Harvest Management of Chinook and Coho Salmon: Current Practices and Opportunities for Improvement

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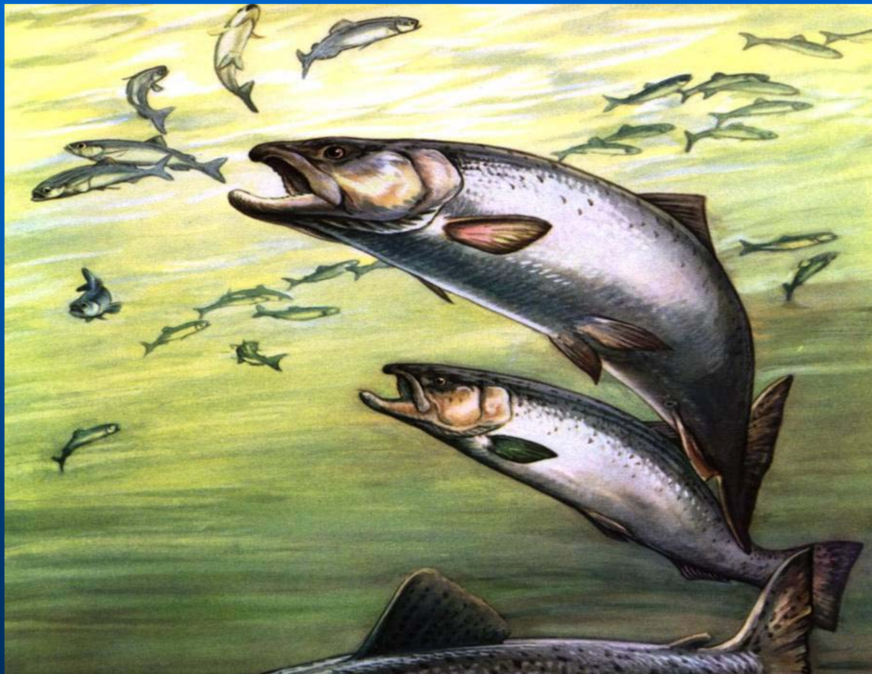
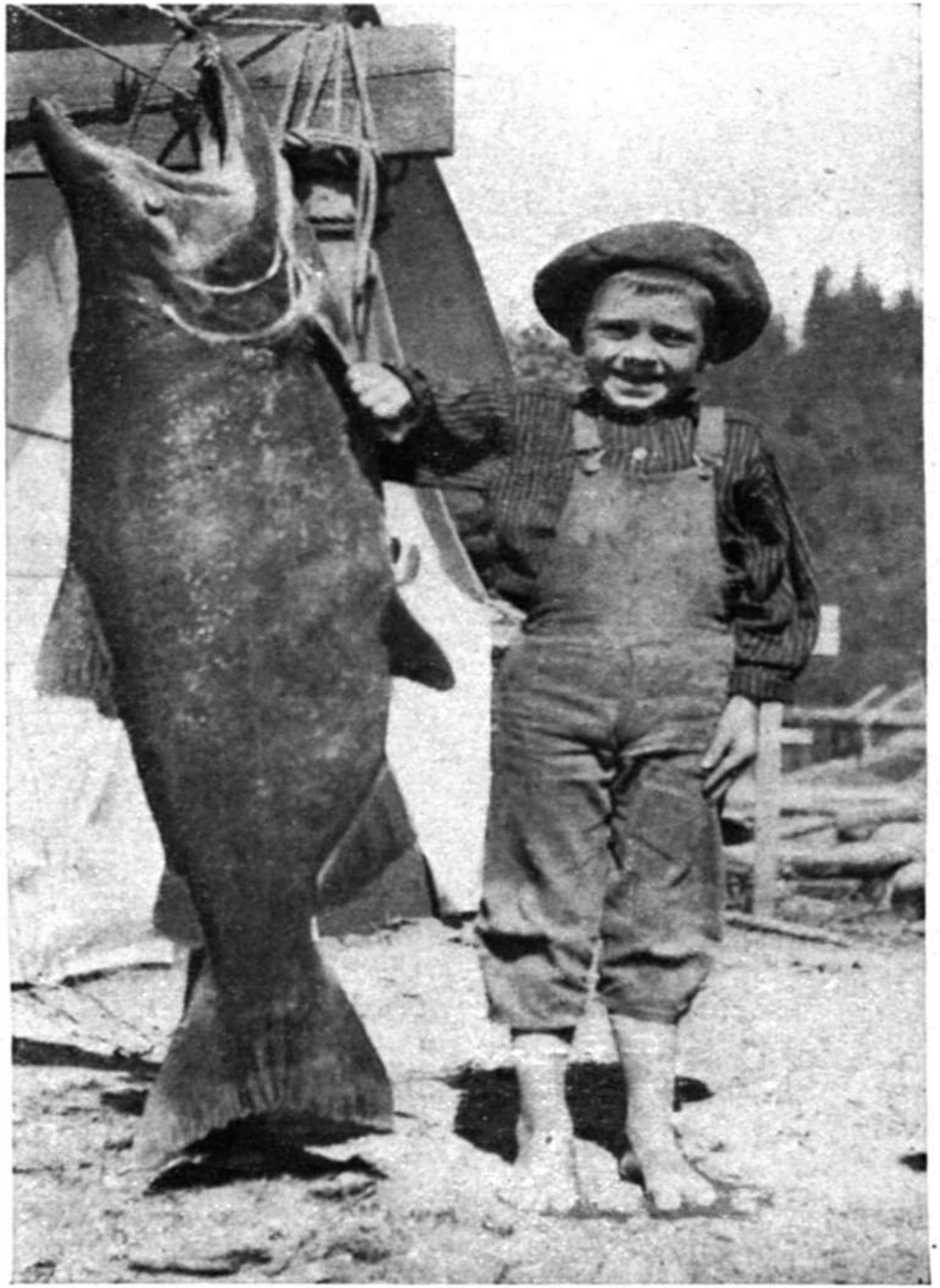
GSI Workshop, Portland, OR

May 2007



Overview

- Basics
- Biology
- Fisheries Management
- CWT & GSI



I. Basics
Exploitation Rate

$$ER_{s,a,f} = \frac{Mortality_{s,a,f}}{CohortSize_{s,a}}$$

Landed or Total

Total Population prior to fishing in time period

Exploitation rates for a given fishery <u>differ</u> by stock and age

Harvest Rate

Landed or Total

$$HR_{s,a,f} = \frac{Mortality_{s,a,f}}{AvailablePopulation_{s,a}}$$

Population **Available** to the fishery at the time fishery occurs

Should be <u>equal</u> for vulnerable populations for all stocks and ages in a given stratum

