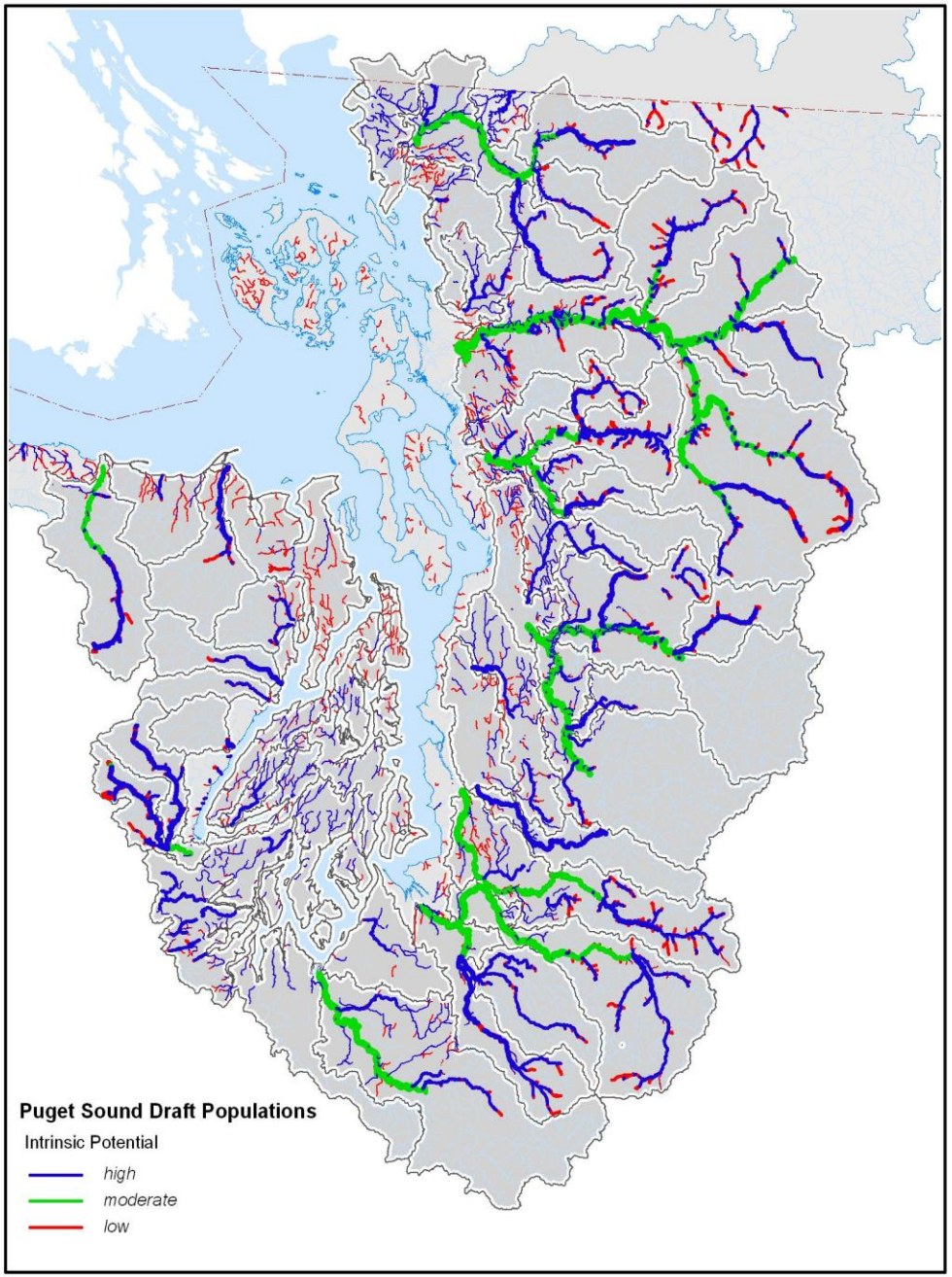
- Steelhead are at 5-10% of historical abundance and exhibit ↓ productivity throughout the DPS
- Many populations in the central and southern Sound, and in Hood Canal and SJF, are small and are continuing to decline
- Status of many populations, including nearly all summer-run populations, is uncertain
- Natural productivities are generally declining

# Approach to steelhead viability

- Identification of historical populations
  - What is the historical distribution and capacity for steelhead?
  - What contributes to persistence & sustainability?
- Viability assessment: based on VSP
  - A and P provide the demographic foundation
  - D and SS provide ecological / evolutionary context
- Diversity and spatial structure are also essential
  - D represents the ability to respond to future change
  - SS helps to guard against catastrophic risk and buffer local environmental effects

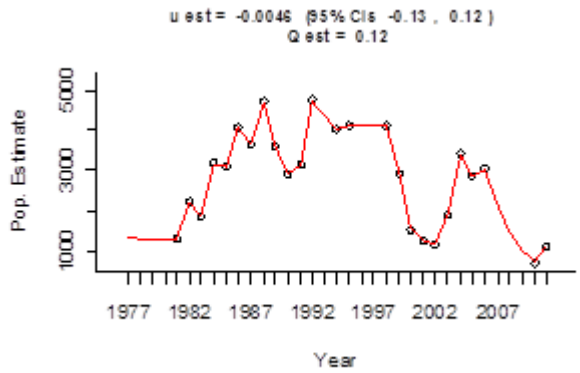
# Proposed steelhead populations

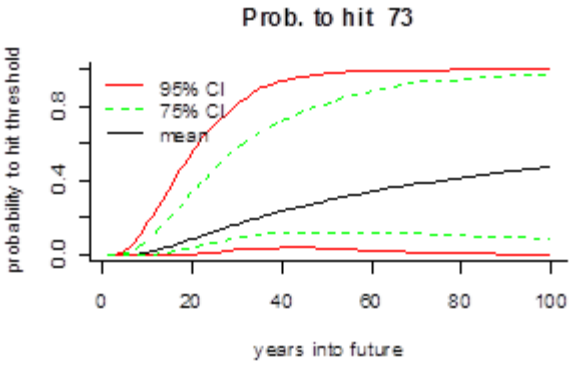
- 32 DIPs > 3 MPGs > DPS
- Highest potential for steelhead production in N & E Puget Sound (16 DIPs)
- Many small populations in S Puget Sound and the Kitsap Peninsula (8 DIPs)
- Potential production in Hood Canal / SJF highest in the larger rivers (8 DIPs)



# The Technical Recovery Team's approach

- DIPs: abundance and productivity
  - Apply Population Viability Analysis to DIPs where possible
  - Rely on MPG-wide average statistics for DIPs w/o quantitative information
  - Consider factors important for PS steelhead, even with little information
  - Use a decision support system (Bayes net) to integrate these data



# The Technical Recovery Team's approach (cont'd)

- DIPs: diversity and spatial distribution
- Incorporate factors important for PS steelhead (e.g., reach occupancy, hatchery fish production, age structure)
  - Consider additional factors (e.g., smolt production from residents, spawn timing distributions, iteroparity)
- MPGs and the DPS
  - Apply state-space analyses
  - Use a hierarchical DSS to relate information at all three levels
  - Attempt to account for uncertainty

# Steelhead intrinsic potential

**Puget Sound**

**Stream Habitat Rating (below natural barriers)**

| Stream gradient | Stream width (bankfull): 0-3 m | 3-20 m | > 20 m |
|---|---|---|---|
| 0.0 – 0.25% | High | Moderate | Low |
| 0.25 – 4.0% | Moderate | High | Moderate |
| > 4.0% | Low | Low | Low |

**Simple**

**Interior Columbia**

(for comparison)

**Intrinsic Potential (Interior Columbia River parameters)**

**Unconfined Stream Habitat Rating (valley width > 4x bank full width)**

| Stream gradient | Stream width: 0 - 25 m | 25 - 50 m | > 50 m |
|---|---|---|---|
| 0.0% - 0.5% | moderate | moderate | low |
| 0.5% - 1.5% | high | moderate | low |
| 1.5% - 4.0% | high | moderate | low |
| 4.0% - 7.0% | low | very low / none | very low / none |
| 7.0% - 15.0% | very low / none | very low / none | very low / none |
| > 15.0% | very low / none | very low / none | very low / none |