Fishery Types

Pre-Terminal

- **Single pool entire cohort**
- **Stock-age-fishery Exploitation Rates**

Maturation

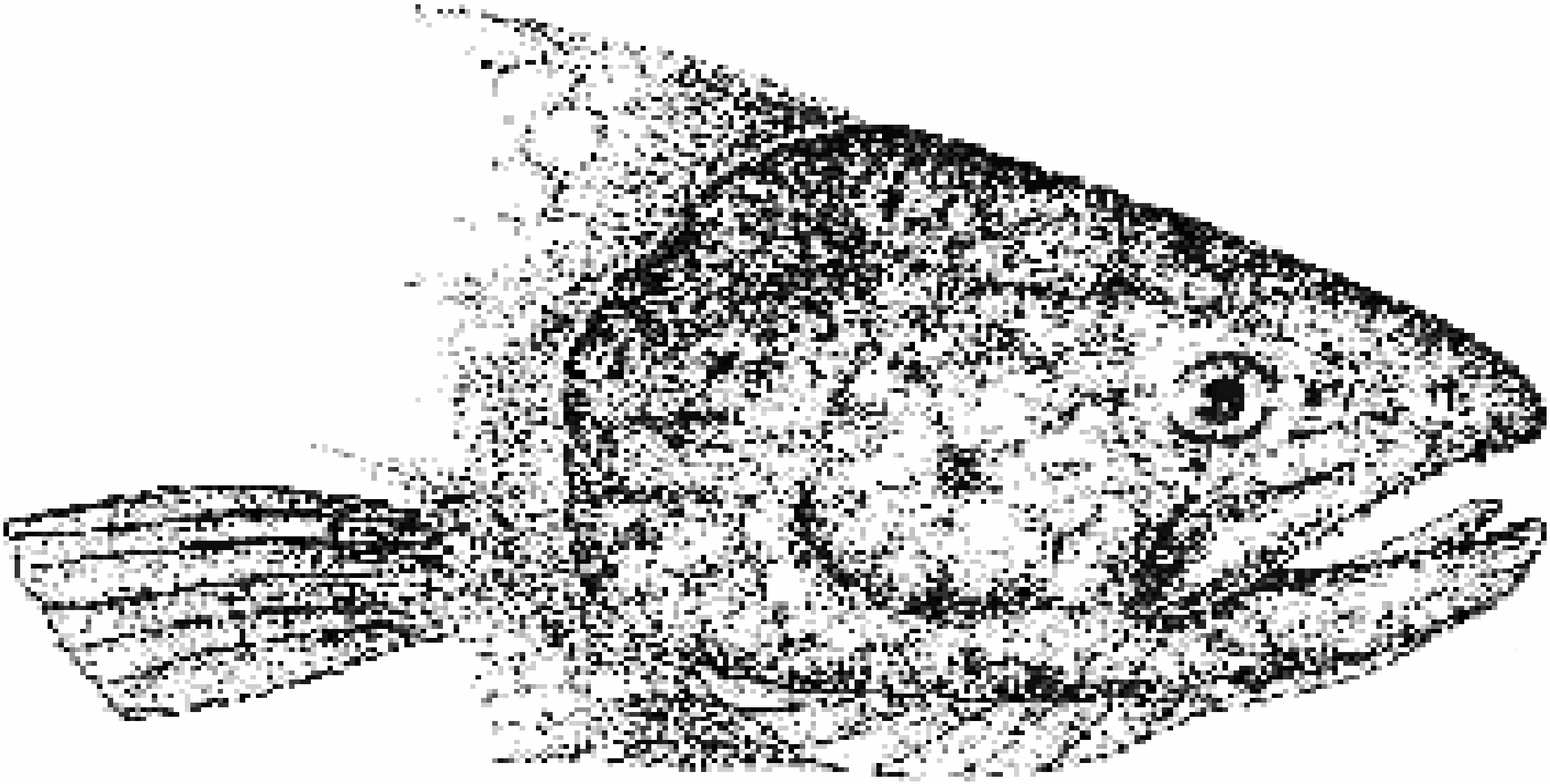
Terminal

- **Single pool of mature fish**
- **Stock-age-fishery Harvest Rates**

Post-fishery, pre-spawning mortality

Spawning Escapement

II. Biology



Salmon Life Cycle

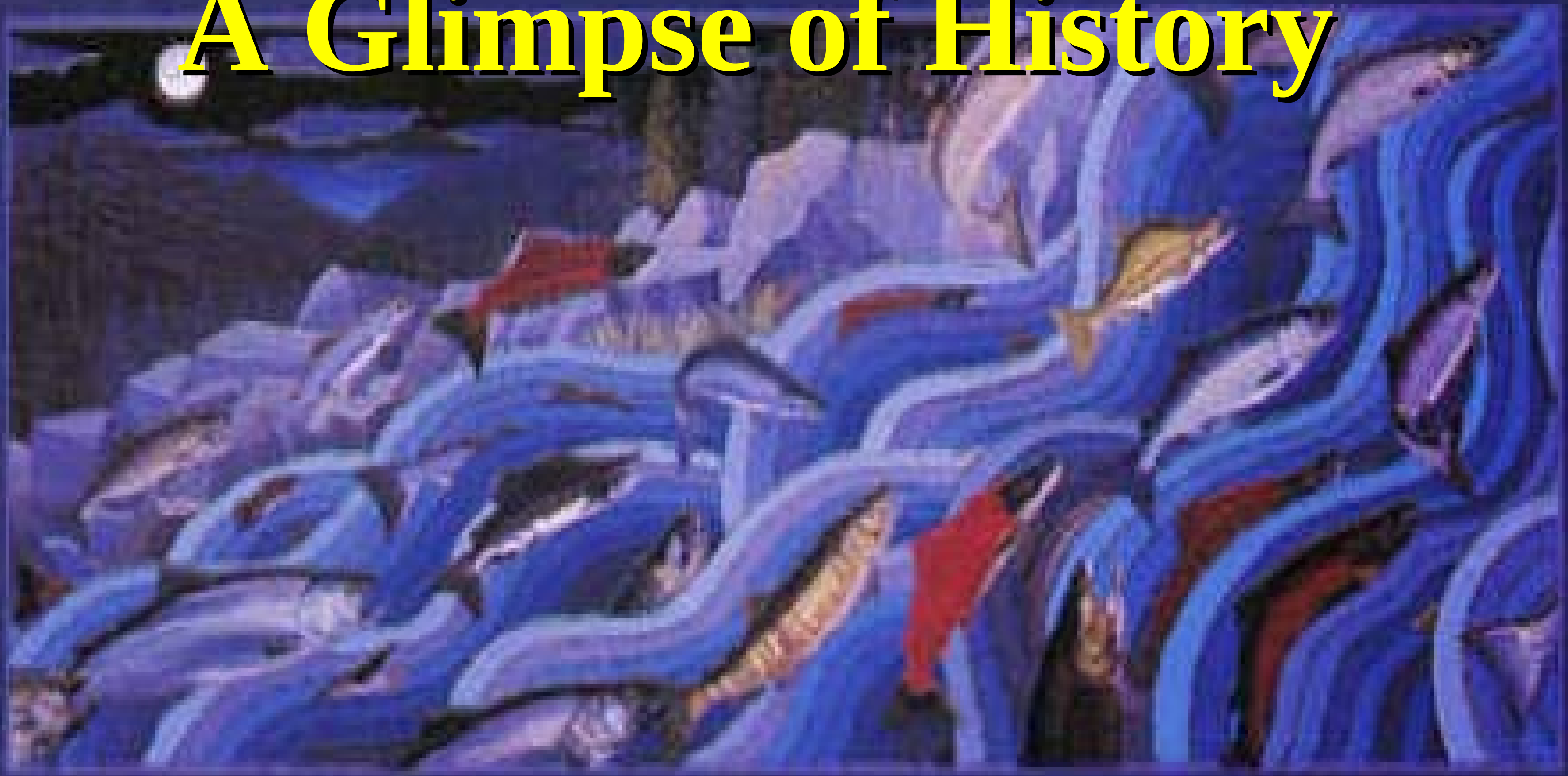
- Anadromous
  - 0-1 year in freshwater
  - 1-4 years in marine waters
- Semelparous
- Homing & Local Adaptation
  - Stock-specific migration can cover thousands of miles
  - Stock-specific exploitation patterns
  - Stock-specific productivities
- High interannual variability in abundance

“Stock” Concept

- Over time, “stocks” adapted to local environments
- Straying varies by species
- Anthropogenic Influences
  - Artificial Propagation
    - Brood stock
    - Rearing Practices
      - Migration
      - Growth
      - Maturation