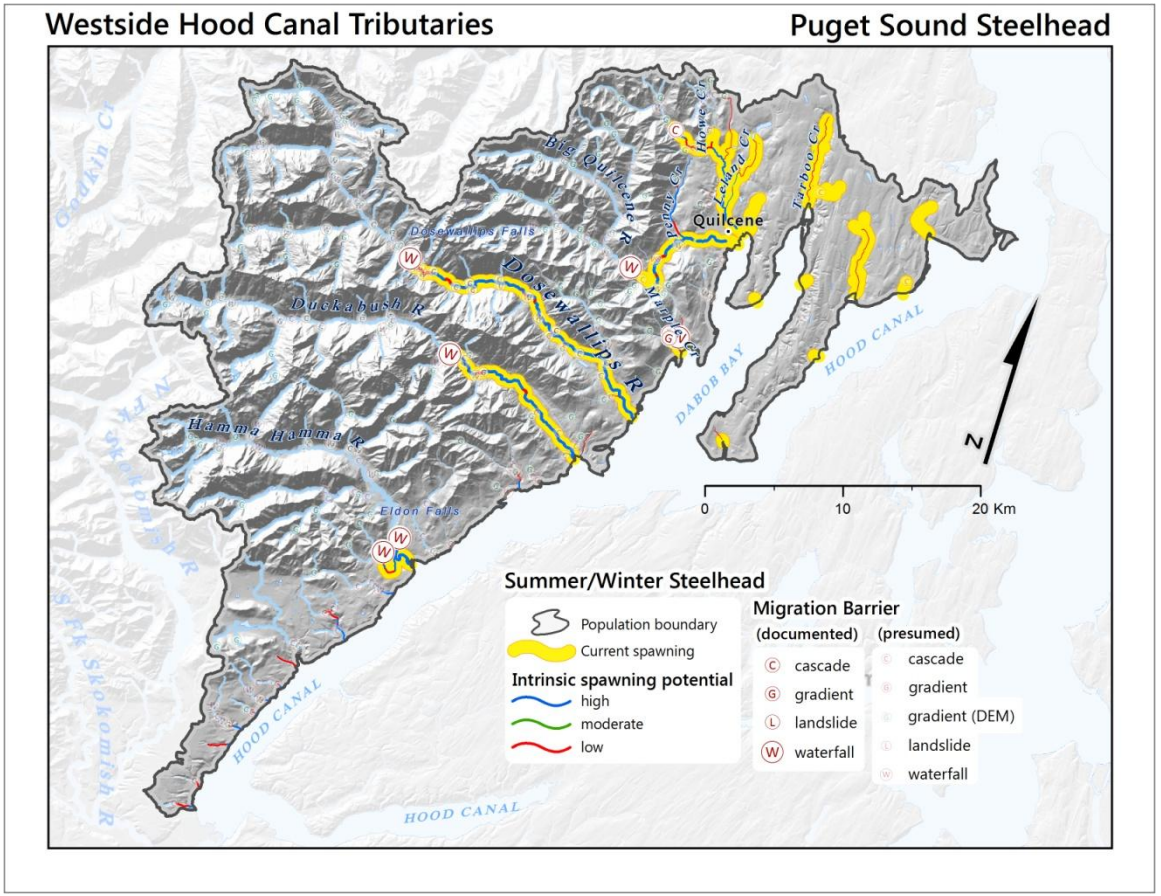
**Confined Stream Habitat Rating (valley width < 4x bank full width)**

| Stream gradient | Stream width: 0 - 25 m | 25 - 50 m | > 50 m |
|---|---|---|---|
| 0.0% - 0.5% | very low / none | low | very low / none |
| 0.5% - 1.5% | low | low | very low / none |
| 1.5% - 4.0% | low | low | very low / none |
| 4.0% - 7.0% | very low / none | very low / none | very low / none |
| 7.0% - 15.0% | very low / none | very low / none | very low / none |
| > 15.0% | very low / none | very low / none | very low / none |

**More complex**

# Intrinsic potential: West Hood Canal

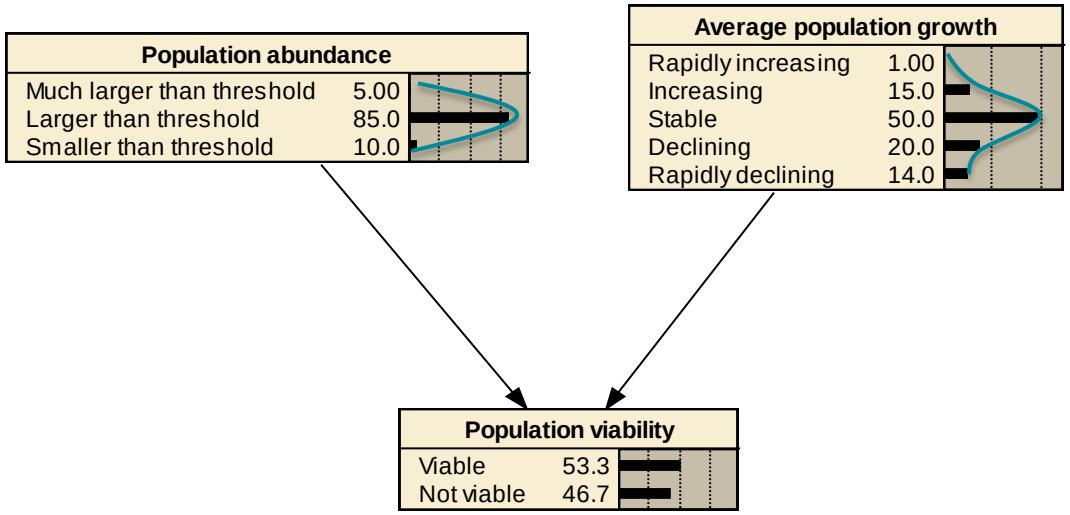
- NHD 100K (USGS) data
- Steelhead in west Hood Canal drainages occupy most suitable reaches
- Higher gradient reaches tend to have higher IP



# Why a Bayes net?

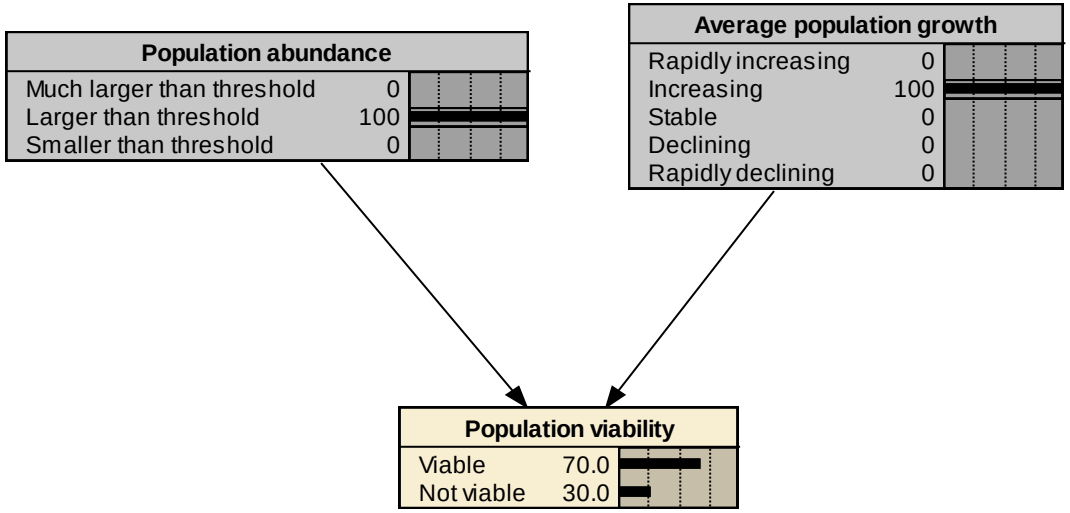
- A Bayes net explicitly incorporates uncertainty
- Almost any relevant variable can be considered
- A Bayes net is a tool that
  - ✓ represents a probability distribution underlying a set of variables
  - ✓ portrays relationships graphically according to the distribution
  - ✓ should incorporate all variables relevant to the data
- Can employ discrete categories or functions
- Provides a transparent, systematic way to assist decision-making or evaluate alternatives

# A simple Bayes net




The probability that this population is viable, *given the prior distributions of abundance and productivity*, is ca. 53%

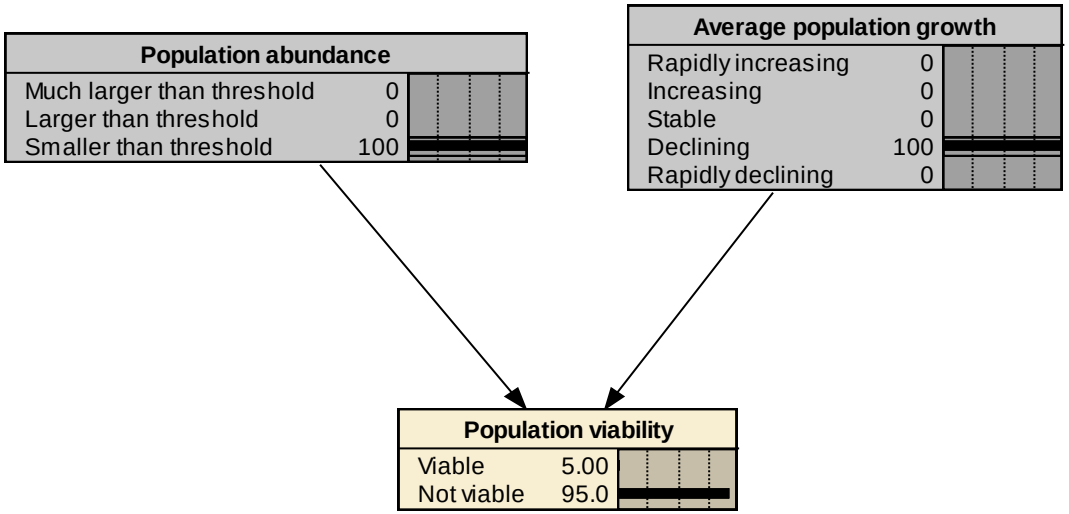
# A simple Bayes net




The probability that this population is viable, *given the prior distributions of abundance and productivity*, is ca. 53%

↑ certainty about abundance and productivity changes the probability of viability

# A simple Bayes net

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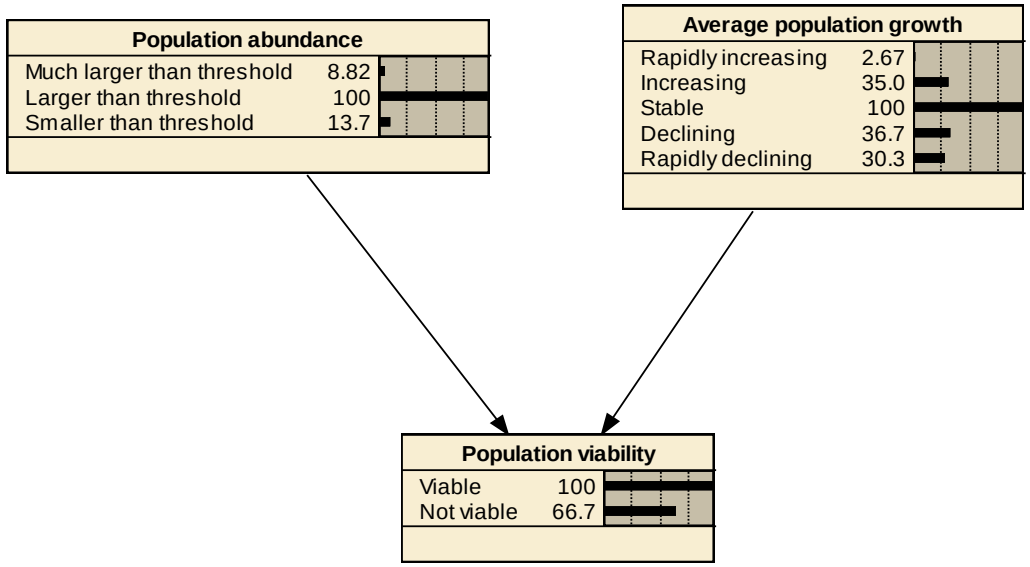
# A simple Bayes net




The probability that this population is viable, *given the prior distributions of abundance and productivity*, is ca. 53%

↑ certainty about abundance and productivity changes the probability of viability

Most Probable Explanation: gives most likely state with the degree of uncertainty

# Conditional probability table

| Population abundance | Average population growth | Viable | Not viable |
|---|---|---|---|
| Much larger than threshold | Rapidly increasing | 0.99 | 0.01 |
| Much larger than threshold | Increasing | 0.95 | 0.05 |
| Much larger than threshold | Stable | 0.90 | 0.10 |
| Much larger than threshold | Declining | 0.75 | 0.25 |
| Much larger than threshold | Rapidly declining | 0.50 | 0.50 |
| Larger than threshold | Rapidly increasing | 0.80 | 0.20 |
| Larger than threshold | Increasing | 0.70 | 0.30 |
| Larger than threshold | Stable | 0.60 | 0.40 |
| Larger than threshold | Declining | 0.45 | 0.55 |
| Larger than threshold | Rapidly declining | 0.35 | 0.65 |
| Smaller than threshold | Rapidly increasing | 0.50 | 0.50 |
| Smaller than threshold | Increasing | 0.40 | 0.60 |
| Smaller than threshold | Stable | 0.30 | 0.70 |
| Smaller than threshold | Declining | 0.05 | 0.95 |
| Smaller than threshold | Rapidly declining | 0.01 | 0.99 |

High

Low

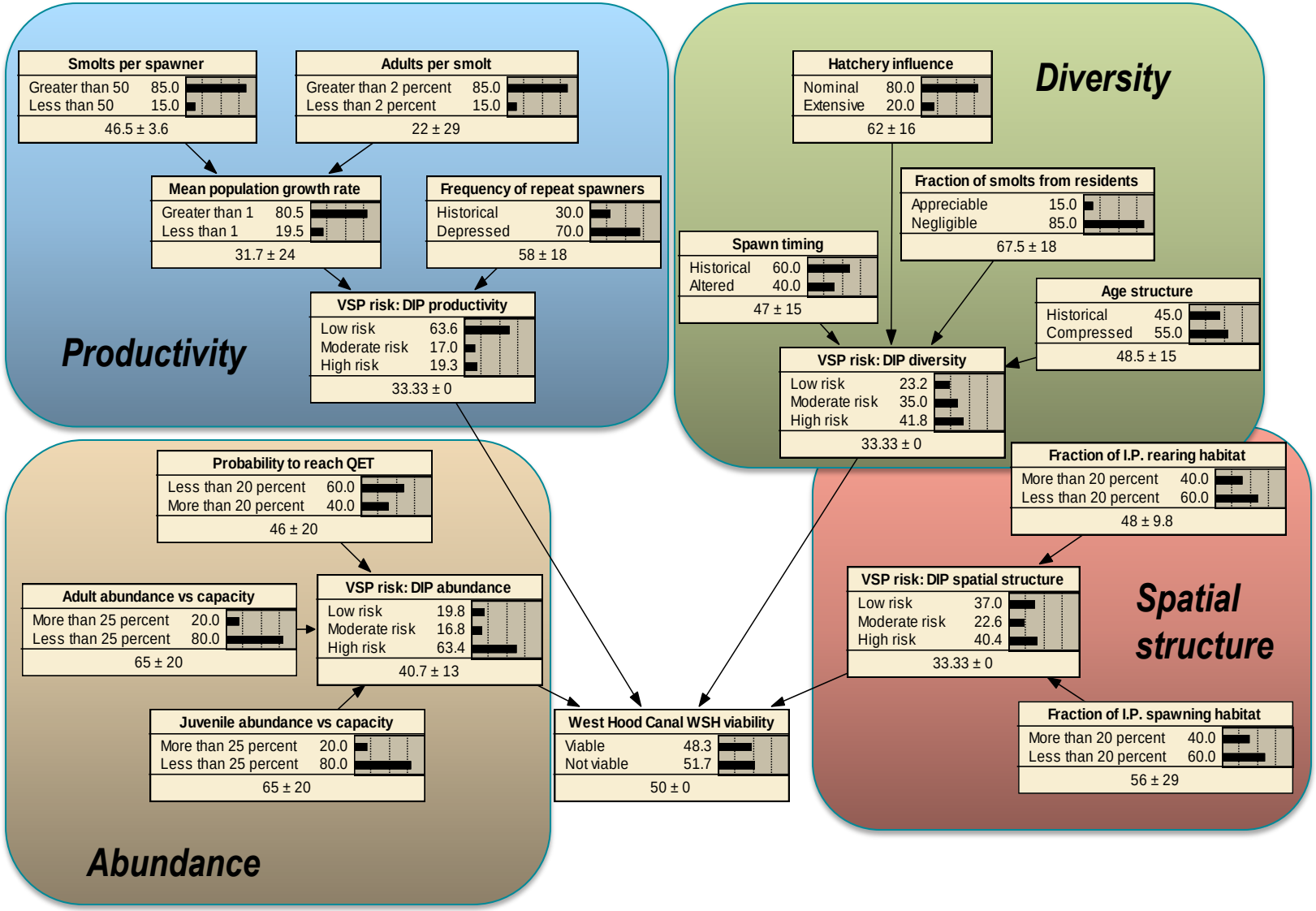
This is the CPT underlying the viability node in the simple BN

It governs how the probability of viability varies with each combination of the root factors

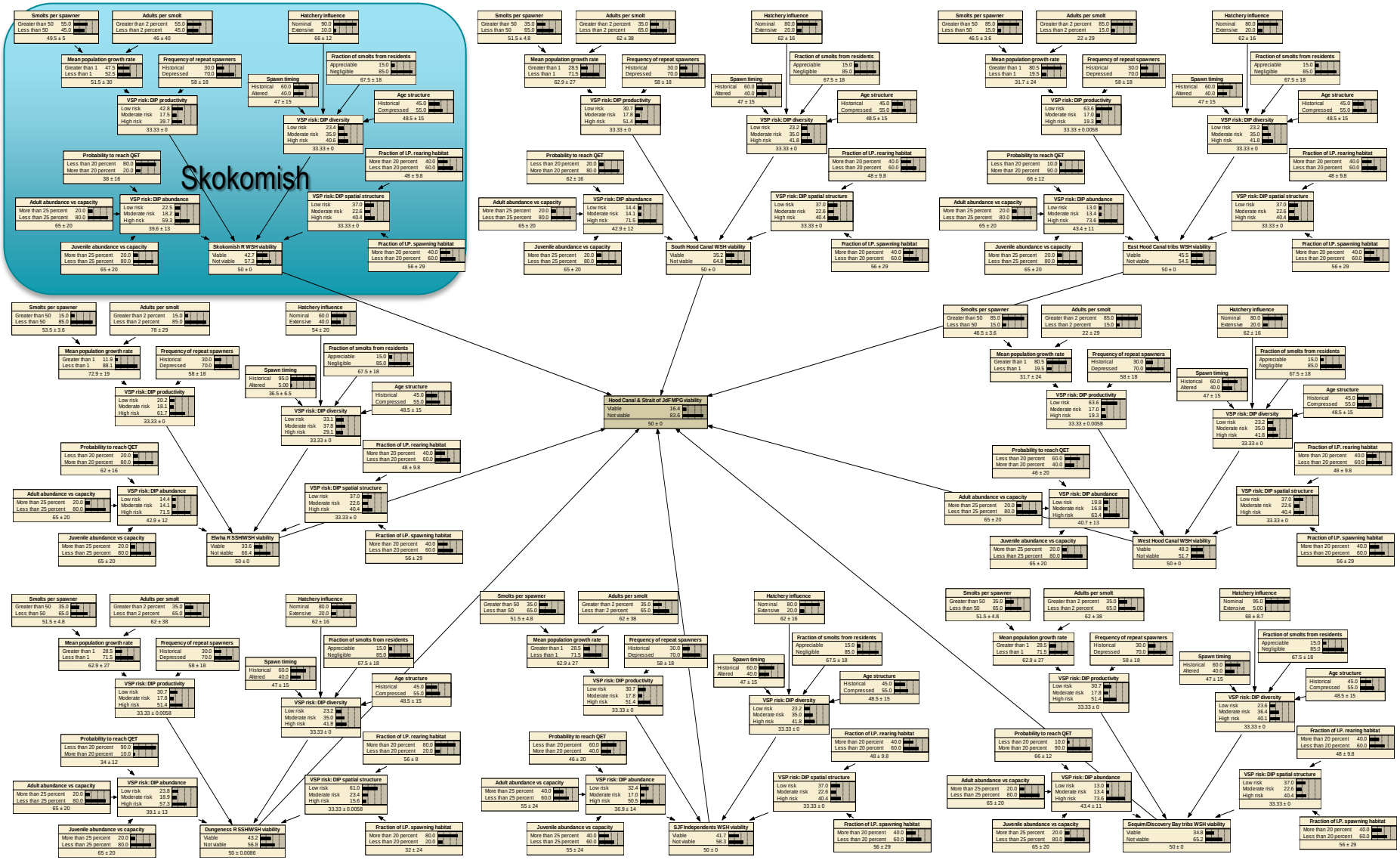
# Viability model inputs

- Adult abundance relative to IP estimates
- Risk of reaching a quasi-extinction threshold
- Population growth estimated from demographic models
- Spawn timing and age structure distributions
- Potential influence of hatchery fish
- Occupancy of suitable habitat (gradient, stream size, influence of snowpack)
- “Place holders”: juvenile abundance and spatial structure, iteroparity, smolt production from residents