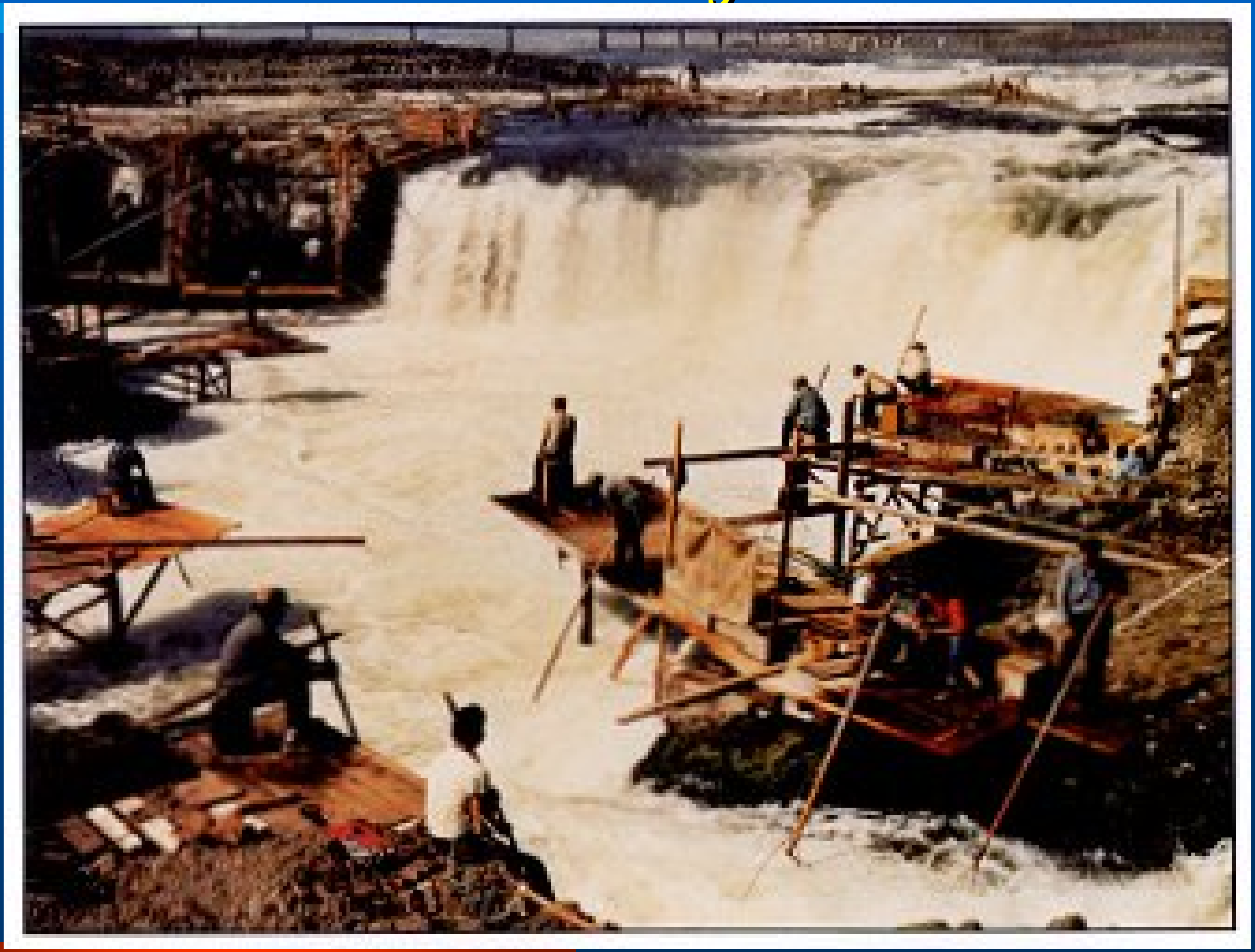
III
Fishery Management

A Glimpse of History



Salmon Once Filled the Rivers to Overflowing

Salmon Were Harvested Predominantly In Rivers

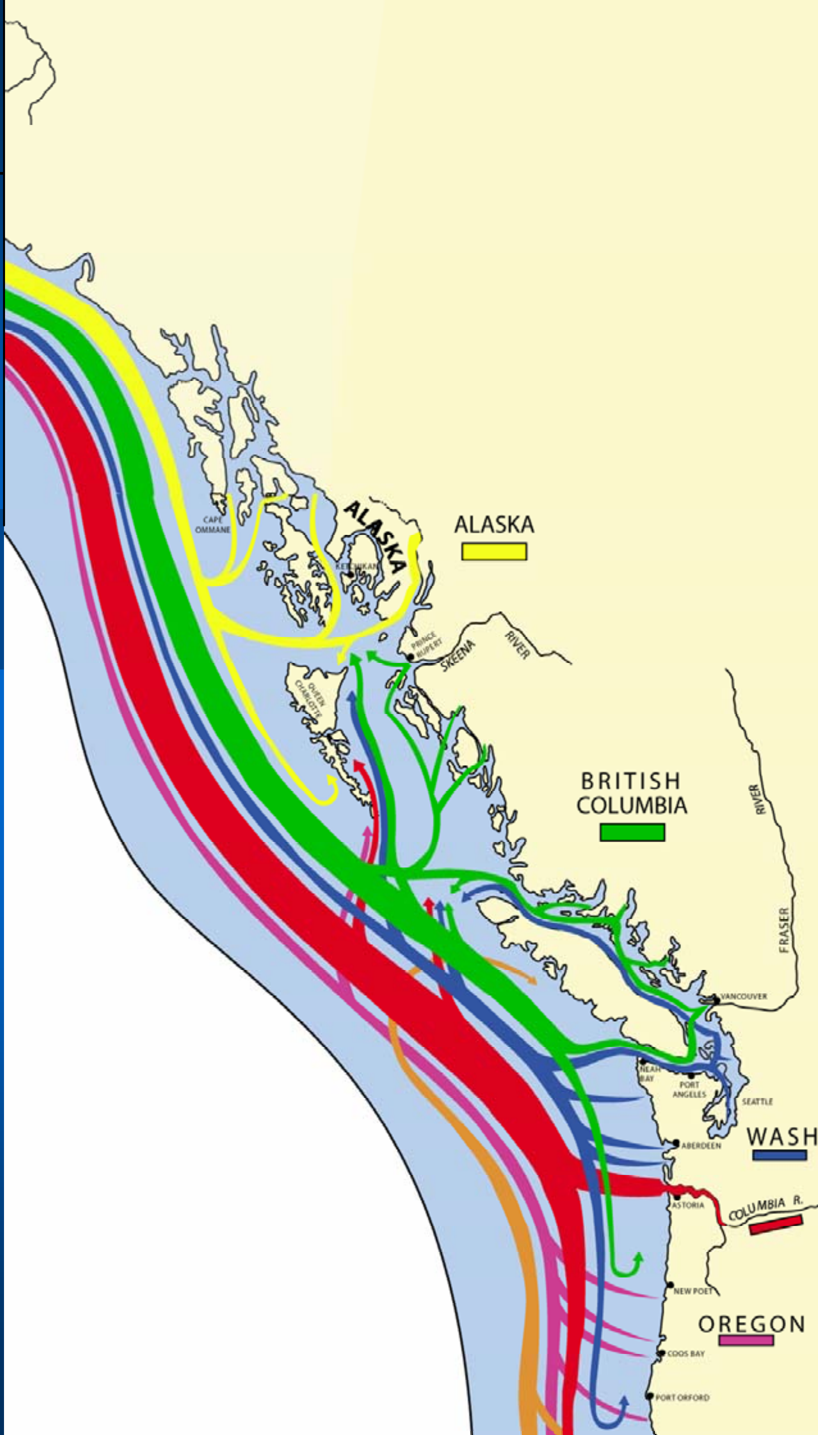


Changing Exploitation Patterns

- In-River Fisheries
- Traps, Wheels, & Seines
- Gillnets
- Purse Seines
- Trollers

- Sportsmen

Chinook



Extensive marine distribution & exploitation

Fish mature at ages 2-6

Pre-Terminal Fishery Management

- Exploits complex highly mix of hatchery & wild stocks at various stages of maturity
- Catch quotas, time/area & retention restrictions
- Annual abundance, stock distribution and migration timing variable
- Fishery effort response to regulations difficult to predict

Terminal Fishery Management

- Less complexity - Far fewer stocks & fisheries than ocean
- Return comprised of mature adults
- Relatively short duration of fishery
- In-season data provides estimates of abundance, timing, and H/W composition
- Fishery adjustments to attain conservation and allocation objectives

Major Fishery Management Questions

- How can we benefit economically?
  - Fishery centric until mid-1070's

- How can we constrain impacts on individual stocks of interest?
  - Stock centric since

The Key: STOCK-Specific Exploitation Rates

Many Types

Brood Year (BYERs)

Landed catch or Total Mortality

Usually in adult equivalents

Proportion of total potential spawners from a brood

Exploitation relative to productivity

Calendar Year (CYERs)

- Landed catch or Total Mortality

- Fishing mortalities divided by total fishing mortality plus escapements during a single year.

Calendar year analog to BYER (e.g., RER ESA Jeopardy standard)

Return Year (RYERs)

- Landed catch or Total Mortality

- Mortalities incurred in the current and all previous years of fish that would be expected to mature in a given return year.

- Exploitation relative to potential spawning escapement (not commonly used, can combine all sources of mortality in a single statistic to measure cumulative effects, could also be useful for allocation.)

Terminal Fishery Harvest Rates (HRs)

Landed catch or Total Mortality

Proportion of terminal run killed by fishing (e.g., Columbia River ESA jeopardy standard).

Stock-Age-Fishery ERs

Landed catch or Total Mortality

$$ER_{s,a,f} = \frac{Mort_{s,a,f}}{Cohort_{s,a}}$$

Fishery shaping (mostly time-area), impact allocation.

Stock-Specific ERs – Foundation for Modern Salmon Management

- **Conservation**
  - **Annual management objectives & constraints (e.g., PSC coho, ESA)**
  - **Drive regime implementation (e.g., PSC Chinook)**
- **Allocation**
  - **Distribution of impacts across sectors**
- **Socio-Economic**
  - **Fishery shaping**

Current Management

- Planning
- Regulation
- Monitoring & Evaluation

Domestic Obligations - FCMA

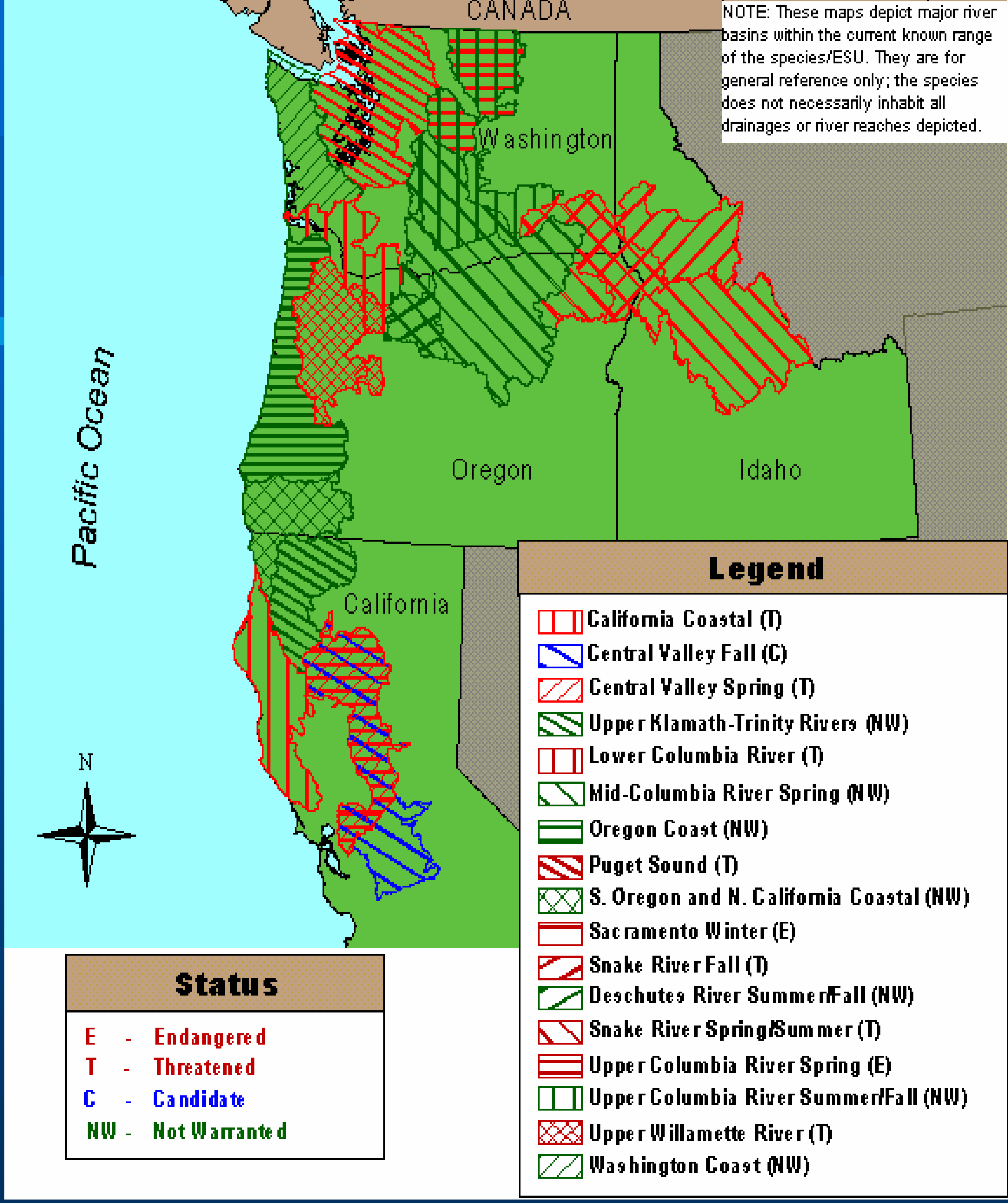
- 1976 – Established EEZ 3-200 miles
- Regional Councils
- Must Comply With Domestic & Interntl Obligations
  – National Standards
  – Overfishing
- Framework Plan
  – Management Objectives
  – Allocation Guidelines

Domestic Obligations – ESA (1973)

- Endangered Species Act – Chinook ESUs
  - Sacramento winter - Endangered '94
  - Snake River sp/summer - Threatened '92
  - Snake River fall - Threatened '92
  - Puget Sound - Threatened '99
  - Lower Columbia – Threatened '99
  - Upper Willamette – Threatened '99
  - Upper Columbia Spring – Endangered '99
  - Central Valley Spring – Threatened '99
  - California Coastal – Threatened '99