# Bayes net for DIP viability

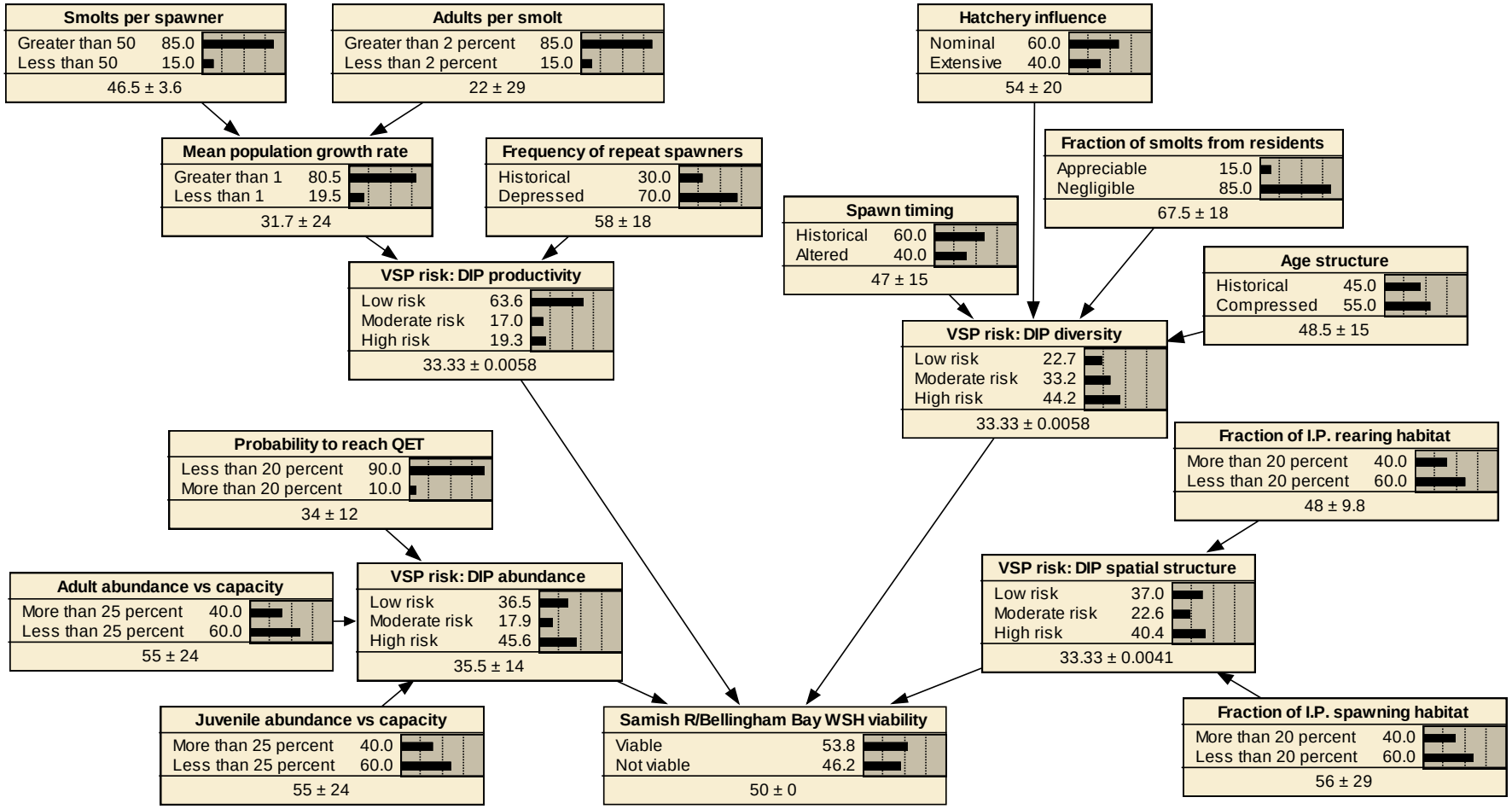


# Bayes net for MPG viability




NOAA FISHERIES

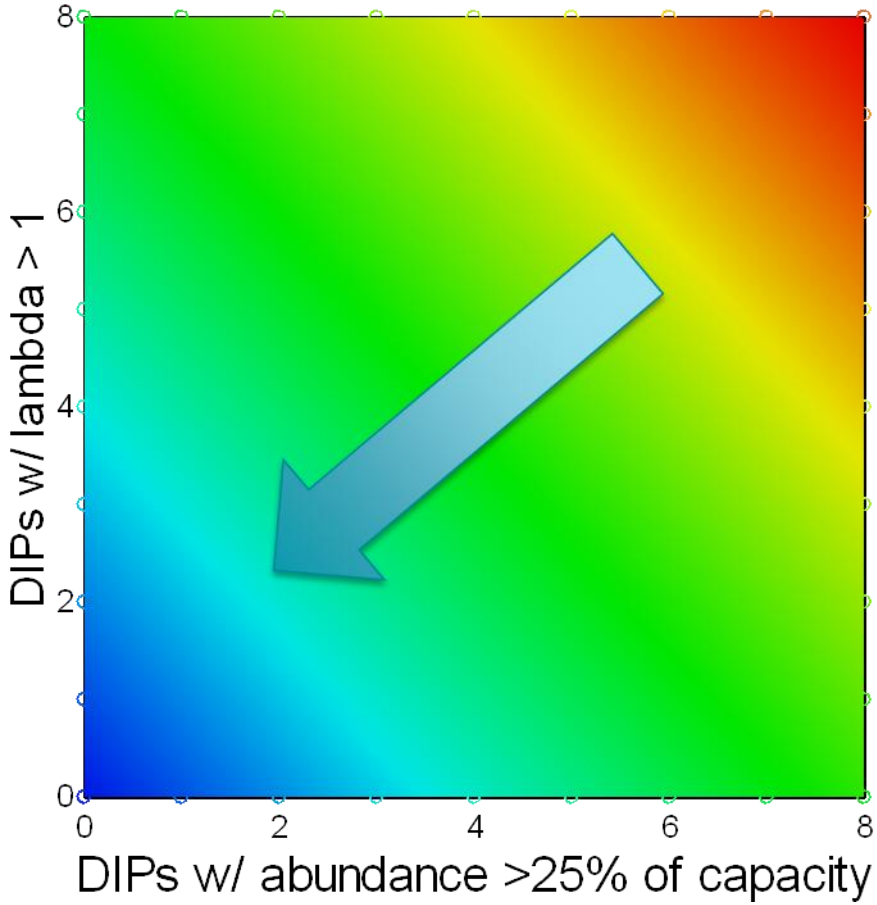
# Example: Samish R/Bellingham Bay WSH



# Example: Samish R/Bellingham Bay WSH

- Probability of viability = 53.8%
- Sensitivity analysis:
  - Abundance (entropy reduction = 6.7%; adult abundance = 2.1%)
  - Productivity (entropy reduction = 5.2%; $\lambda$ = 2.0%)
  - Diversity (entropy reduction = 1.3%)
  - Spatial structure (entropy reduction = 1.6%)
- Mutual information for most variables < 5%
- Error rate (confusion matrix) = 46.2%
- Most Probable Explanation = Not viable
  - Probability the DIP could be viable = 69.2%

# Influence of DIP viability on MPG viability



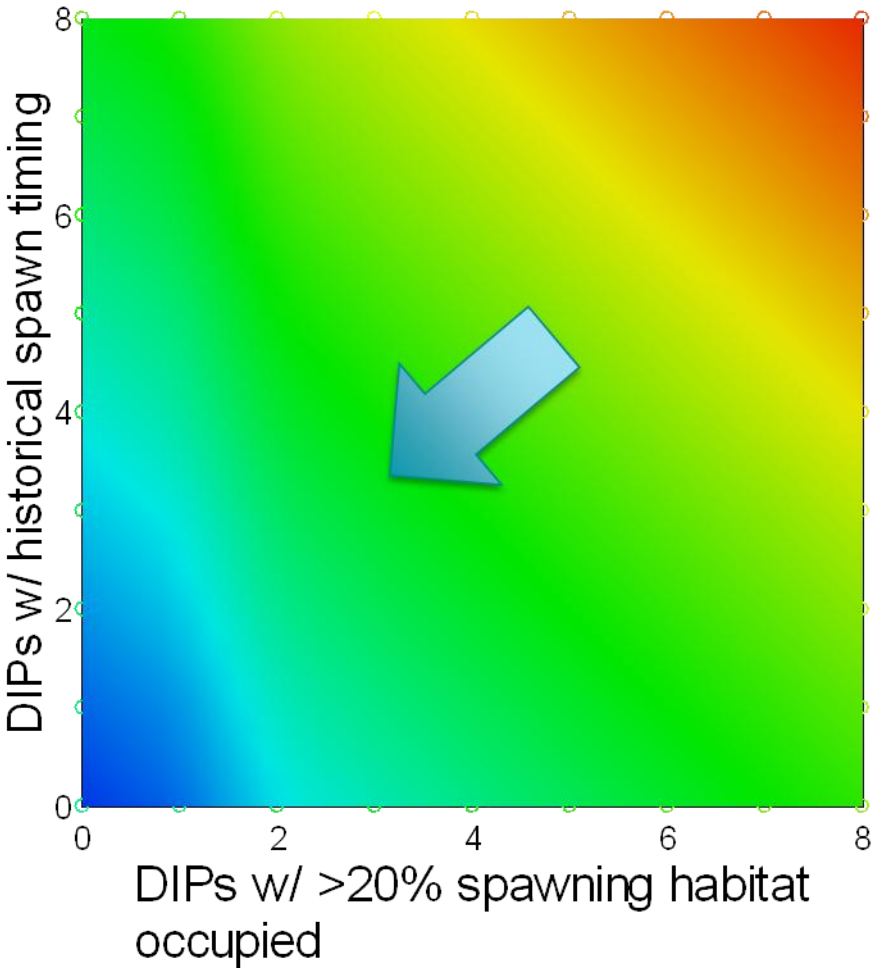

Abundance and productivity

(diversity and spatial structure at maximum)

P(MPG is viable, %)

- 100
- 80
- 60
- 40
- 20

# Influence of DIP viability on MPG viability



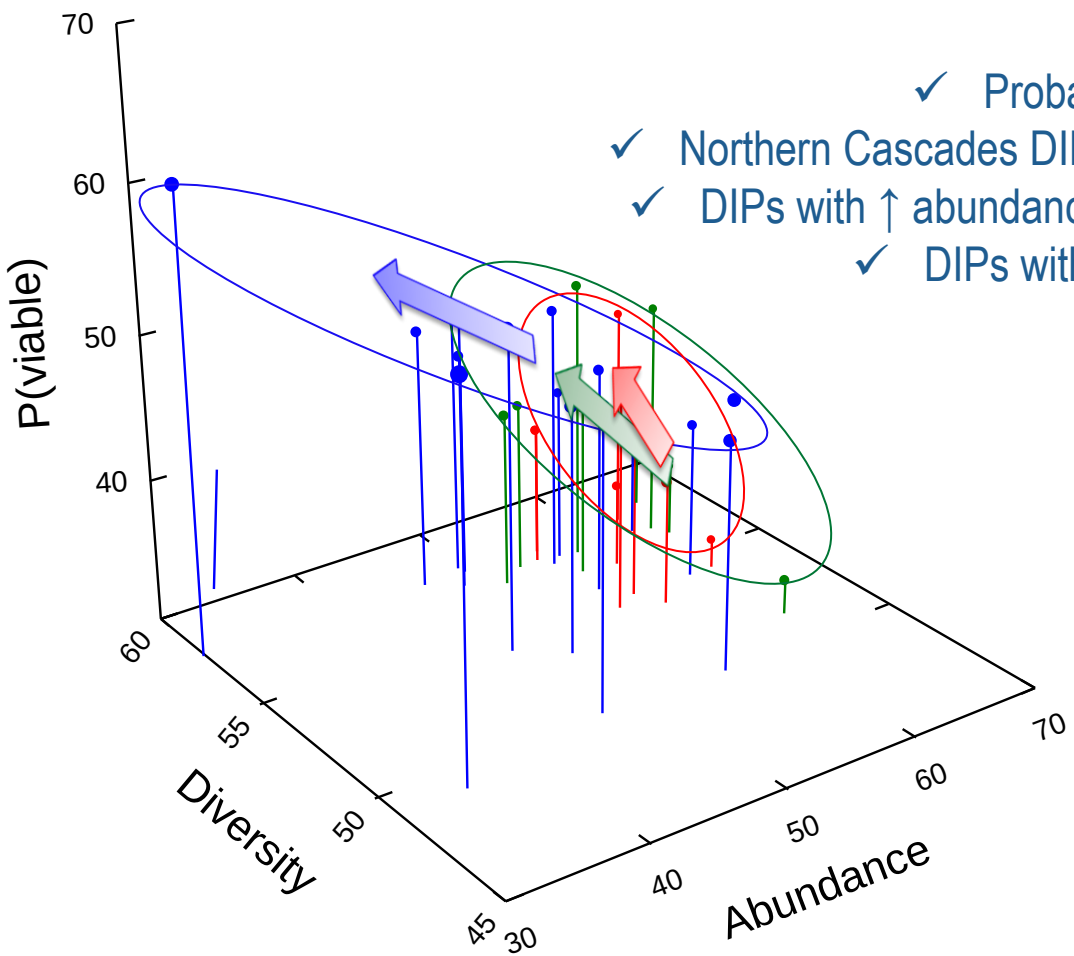

Diversity and spatial structure
(abundance and productivity at maximum)

***At least 40% of DIPs must be viable***

P(MPG is viable,%)

- 99
- 97
- 95
- 93
- 91
- 89

# VSP influence on DIP viability




Abundance and diversity:

- ✓ Probabilities of viability are low (~30-60%)
- ✓ Northern Cascades DIPs have ↑ viabilities (and ↑ variation)
- ✓ DIPs with ↑ abundance don't necessarily have ↑ viabilities
- ✓ DIPs with ↑ diversity tend to have ↑ viabilities

MPG

- Central & South Sound
- Hood Canal & SJF
- Northern Cascades

# Patterns of DIP viability

## Declining trends in abundance and productivity

Most DIPs score low for all VSP criteria

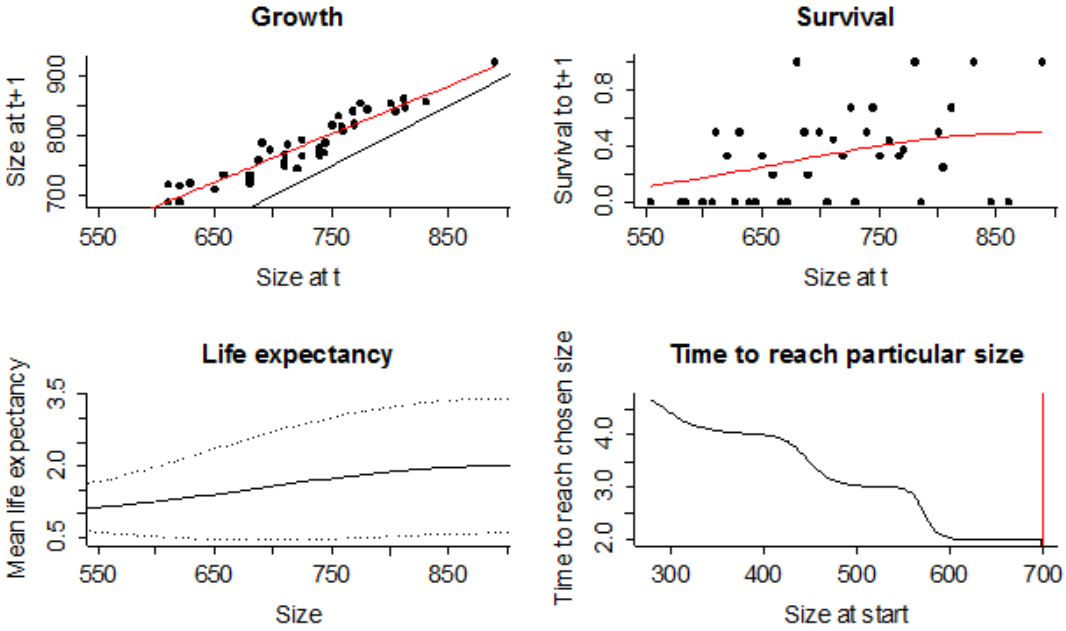
Nearly all DIPs, esp. in the C & S Sound and the HC & SJF MPGs, are not viable

DIPs across the DPS as a whole exhibit low A & P

## Limited diversity and spatial distribution

Most DIPs have limited diversity and weak spatial structure

Low viability wrt D & SS is widespread in Puget Sound and includes both run types



# Rolling up: MPG viability

## Northern Cascades MPG: P(v) = **36%**

- Average DIP P(v) = **48%**
- Highest = **63%** (Canyon Cr SSH)
- Lowest = **36%** (Stillaguamish R WSH)
- MPE = **Not viable** (probability it could be viable = **4%**)

## Central & South Puget Sound MPG: P(v) = **17%**

- Average DIP P(v) = **40%**
- Highest = **49%** (White R WSH)
- Lowest = **33%** (Cedar R WSH)
- MPE = **Not viable** (probability it could be viable < **1%**)

## Hood Canal / Strait of Juan de Fuca MPG: P(v) = **16%**

- Average DIP P(v) = **41%**
- Highest = **48%** (W Hood Canal WSH)
- Lowest = **33%** (Elwha R SSH/WSH )
- MPE = **Not viable** (probability it could be viable = **1%**)

# MPG viability: what if?

## Northern Cascades MPG

- P(viability) → up to **89%** if ½ the DIPs were viable
- P(viability) → **88%** if ½ the DIPs of each run type were viable
- P(viability) → **86%** if all 5 SSH and the Skagit DIPs were viable

## Central & South Puget Sound MPG

- P(viability) → **88%** if > 1 DIP from each of the 4 regions of the MPG were viable

## Hood Canal / Strait of Juan de Fuca MPG

- P(viability) → **~99%** if > 1 DIP from each of the 4 regions of the MPG were viable
- P(viability) → **89%** if all 4 DIPs along the SJF were viable

# DPS viability

Probability of viability for the DPS is very low: **1%**

The reason?