ESA-ESUs

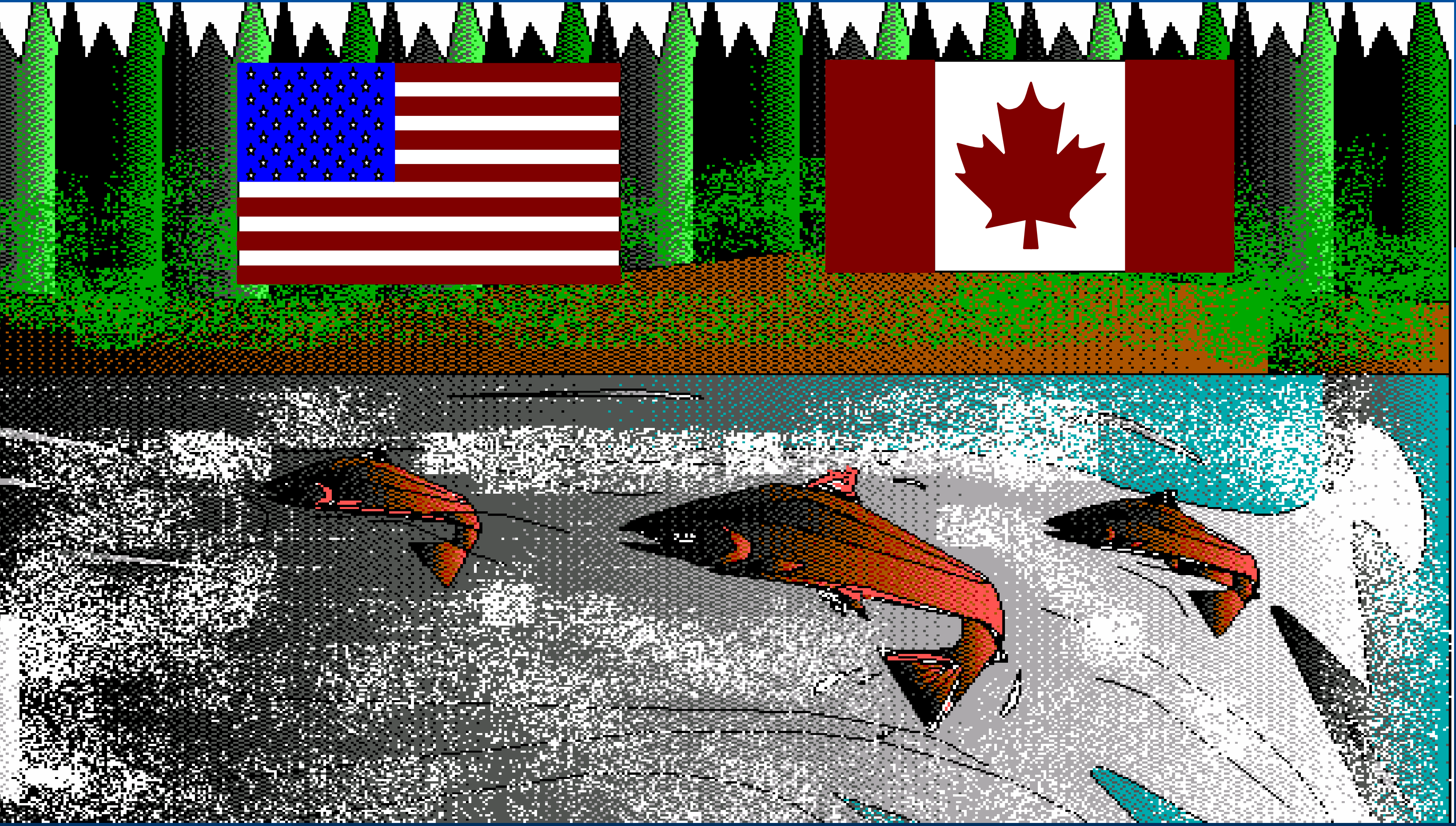
- Stock-specific annual fishery impact constraints, commonly expressed in terms of exploitation rates



U.S. Domestic Obligations – Indian treaty rights

- 50% of harvestable surplus originating in, or passing thru, U&A
- River x River, Run x Run

International Obligations PST



PST- Chinook

- AABM Fisheries
  - Aggregate Abundance Index (AI) Driven
    - SEAK
    - NBC
    - WCVI
  - Harvest rates vary, depending on AI
- ISBM Fisheries
  - All non-AABM fisheries
  - Reduction in harvest rate impacts on stocks not meeting escapement goals

PST- Southern Coho

- Total Mortality Exploitation Rate Constraints
  - Specific Naturally Spawning Management Units
  - MSY & preservation of biological diversity
  - ER constraints vary, depending on MU status

Reference:

Morishima, G.S. 2004. In a nutshell: coded wire tags and the Pacific Salmon Commission's fishery regimes for chinook and southern coho salmon.

File: **Morishima2004.pdf**

Planning Objectives

- **FISHERIES – meet constraints for all stocks**

- **STOCKS – meet conservation objectives by constraining all fisheries along a stock’s migratory path**

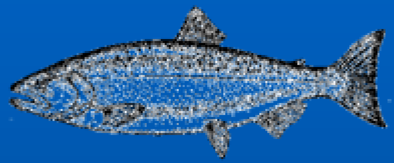
The Manager's Dilemma

- Biological Complexity
  - Mixed stocks - differences
    - Knowledge & uncertainty
    - Managemen
- Interannual v
  & distributio
- Unpredictable fishery participation

Jurisdictional patchwork

- Salmon migrate through many jurisdictions
- No single entity can control all harvest

Multiple Jurisdictions – Columbia River Chinook



Constrain impacts throughout migratory range

NPFMC
Alaska

Canada

PFMC
Makah
Quinault
Quileute
Hoh
S'Klallam
Washington

Columbia River Compact
Washington
Oregon

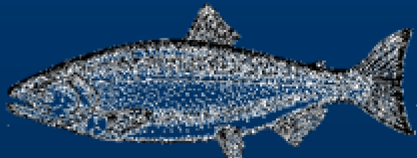
Treaty Indian
Yakama
Warm Springs
Umatilla
Nez Perce

States
Washington
Oregon
Idaho

Sport & Net | Net | Sport | Escapement

PFMC
Oregon
California

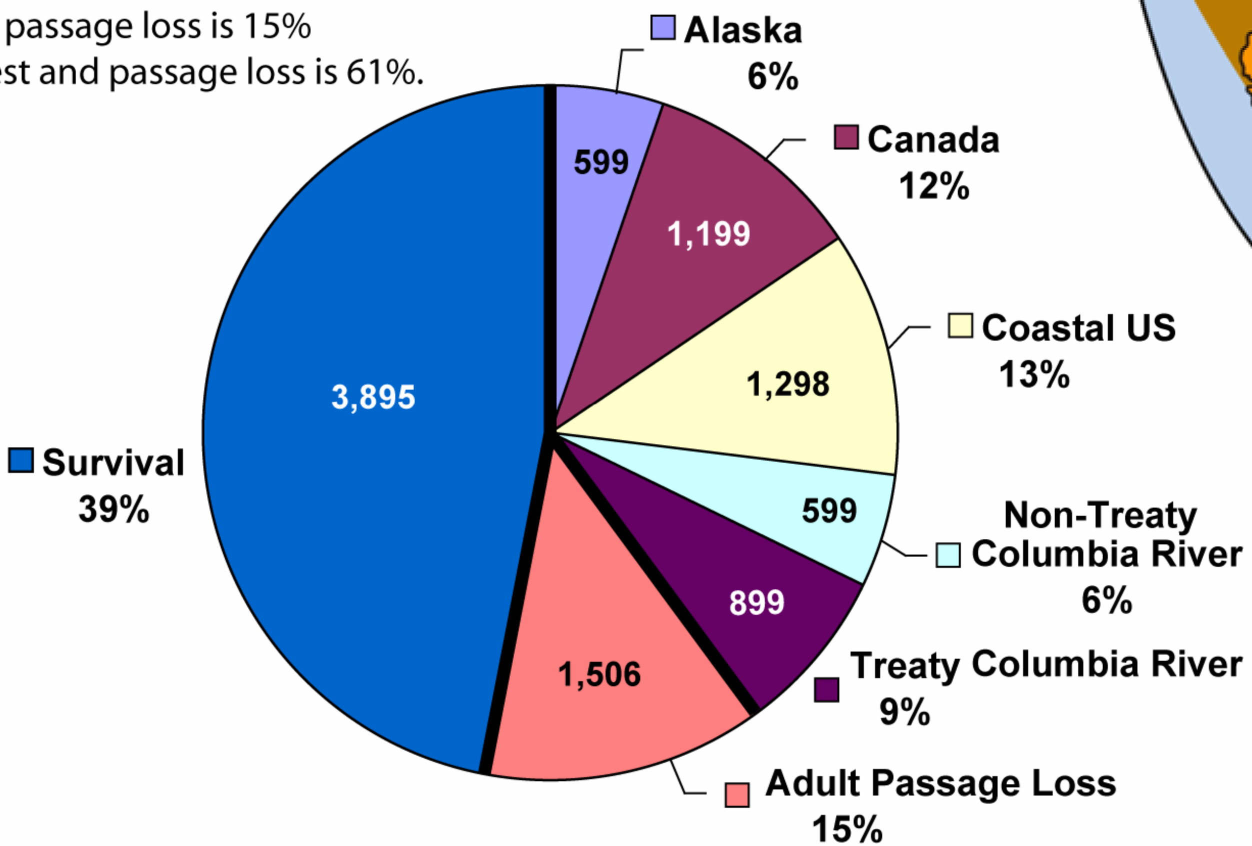
Sport & Troll



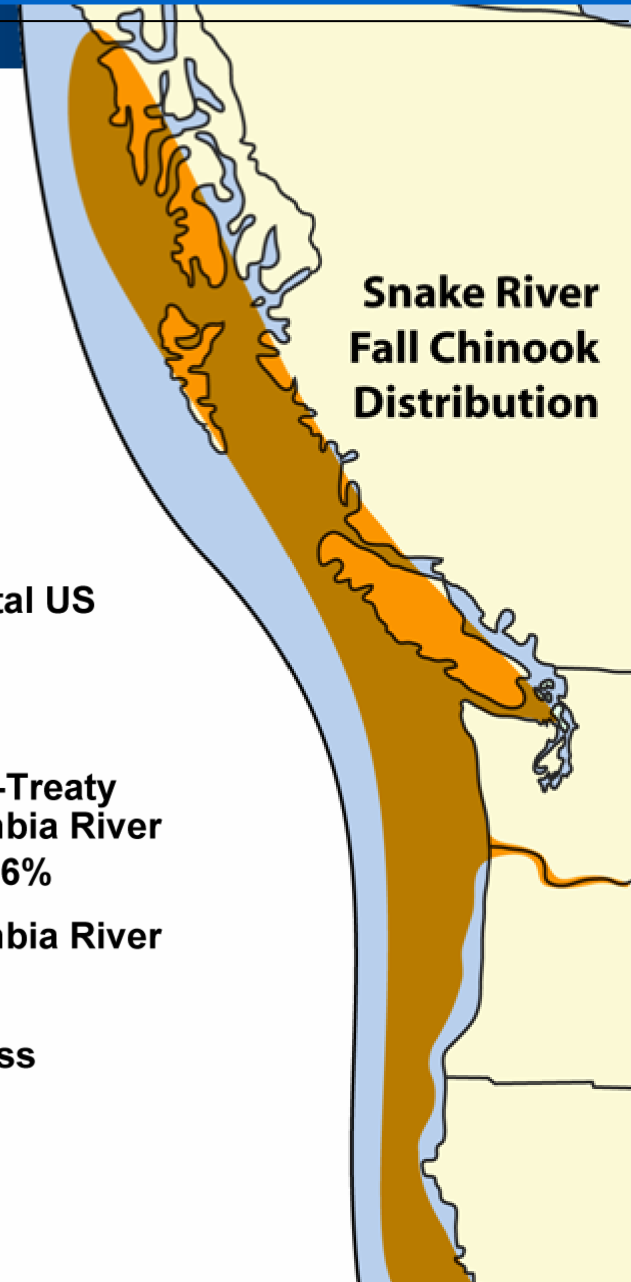
Snake River Fall Chinook

2003 - Estimated Harvest Rate and Adult Passage Loss
Snake River Wild (SRW) Fall Chinook

Total estimated harvest in 2003 is 4,595.
Total harvest rate is 46%.
Total adult passage loss is 15%
Total harvest and passage loss is 61%.