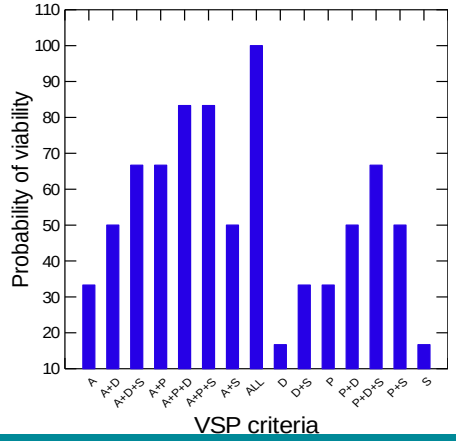
For the DPS to be viable, all 3 MPGs must be viable

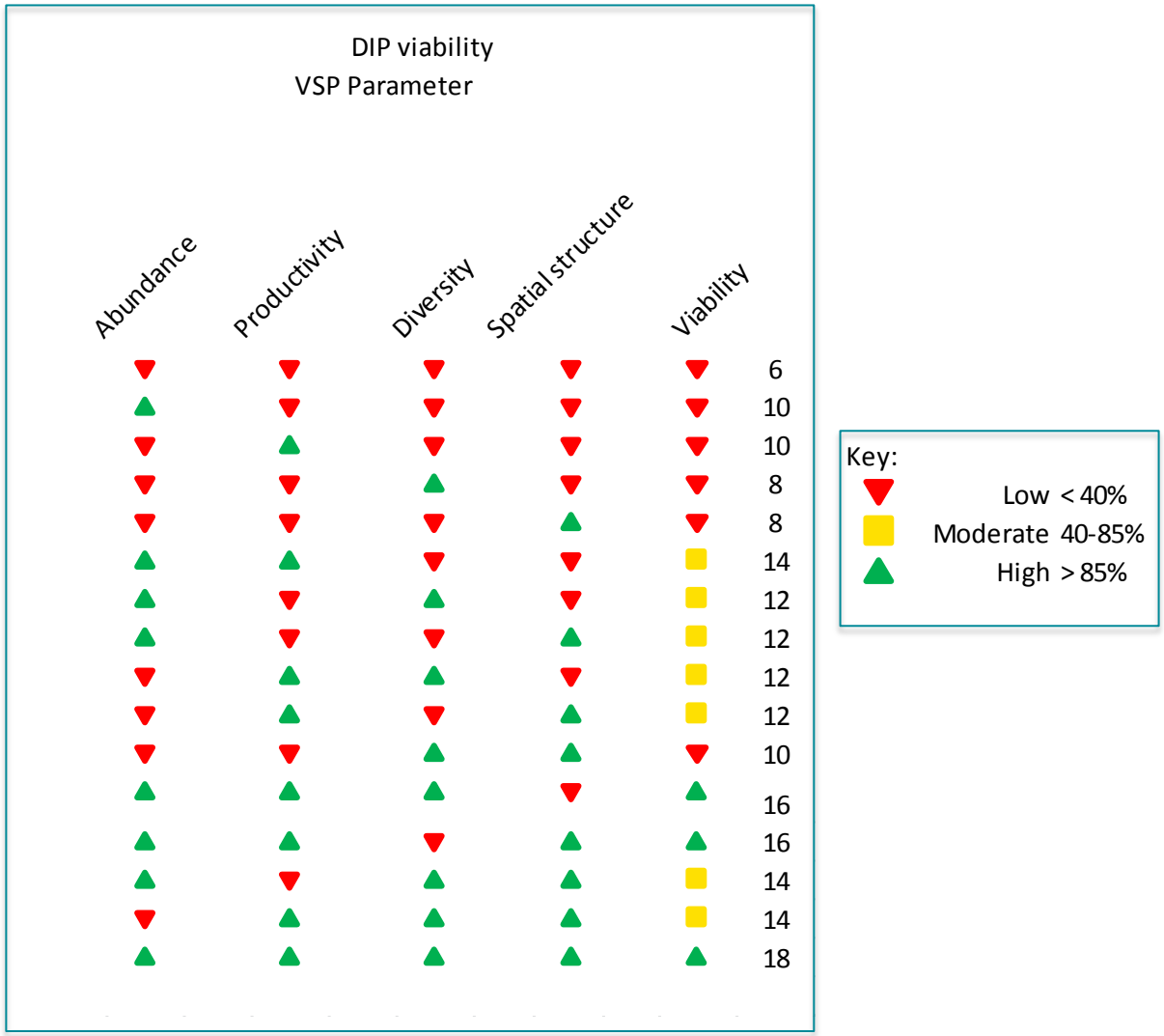
DPS viability is influenced heavily by 2 MPGs:

- HC & SJF MPG: its influence on DPS viability is **33%**
- C & SS MPG: its influence on DPS viability is **32%**
- NC MPG: its influence on DPS viability is **18%**

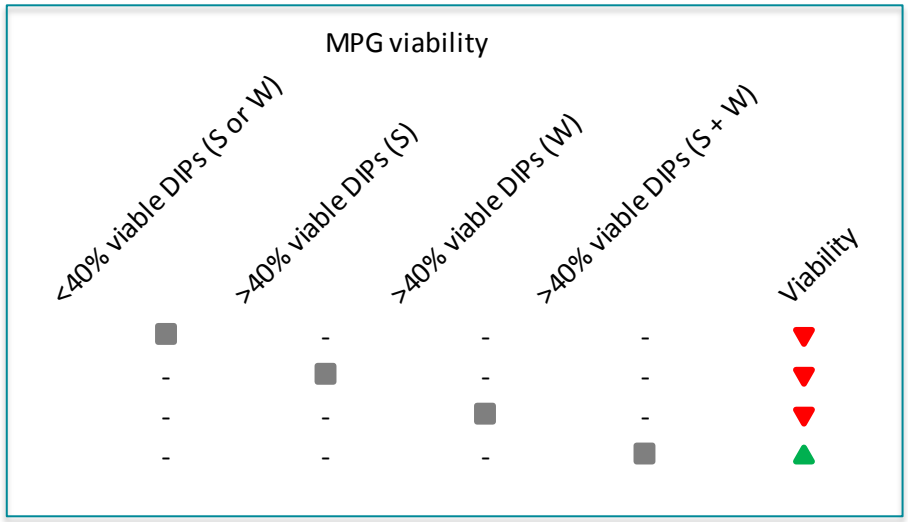
# DIP viability: simplifying the framework

- All four VSP criteria from the BNs are used to categorize viability states
- A & P scores are weighted 2X D & SS scores



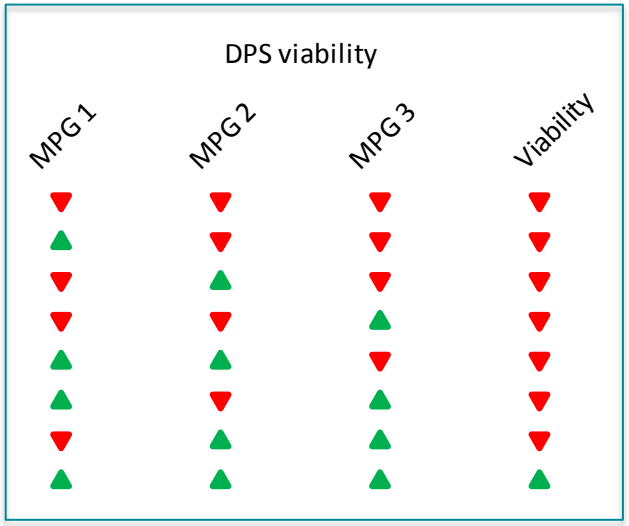



# MPG and DPS viability




- A viable MPG has at least 40% of its constituent DIPs at viability

- All MPGs must be viable for the DPS to be viable



# Viabilities across the DPS

| | | VSP Parameter | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Abundance | | | Productivity | | | | Diversity | | | | Spatial structure | | Viability | | |
| MPG | DIP | Adult | Juvenile | QET | Smolts/sp. | Adults/smolt | Lambda | Iteroparity | Hatchery | Spawn timing | Residents | Age | Spawn IP | Rear IP | DIP | MPG | DPS |
| N. Cascades | Drayton Harbor trib. (W) | Ins. | Ins. | High | Ins. | Ins. | Ins. | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Nooksack R. (W) | Low | Low | High | Ins. | Ins. | Ins. | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | S. Fk. Nooksack R. (S) | Low | Low | High | Ins. | Ins. | Ins. | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Samish R./Bellingham (W) | Moderate | Moderate | High | Moderate | Moderate | Moderate | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Skagit R. (S/W) | Low | Low | High | Moderate | Moderate | Moderate | Ins. | High | High | Low | Moderate | Moderate | Moderate | Moderate | | |
| | Nookachamps Cr. (W) | Ins. | Ins. | High | Ins. | Ins. | Ins. | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Baker R. (S/W) | Ins. | Ins. | High | Ins. | Low | Low | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Sauk R. (S/W) | Low | Low | Ins. | Ins. | Ins. | Ins. | Ins. | High | High | Low | Ins. | Moderate | Moderate | Low/Moderate | | |
| | Stillaguamish R. (W) | Low | Low | Moderate | Low | Low | Low | Ins. | Moderate | Ins. | Low | Moderate | Moderate | Moderate | Low | | |
| | Deer Cr. (S) | Ins. | Ins. | High | Ins. | Ins. | Ins. | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Canyon Cr. (S) | High | High | High | Ins. | Ins. | Ins. | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Moderate/High | | |
| | Snohomish/Skykomish R. (W) | Moderate | Moderate | High | Moderate | Moderate | Moderate | Ins. | Low | Ins. | Low | Moderate | Moderate | Moderate | Moderate | | |
| | Pilchuck R. (W) | Low | Low | Low | Moderate | Moderate | Moderate | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | N. Fk. Skykomish R. (S) | High | High | High | Ins. | Ins. | Ins. | Ins. | Low | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Snoqualmie R. (W) | Moderate | Moderate | High | Moderate | Moderate | Moderate | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Tolt R. (S) | Moderate | Moderate | Low | Moderate | Moderate | Moderate | Ins. | Low | Ins. | Low | Ins. | High | High | Moderate | | |
| Central/S. Sound | N. Lk. Washington trib. (W) | Low | Low | Ins. | Low | Low | Low | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | Cedar R. (W) | Low | Low | Low | Low | Low | Low | Ins. | High | High | Ins. | Ins. | Moderate | Moderate | Low | | |
| | Green R. (W) | Low | Low | Moderate | Moderate | Moderate | Moderate | Ins. | Moderate | High | Low | Moderate | Moderate | Moderate | Low | | |
| | Puyallup/Carbon R. (W) | Low | Low | Moderate | Low | Low | Low | Ins. | Moderate | Moderate | Low | Moderate | Moderate | Moderate | Low | | |
| | White R. (W) | Low | Low | Moderate | Moderate | Moderate | Moderate | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | Nisqually R. (W) | Low | Low | Moderate | Low | Low | Low | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | S. Sound trib. (W) | Low | Low | Ins. | Low | Low | Low | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | E. Kitsap Penin. (W) | Ins. | Ins. | Low | Low | Low | Low | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| Hood Canal & SJF | E. Hood Canal (W) | Low | Low | Low | Moderate | Moderate | Moderate | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | S. Hood Canal (W) | Low | Low | Low | Low | Low | Low | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | Skokomish R. (W) | Low | Low | Moderate | Moderate | Moderate | Moderate | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | W. Hood Canal (W) | Low | Low | Moderate | High | High | High | Ins. | Moderate | Ins. | Low | Ins. | Moderate | Moderate | Moderate | | |
| | Sequim/Discovery Bay trib. (W) | Low | Low | Low | Low | Low | Low | Ins. | High | Ins. | Low | Ins. | Moderate | Moderate | Low | | |
| | Dungeness R. (S/W) | Moderate | Moderate | High | Low | Low | Low | Ins. | Moderate | Ins. | Low | Ins. | High | High | Moderate | | |
| | Strait of Juan de Fuca indep. (W) | Moderate | Moderate | Moderate | Low | Low | Low | Ins. | Moderate | Ins. | Low | Moderate | Moderate | Moderate | Low | | |
| | Elwha R. (S/W) | Low | Low | Low | Low | Low | Low | Ins. | Moderate | High | Low | Ins. | Moderate | Moderate | Low | | |