The run-size for SRW at the mouth of the Columbia River was 6,892.
The total run-size for the entire Fall Chinook run at the mouth was 893,100.



The Challenge

- Many Management Units
  - Highly variable abundance
  - Different productivities, migration patterns, maturities
  - Multiple species
- Many fisheries & social goals
- Specific legal obligations

Whadda I do now?

Without an acceptable means to evaluate alternatives, we are faced with

- Actions unsupported by science
- Increased risk to the resource
- Inability to meet legal obligations

How to Cope?

Traditional “Science” Models Can’t Be Readily Applied

- State Hypothesis
- Design experiment
- Conduct experiment
- Analyze Results
- Draft Report
- Peer Review
- Publish

Why?

- Not possible, physically or socially, to embark on controlled, replicable experiments (e.g., time-treatment interactions)
- Sparse data, often not directly applicable to most stocks in most critical need (e.g., ESA-listed)
  - Inference commonly through statistical association of available data, often using surrogate measurements
  - Uncertainty high, costs and consequences are dear
  - As stakes increase, political and judicial decision-makers become increasingly critical and demanding
- Time constraints – short window of opportunity to respond to changes in stock status

Institutional Structure

Coordinate actions throughout migratory range of individual stocks

Voluntary: PSMFC

Legislative: MFCMA

Regulatory: ESA

International Agreements: Pacific Salmon Treaty

Implemented Through

Annual Management Plans

PFMC Jurisdiction

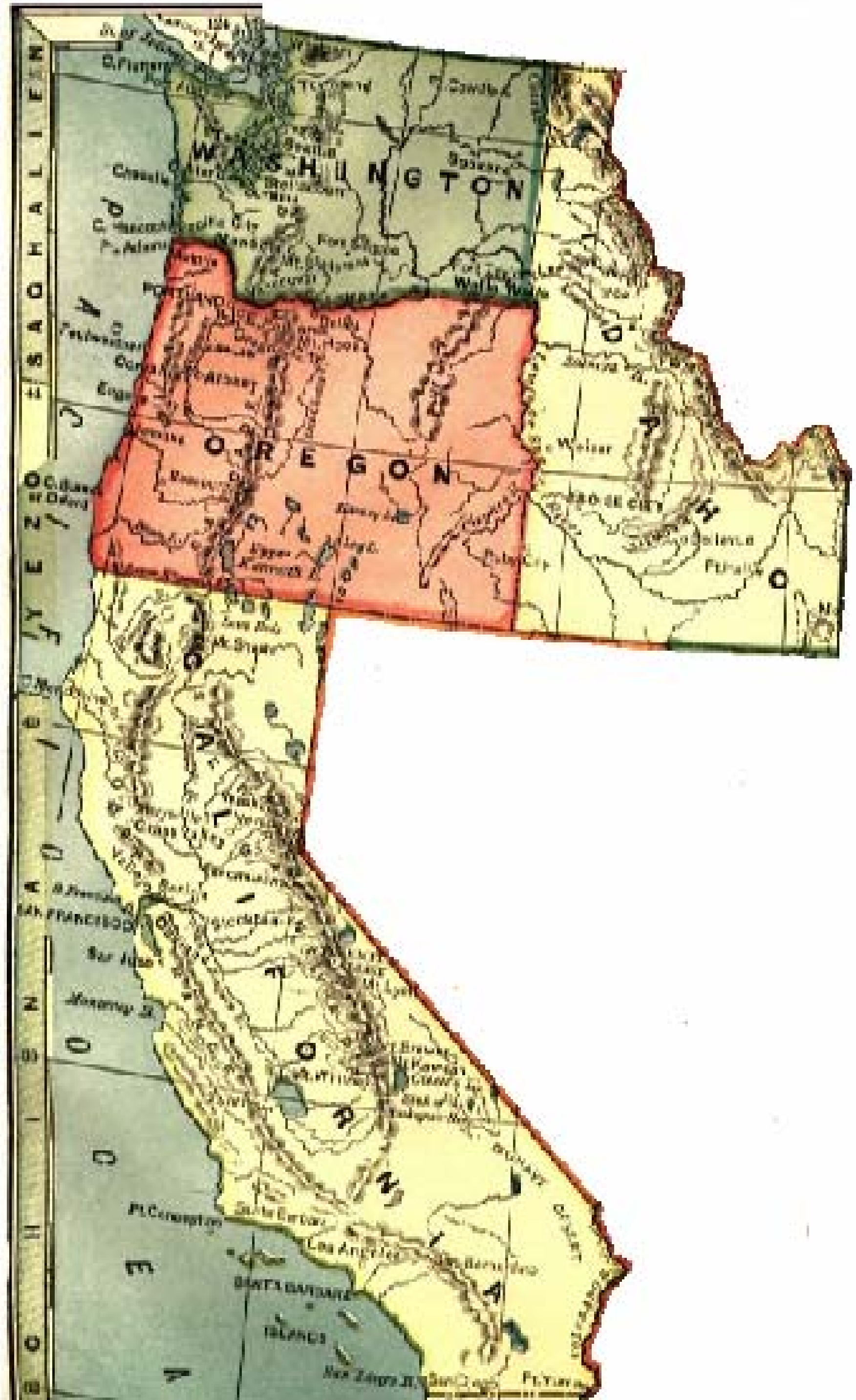
EEZ 3-200 miles

Southern U.S.

Rely on annual planning processes

Co-Managers & Stakeholders

Ocean & Terminal Fisheries



Framework Plan

- Identifies Management Units
- Establishes Management Objectives
- Describes Regulatory Options
- Specifies Sector Allocation Requirements
- Guidance on National Standards
  - Overfishing
  - Essential Fish Habitat

Current Management Boundaries

Zones

Planning forums

North of Falcon

Klamath

Fishery Management Planning Needs

- Constrain stock-specific impacts
  - Shaping - time/area/size limits/gear restrictions/retention constraints
  - Catch ceilings

More Information

Quick

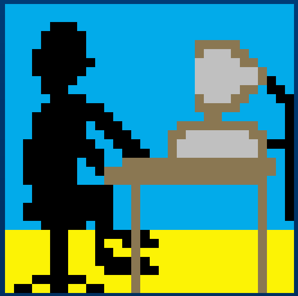
Rely on Harvest Management Models

- Enable managers to develop ways to meet needs of fisheries within constraints dictated by conservation requirements for individual stocks

- Encapsulate knowledge, theory, assumptions, and information in a convenient, transferable form acceptable to:
  - **co-managers**
  - **multiple jurisdictions**
  - **diverse user groups**

Why do we use models?

- Improve accessibility to information
- Provide consistency in analysis
- Function within demanding time schedule for decision processes



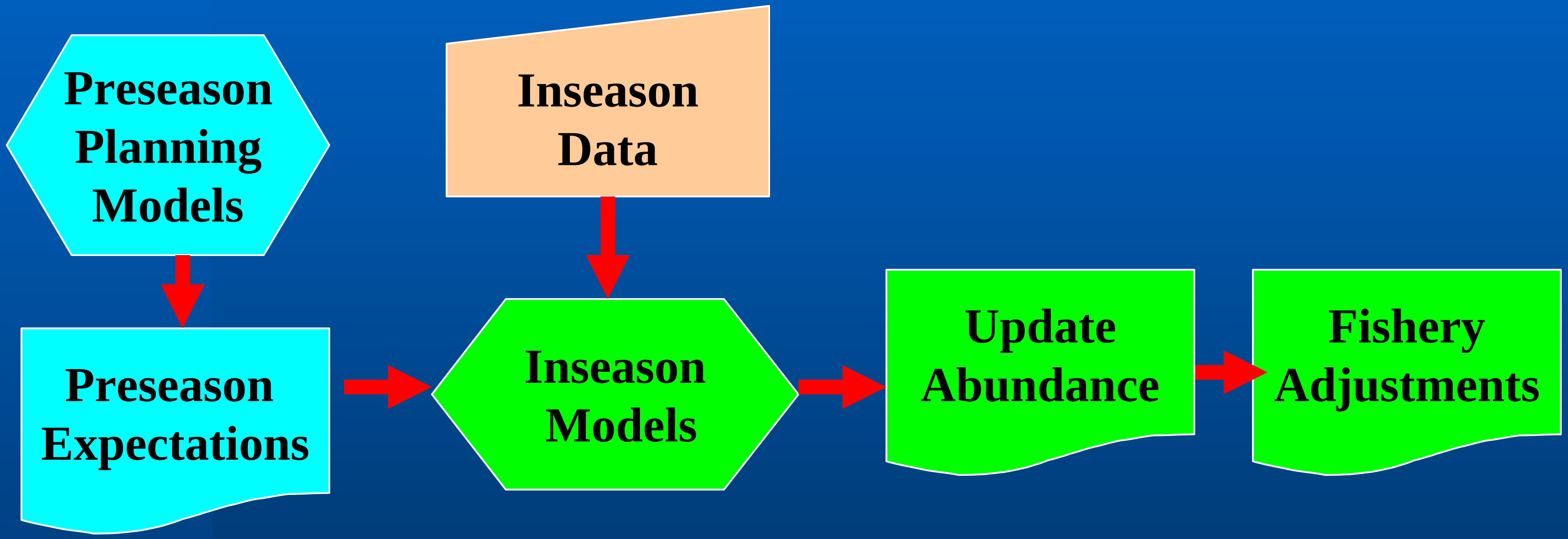
Application of Planning Models

- Universe of possibilities
- Resource Status
- Framework Plan
  - – Objectives
  - – Escapement Rqmts
  - – Allocation
    - Sectors
    - Ports

Models in Preseason Planning Process

Jan	States & Tribes Report Catches & Esc
Feb	States & Tribes prepare Forecasts
	STT - Calibrate Models
	STT - Preview last year's regs & projected abundance
Mar	Development of Options
	Exploration of Options in Regional Forums
Apr	Analysis of Options & Final recommendations
	Inseason Management

Inseason Management Models



e.g., Seasons, bag limits

- Spawning escapements
- Allocations & Entitlements
- "Wastage"

Models Come in Many Flavors

- Specialized Purposes
- Differ in scope
  - Stocks
  - Fisheries
  - Time Periods

Model Commonalities

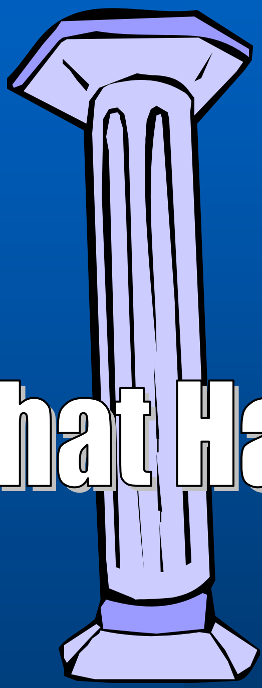
- “Stocks”
  – Aggregate complexes of interest
  – Hatchery & Natural
- Fisheries
  – Principal impacts
- Single Pool
  – Exploitation Rate-Based
  – No explicit migration
- Deterministic
  – Uncertainty and risk only in parameters
- Structure

Stratification of Planning Models

	PSC Chinook Model	Chinook FRAM	Coho FRAM
# Years	Multiple	Single	Single
Time Steps Per Year	1	3	7
Fisheries	28	73	206
Fishery strata	28	219	1,442
Stocks	30	32	128
Total ER Estimates Rqd	840	7,008	184,576

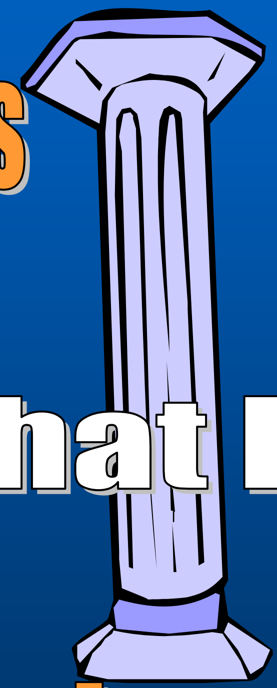
Model Structure

Two Main Components



What Happened?

Reconstruction



What If?

Projection

What Happened Reconstruction

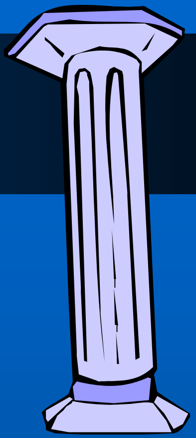
COHORT ANALYSIS

- CWT Recoveries of <u>indicator stocks</u>
  - ✓Fisheries
  - ✓Escapement
- Assumptions on mortality rates
  - ✓Incidental
  - ✓Natural

BASE PERIOD

- Extensive, intensive fisheries – adequate recoveries

What If Projection



- Abundance forecasts
- Estimate impacts of regulatory packages
- Assuming base period distribution & exploitation patterns
- Project impacts under proposed regulations

- **DETERMINISTIC**

<u>INTERPRETATION</u>

- Average expectations
- Not exact predictions

Common Basis

- Stock-Age-Fishery

Exploitation Rates

Exploitation Rates

- Derived from CWT Analysis
  - Indicator Stocks (Predominantly Hatchery Origin)
    - Brood, rearing, & release strategies
  - Coastwide Recovery & Reporting
  - Cohort Analysis

Cohort Analysis

OBJECTIVE: Estimate

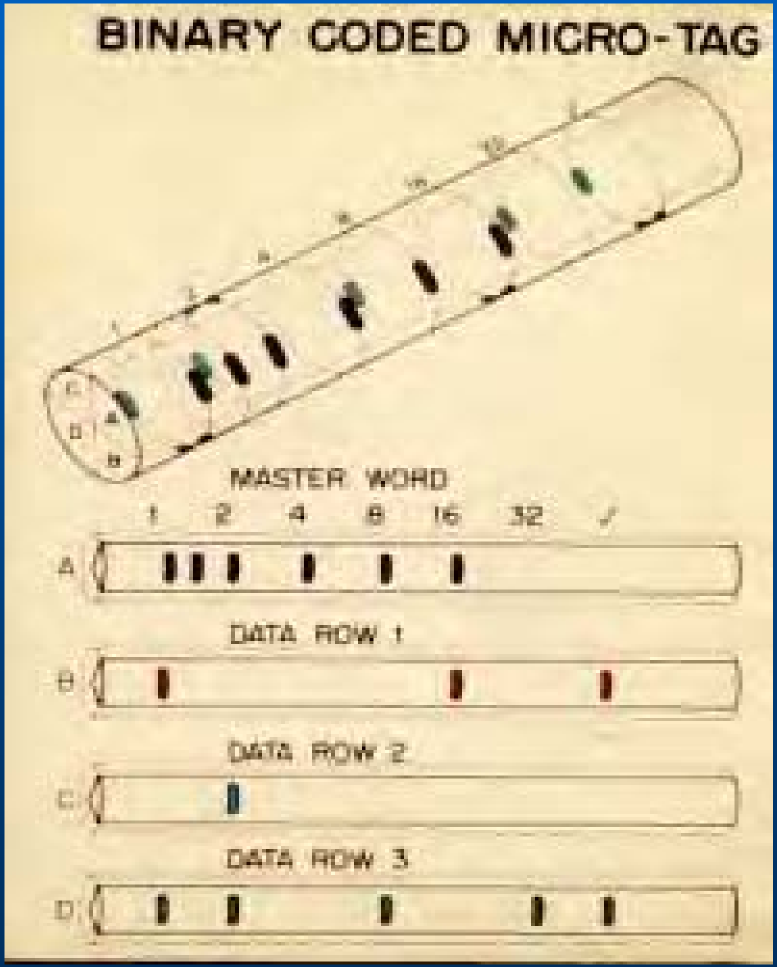
- ✓ Exploitation & Harvest Rates
- ✓ Maturation Rates

Technology:

Late 1970's Coded-Wire-Tags

Methods early 1980's

Coded-Wire-Tags



Harvest Management Planning for chinook and coho is based principally on CWT data.

Assessment and management of wild stocks of coho and Chinook salmon,

- Rely on CWT recoveries in fisheries and in escapement for indicator stocks (usually tagged groups of hatchery fish) to reconstruct cohorts and to make inferences about exploitation rates for associated wild stocks.

The CWT Program is vital to salmon management

- Only historic record of stock-specific impacts over time
- Fully integrated tagging, sampling and recovery programs coastwide
- Sufficient resolution to support thousands of simultaneous stock-specific experiments
- High homing fidelity, semelparity, and coastwide recovery enable cohorts to be readily constructed

1985 Pacific Salmon Treaty Memorandum of Understanding

"The Parties agree to maintain a coded-wire tagging and recapture program designed to provide statistically reliable data for stock assessments and fishery evaluations."

CWTs are inserted into nasal cartilage of juveniles

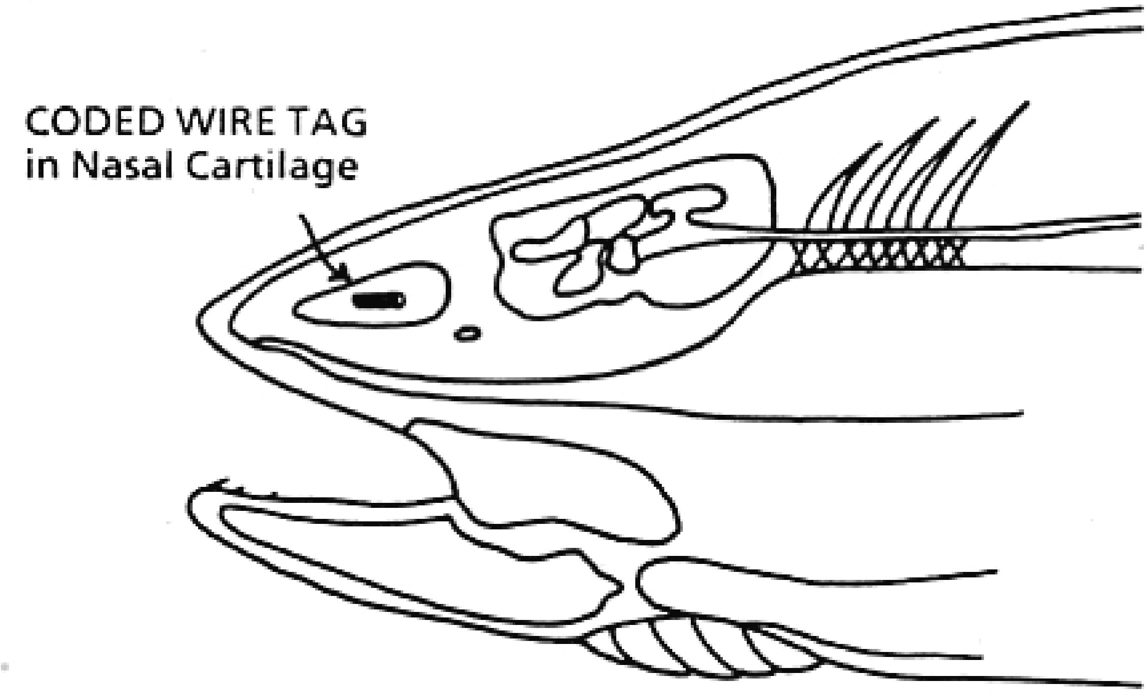


FIGURE 1.—Longitudinal section through the head of a juvenile salmonid showing the correct placement of a coded wire tag in the nasal cartilage. (After Koerner 1977.)

Each Year Millions of Juveniles are CWT'd & Ad-Clipped

Clip=Visual cue

Each Year Millions of Juveniles are CWT'd

- ~ 45 million smolts
  - ~ 32 million chinook
  - ~ 8 million coho
- 55 federal, state, tribal & private agencies
- $ 5 million for tagging
- $12 million for recovery

Some Uses of the coastwide CWT program

Research to improve understanding
- Experimental Studies to improve survival
- Estimating hatchery contributions to fisheries
- Evaluate mitigation effectiveness
- Evaluating straying of hatchery production
- Evaluate diet, rearing, release strategies
- Brood stock selection

How are CWT data used in harvest management?

- Post-season evaluation of fishery impacts, pre-terminal and terminal
- Monitoring marine survival and exploitation rates
- Estimating in-season abundance
- Inputs for pre-season management models
- Abundance forecasts

Fishery & Stock Management Uses

Estimate fishery harvest patterns and impacts

- Modeling
- Monitoring

Indicator Stocks

- Commonly hatchery stocks, selected to represent wild or naturally produced stocks of salmon
  - Data collection (especially escapement estimation & recovery)

- Tagged annually to provide estimates of stock and fishery statistics

What information does the Indicator Stock Program Provide?

- Total release
- Recoveries in fishery by time, area, and age
- Recoveries in spawning escapements
- For individual release groups

What can we estimate with this information?