Key:

- Low < 40%
- Moderate 40-85%
- High > 85%
- Ins. data

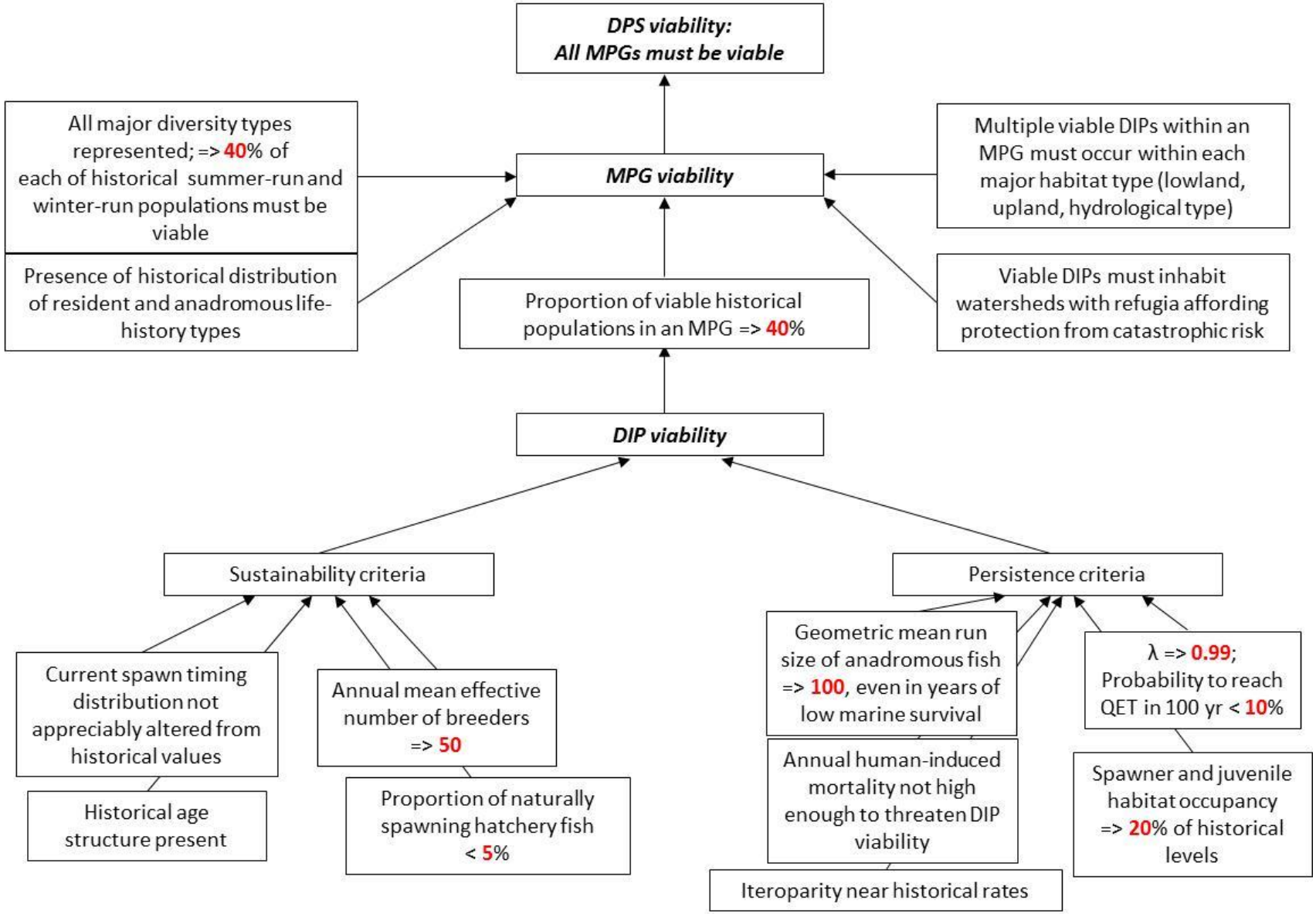
# Viabilities across the DPS: Alternate

| | | Abundance | | | Productivity | | | | Diversity | | | | Spatial structure | | Viability | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MPG | DIP | Adult | Juvenile | QET | Smolts/sp. | Adults/smolt | Lambda | Iteroparity | Hatchery | Spawn timing | Residents | Age | Spawn IP | Rear IP | DIP | MPG | DPS |
| N. Cascades | Drayton Harbor trib. (W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Nooksack R. (W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | S. Fk. Nooksack R. (S) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Samish R./Bellingham (W) | ■ | ■ | ▲ | ■ | ■ | ■ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Skagit R. (S/W) | ▼ | ▼ | ▲ | ■ | ■ | ■ | ⊠ | ▲ | ▲ | ⊠ | ■ | ■ | ■ | ■ | | |
| | Nookachamps Cr. (W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Baker R. (S/W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Sauk R. (S/W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ▲ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Stillaguamish R. (W) | ▼ | ▼ | ■ | ▼ | ▼ | ▼ | ⊠ | ■ | ⊠ | ⊠ | ■ | ■ | ■ | ▼ | ▼ | |
| | Deer Cr. (S) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Canyon Cr. (S) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Snohomish/Skykomish R. (W) | ■ | ■ | ▲ | ■ | ■ | ■ | ⊠ | ▼ | ⊠ | ⊠ | ■ | ■ | ■ | ■ | | |
| | Pilchuck R. (W) | ▼ | ▼ | ▼ | ■ | ■ | ■ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | | |
| | N. Fk. Skykomish R. (S) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▼ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Snoqualmie R. (W) | ■ | ■ | ▲ | ■ | ■ | ■ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Tolt R. (S) | ■ | ■ | ▼ | ■ | ■ | ■ | ⊠ | ▼ | ⊠ | ⊠ | ⊠ | ▲ | ▲ | ■ | | |
| Central/S. Sound | N. Lk. Washington trib. (W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | ▼ |
| | Cedar R. (W) | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ⊠ | ▲ | ▲ | ⊠ | ⊠ | ■ | ■ | ▼ | | |
| | Green R. (W) | ▼ | ▼ | ■ | ■ | ■ | ■ | ⊠ | ■ | ▲ | ⊠ | ■ | ■ | ■ | ▼ | | |
| | Puyallup/Carbon R. (W) | ▼ | ▼ | ■ | ▼ | ▼ | ▼ | ⊠ | ■ | ■ | ⊠ | ■ | ■ | ■ | ▼ | | |
| | White R. (W) | ▼ | ▼ | ■ | ■ | ■ | ■ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | ▼ | |
| | Nisqually R. (W) | ▼ | ▼ | ■ | ▼ | ▼ | ▼ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | | |
| | S. Sound trib. (W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | E. Kitsap Penin. (W) | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| Hood Canal & SJF | E. Hood Canal (W) | ▼ | ▼ | ▼ | ■ | ■ | ■ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | | |
| | S. Hood Canal (W) | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | | |
| | Skokomish R. (W) | ▼ | ▼ | ■ | ■ | ■ | ■ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | | |
| | W. Hood Canal (W) | ▼ | ▼ | ■ | ▲ | ▲ | ▲ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ■ | ■ | ■ | | |
| | Sequim/Discovery Bay trib. (W) | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ⊠ | ▲ | ⊠ | ⊠ | ⊠ | ■ | ■ | ▼ | ▼ | |
| | Dungeness R. (S/W) | ■ | ■ | ▲ | ▼ | ▼ | ▼ | ⊠ | ■ | ⊠ | ⊠ | ⊠ | ▲ | ▲ | ■ | | |
| | Strait of Juan de Fuca indep. (W) | ■ | ■ | ■ | ▼ | ▼ | ▼ | ⊠ | ■ | ⊠ | ⊠ | ■ | ■ | ■ | ▼ | | |
| | Elwha R. (S/W) | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ⊠ | ■ | ▲ | ⊠ | ⊠ | ■ | ■ | ▼ | | |

Key:

- ▼ Low < 40%
- ■ Moderate 40-85%
- ▲ High > 85%
- ▲ ⊠ ▼ Ins. data

# Proposed viability criteria

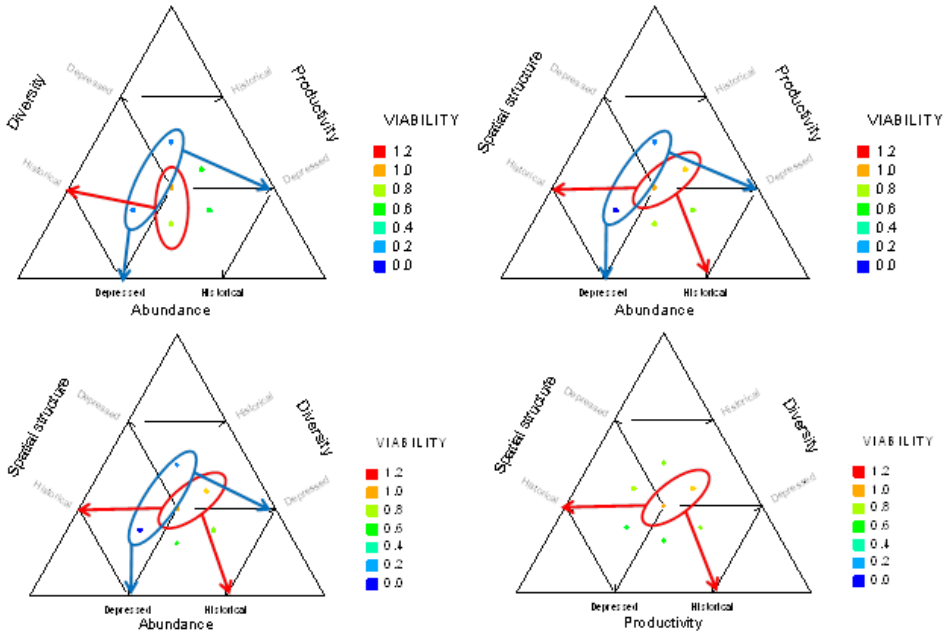


# Summary

- At least 40% of DIPs in each MPG are viable
- Extinction risk < 10% in 100 yr
- Populations are sufficiently large, productive, and diverse
- Habitat use is at least 20% of capacity
- Distribution of viable populations minimizes catastrophic risk
- Life history expression (e.g., run type, age structure, degree of iteroparity, spawn timing, residency) is similar to historical
- Impacts of human activities, including the frequency of naturally spawning and rearing hatchery fish, pose only nominal risk

# Next steps?

- Jump start the recovery process
- Identify information needed to assist recovery, and to guide M & E
- Additional analyses:
  - Work focused on SARs, iteroparity, densities
  - RS studies
  - Fine-scale genetic structure
  - Improved I.P. estimates



# Thank you for your attention

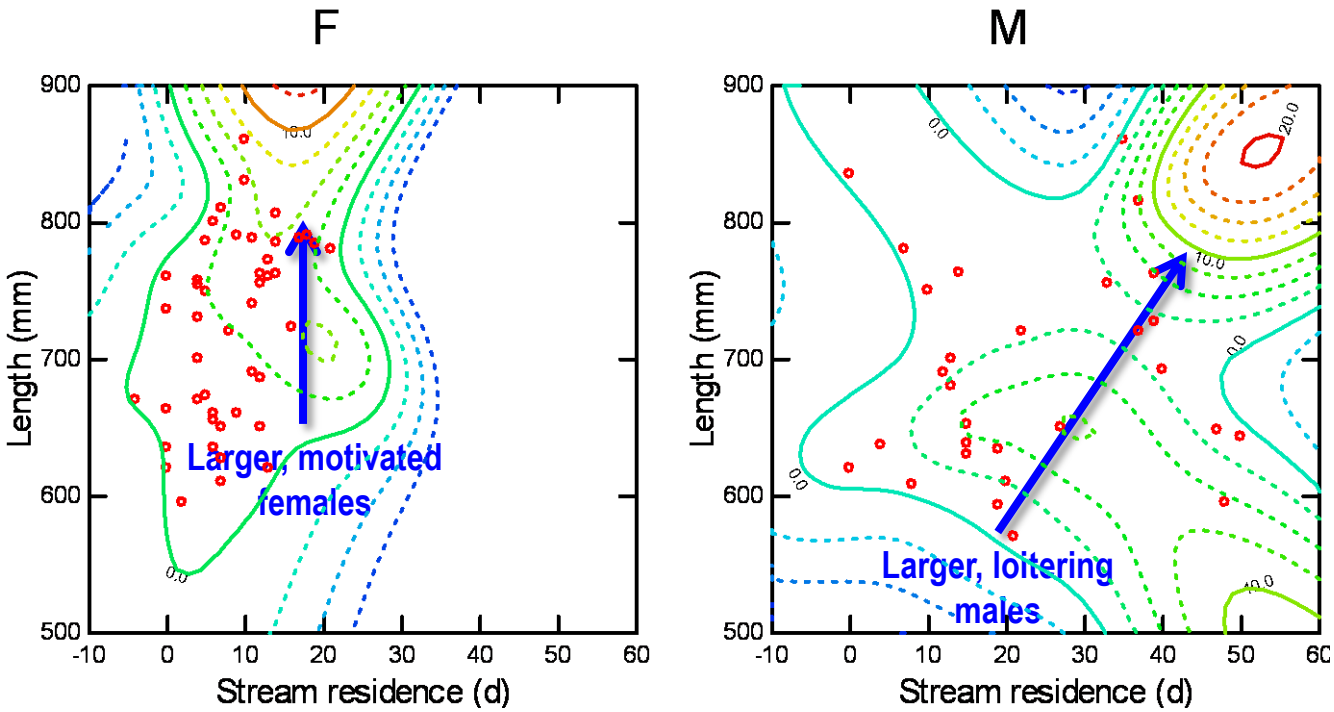
Photo by F Thrower

Photo by J McMillan

# Components of steelhead productivity

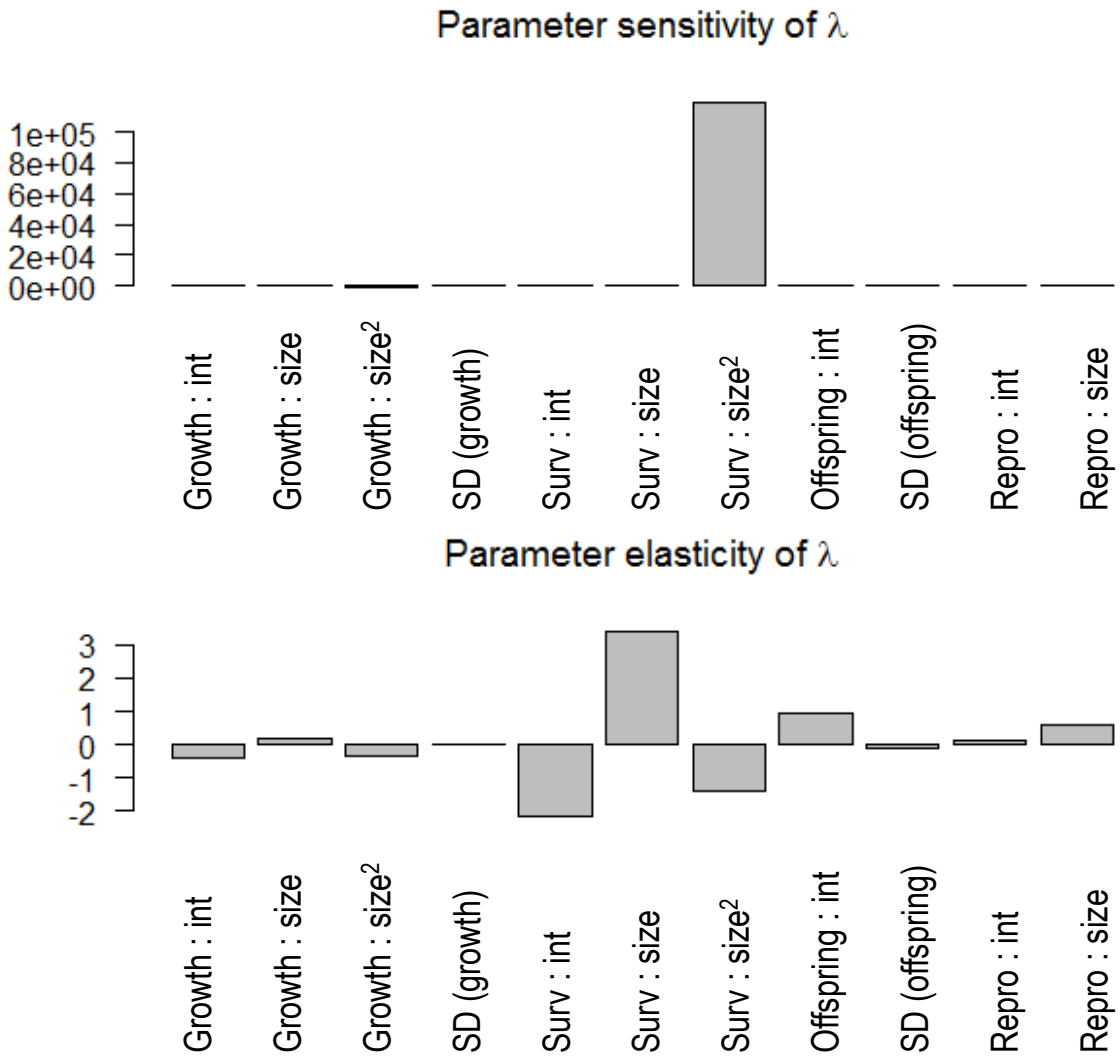
## Contribution to population growth rate

Lifetime $p_{t(i)} \times 10^3$




Fitter females are larger but do not stay long

Fitter males tend to be larger and stay longer, siring more surviving progeny

# Dissecting wild steelhead productivity

- Productivity is enhanced by the ↑ in survival with ↑ size, and by mean RS
- Productivity tends to be limited by low SAR, and by the deceleration in ↑ survival with ↑ size