- Distribution patterns of fishery mortality (time, area, age)
- Maturation Rates – Proportion of fish at a given age expected to spawn
- Marine Survival – Proportion of all releases recovered in fisheries or escapement.
- Fishery Exploitation Rates – Proportion of population caught or killed by fishery strata

Stock-Age-Fishery ERs Derived From CWT Indicator Stocks

- Selected *CWT indicator stock* and associated wild stocks have same ocean migration path and timing.
- After entering marine waters and before returning to terminal areas where they might be differentially impacted by fisheries.

Validation

- **Coho** - wild stock tagging in Puget Sound, Washington coast and Canada.
- **Chinook** – progeny from wild and hatchery brood stock tagged as indicator stock groups. Some wild stock tagging in Alaska.

An Emerging Tool
Mark-Selective Fishing

Mark Selective Fisheries (MSFs)

Sort & keep

- Mass Mark Hatchery Fish
- Retain ad-clipped fish
- Release others

How can MSFs affect the viability of the CWT Program?

- The ad-clip is used as a mass mark to identify hatchery fish
  - **Mass marked fish can be kept**
  - **Unclipped fish must be released**
  - *Under MSFs, mass marked and unmarked fish do not experience the same patterns of exploitation*

Why use the ad-clip as a mass mark?

For years, the ad-clip was used to indicate the presence of a CWT.

The ad-clip was selected as the mass mark because

- Visible & familiar
- Minimal mortality
- Minimal variability in mortality

PSC Concerns For Viability of CWT program

- Establish Selective Fishery Evaluation Committee

- Viability defined:

1. Ability to use CWTs to make inferences on fishery impacts on wild fish
2. Not appreciably increase uncertainty for management

Implications of MSFs For Wild Fish

CWT groups associated with untagged (wild) fish

- **WITHOUT** MSF, CWT indicator stocks and untagged fish have same patterns of exploitation
- **WITH** MSF, marked & unmarked fish exploited differently (mortalities of unmarked fish no longer directly observed in MSF)

Can't use single CWT releases to estimate impacts on unmarked fish

Can this problem be overcome?

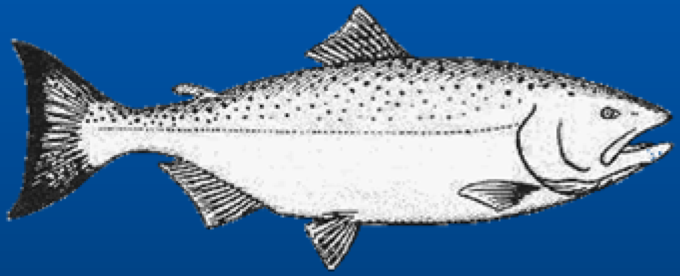
The PSC Ad Hoc Selective Fishery Committee (ASFEC) proposed to employ a double index tag system, or DIT.

What is DIT?

Two groups of fish, each with its own CWT, presumed identical, except that

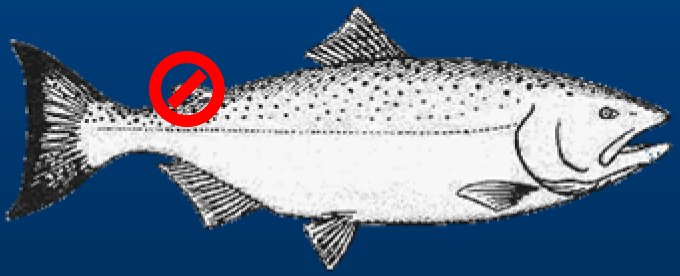
One group is unmarked

represents wild fish



And the other is marked

Represents hatchery fish



Lose Independence of CWT groups

Paired CWT groups to estimate impacts on unmarked fish

- Double the number of CWTs released and processed
- The two groups must be identical except for the mark
  - Same broodstock
  - Same treatment during rearing, tagging and release

DIT, Cohort Analysis, & Viability

CWT recoveries of DIT groups

↓

SFEC-AWG Methods

↓

Mortalities of Unmarked Fish in MSF

↓

Cohort Analysis

↓

Exploitation Rates

Maintain Viability of CWT Program?

Types of mortalities

- **Non-Selective**
  - Catch
  - Drop-Off
  - Incidental (sublegal, species restrictions)
- **Mark-Selective fishery (within species)**

  Same, plus
  - Release Mortality
  - Multiple Encounters
  - Mark Recognition Error
  - Unmarked Retention Error

Requirements for DIT

- Recoveries of both groups in landed catch by all fisheries and in escapements.
  - Direct sampling programs
- Electronic tag detection may be needed to reduce costs of recovering CWTs

What can we estimate with DIT?

- All parameters for the tagged and clipped DIT group

- Rely upon the difference, or contrast, in recoveries between the two DIT groups to estimate cumulative unmarked mortalities in MSFs

What can we estimate with DIT?

For coho salmon we can use DIT to estimate the total mortality of unmarked coho in MSFs

- Assuming mark induced mortalities are known, or zero
- If the differences between the DIT groups are large enough

DIT Won’t Provide S-A-F ERs

Coho – unable to allocate mortalities among multiple MSFs

Chinook – same, plus fishery & natural mortality are confounded

Need a means to allocate differential mortalities for paired DIT groups

MSF Summary

Impacts on wild fish not based on recoveries for indicator stocks = increased uncertainty

Estimates of mortalities of unmarked fish depend on:

- The intensity of MSF
- Sampling of fisheries and escapements
- Association between marked and unmarked fish in DIT tag group
- Assumptions (e.g., release mortality rate, drop off, multiple encounters)

IV
CWTs and GSI Methods

Current Harvest Management

What are the Weaknesses?

And the Strengths?

Weaknesses

- Overly dependent on models
  - Unrealistic view of model results
  - Deficiencies in documentation
  - Dependence on a few individuals
- Fishing constituents engage in gaming (taking advantage of quirks in available data)
- Incomplete picture of stocks and fisheries coastwide

Weaknesses

- Technical limitations
  - Deterministic, uncertainty not reflected
  - Stock-Fishery-Time Strata
  - Discrete catch equations
  - No fishery interactions between concurrent fisheries
  - Single pool structure (exploitation rates vs harvest rates)
  - Dependence on base period data
  - Biased estimation (e.g., linear structure, MSFs)

Strengths – Experts on tap, not on top

- Consistent methods for analysis accepted by co-managers & users
  - Force resolution/containment of technical issues and disputes over data, assumptions, and methods
  - Decision makers can focus on issues
- Provides useful information for decision-making in timely manner
  - Organize relevant information and make it readily accessible
  - Independent exploration of alternatives – manager & constituency access to expertise
  - Rapid turnaround of scenarios
  - Custom reports to meet specific needs

Strengths

- Expectations can be evaluated using observational data in short time period
  - Catch & effort
  - Escapement & exploitation rates
- Annual review & evaluation of performance provides opportunity for correction and improvement
  - Bias correction
  - Methods & model improvements
  - Incorporate new information, e.g., El Nino, monitoring of MSFs, research results

How Good Are Our Models?

- Are they perfect?

  Not by any stretch of the imagination

- Are they the best that we could do?

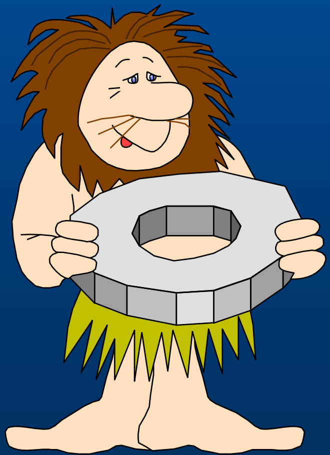
  NO – We could do better, but for…

- Are they the best we have?

  YES. despite their warts and pimples

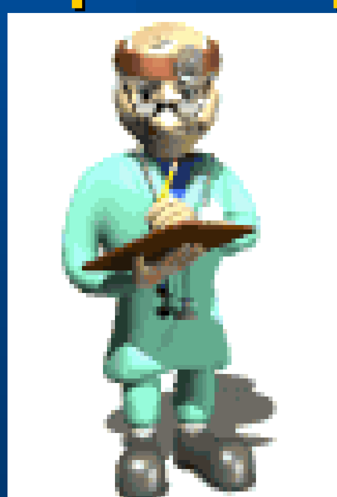
Changing Social Climate

- Diminishing public trust in government and regulation
- Reduced funding for management
  - Deteriorating capability



Current Situation

- Escalating demands for more information
- Models and assessment tools are being pushed beyond their capabilities
  - Expected precision of ERs is <0.1%



CWT's – Basic source of data for 30 years

Most Suitable

- Cohort Analysis for individual release groups
  - little chance for assignment or aging error

Less suited for

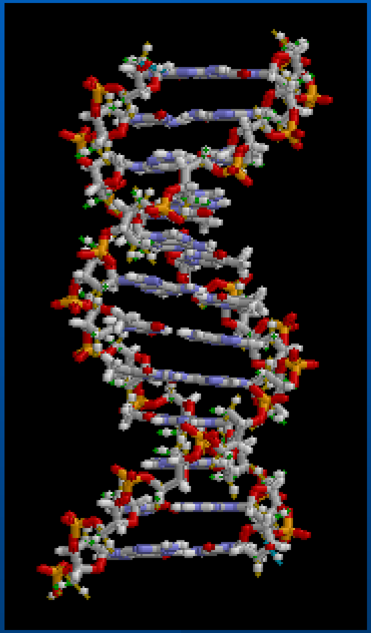
- Estimation of non-catch fishing mortalities
- Fine-scale shaping based on in-season data
- Estimation of stock composition

Concern for CWT system

- Increasing uncertainty as fishery harvest rates decline
- New management measures (e.g., mark selective fishing)
- QA/QC with data reporting

PSC Expert Panel and CWT Workgroup

Genetic Stock Identification Methods



- Semelparity and high degree of homing fidelity leads to genetically distinct populations

- How can genetic methods improve salmon management?

Framework For Evaluation

Consistent way to evaluate the capabilities of CWTs and alternative and/or supplemental technologies

Data & Process Matrices

Reference:

Morishima, G.S., and Alexandersdottir, M. 2004. Data matrix: requirements for assessment of fishery impacts on salmon stocks.

Efile: datamatrix2004.pdf

Sample Design

Level of resolution required is fishery, period, stock and age.

- Fishery and period provided by sample design stratum
- Stock & Age provided by CWT indicator tag group code

Sample Design

Coverage is all fisheries on migration path of the stock and in all escapement locations

- Coverage is provided by sample design stratum

Data & Process Matrices

- **Data** required for cohort reconstruction,
- **Sample design** (indicator stocks, fishery and escapement locations and periods sampled, numbers tagged and proportions of harvest and escapement sampled),
- **Methods and costs of data collection** and uncertainties due to these methods,
- **Coastwide protocols** for coordination and reporting,
- **Accepted analytical methods** to estimate exploitation rates and their uncertainty.

Estimates needed and Derivation

ESTIMATES	DERIVATION
Landed catch and escapement	Directly from catch sampling
Natural & incidental fishing, and pre-spawning mortalities	Assumption-based

Depends on method: CWTs, otoliths, GSI

Uncertainty in general

What is it?

- **<u>Precision</u>: Sampling error**
- **<u>Bias:</u> Directional error**

Reducing Uncertainty

Precision - # recoveries can be improved by increasing sampling and/or tagging rates.

Bias – unsampled fisheries or escapements, invalid assumptions

Uncertainty cannot be reduced below the level of bias

GSI Issues

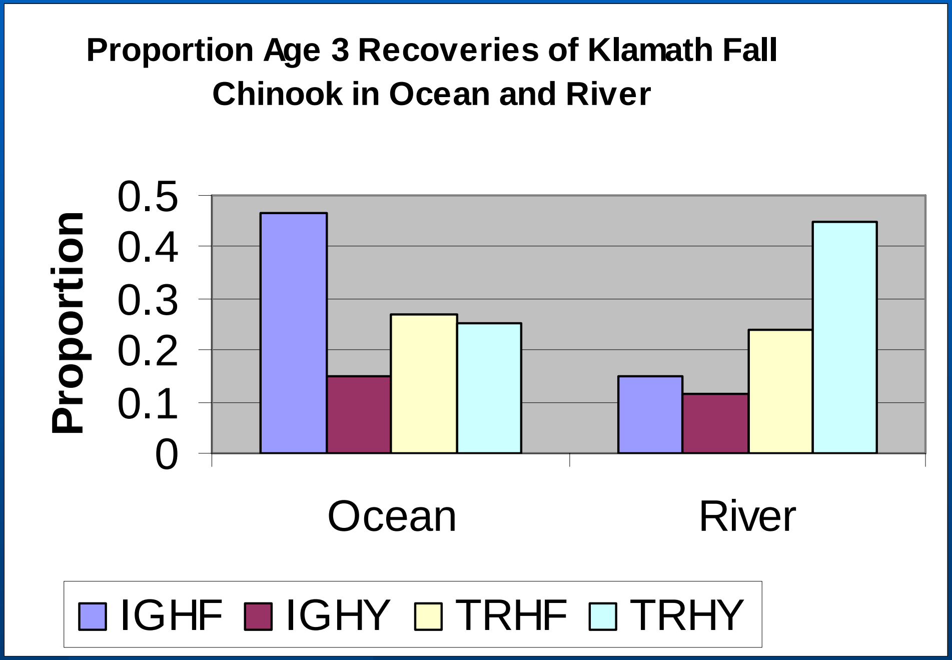
Uncertainty of estimates
- Level of resolution
- Precision and bias (Sample size requirements)
  - Stock/Age assignment error
  - Adequacy of baseline
- Detection, consistency and predictability of distribution & migration patterns

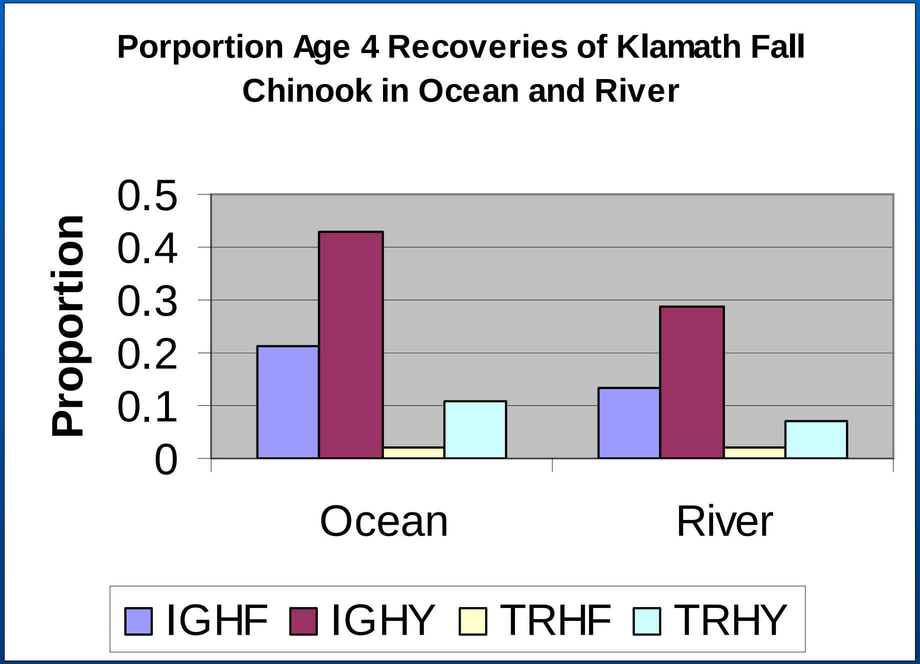
Coastwide coordination and accepted methods of analysis

Comparison of CWT and GSI

	CWT	GSI
Resolut'n	Individual release group. Stock, race, brood year, release type, size, location, time	Depending on level of resolution needed, current GAPS baseline may require auxiliary means to separate fish with similar genetic characteristics

Example: Differences in Ocean and River - CWT Recovery Patterns 1983 BY Klamath Fall Chinook





Ocean Distribution, Exploitation and Maturation Rates Differ Among Component Populations

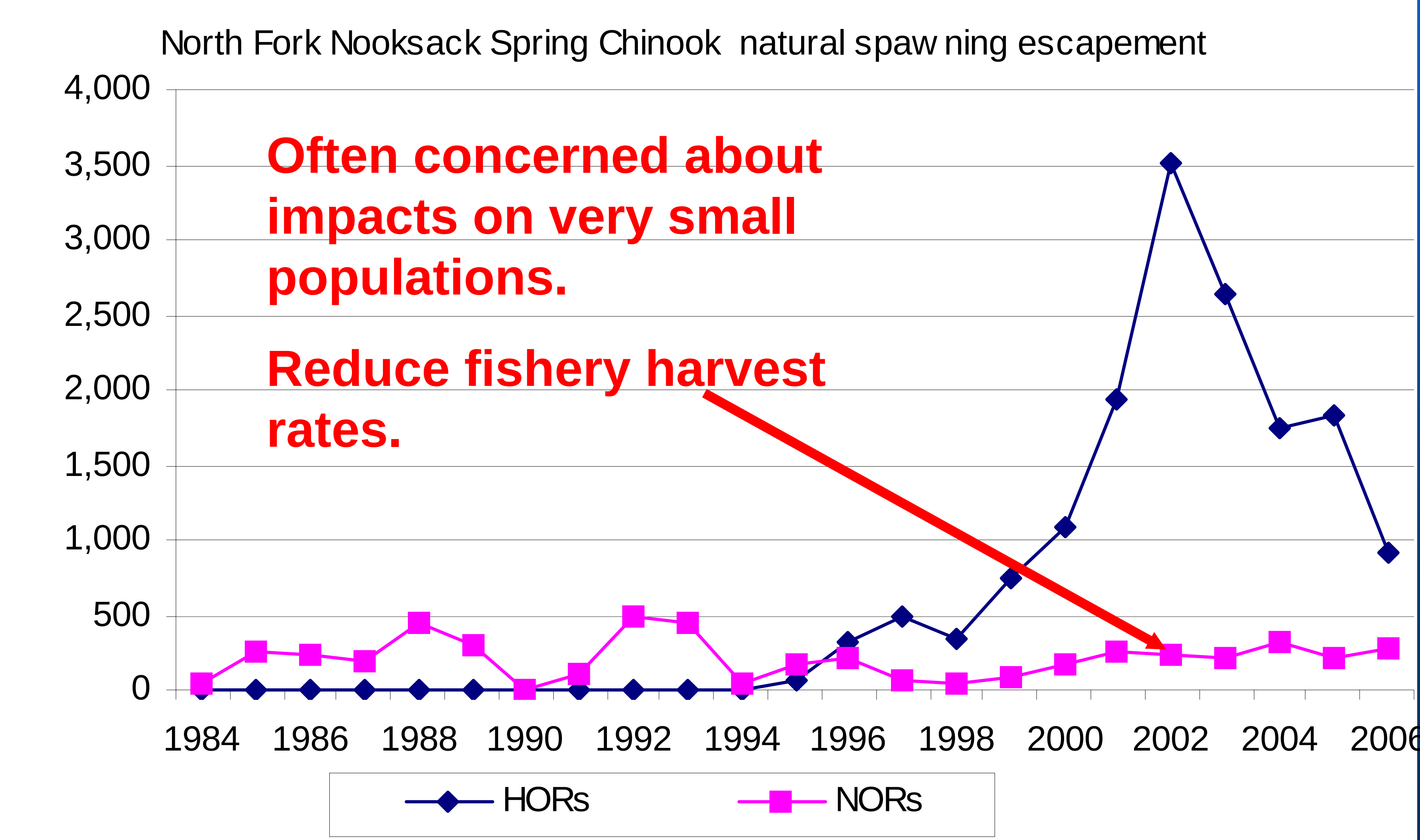
Example: Aging Error As Well
2004 Klamath Fall Chinook Scale Validation

		Known Age (from CWT)			
		2	3	4	5
Scale Age	2	102	**6**	**0**	**0**
	3	**4**	510	**52**	**0**
	4	**1**	**40**	540	**15**
	5	**0**	**0**	**2**	8
		Percentages			
Scale Age	2	**95.3**	**1.1**	**0.0**	**0.0**
	3	**3.7**	**91.7**	**8.8**	**0.0**
	4	**0.9**	**7.2**	**90.9**	**65.2**
	5	**0.0**	**0.0**	**0.3**	**34.8**

Comparison of CWT and GSI

	CWT	GSI
Accuracy & Precision	Depends on number of CWTs recovered and QA/QC for sampling and reporting. Little chance of stock or aging assignment error	Depends on adequacy of baseline to represent populations of interest, sample size, and the proportion of the stock of interest in the sampled population. Stability of genetic baseline is a concern, particularly for small populations. Assignment error can bias estimates, particularly for stocks that comprise a small proportion of the sampled population.

Chinook escapement summary: NF Nooksack



GSI

Most Suitable

- Estimating contributions of major stocks in/post-season
- Non-Lethal sampling
- Parentage analysis

Less Suited For

- Estimating contributions of small stocks
- Cohort analysis (assignment/aging error, escapement estimation)

What's the applicable standard?

- Scientific certainty?

- Acceptance by co-managers
- Best available scientific information

The End