

Selective Fisheries Evaluation Committee

Analysis of
Coho Salmon Double Index Tag Groups
for Brood Years 1998-2011

April 19, 2022

SFEC - Selective Fisheries Evaluation Committee

- Provide advice to PSC regarding adverse impacts of on the viability of the Coded Wire Tag (CWT) system.
- Review Mark Selective Fishery (MSF) and Mass Marking (MM) proposals.
- Assess and monitor cumulative impacts of MSFs on stocks of concern.
- Develop analytical tools for estimating impacts of MSFs on escapement and exploitation rates (ERs) for stocks of PSC concern.
 - DIT - Double Index Tag groups is one tool

SFEC presentations

- A brief primer on MSF and DIT
 - What is an “MSF Impact” ? How are we thinking about this?
- DIT report – try to answer
 - Did MSFs cause differential ERs? – Total Impact question [Section 2]
 - Can we estimate the unmarked ER? How? [Section 3]
 - Do we really need DIT to estimate unmarked ER? [Section 4]
 - What about FRAM? [Section 5]
- Information – what a DIT group can answer, under what conditions
- Regional results [Section 6]
- Data gaps and pitfalls [Section 7]
- Recommendations [Section 9]
 - Improve DIT programs

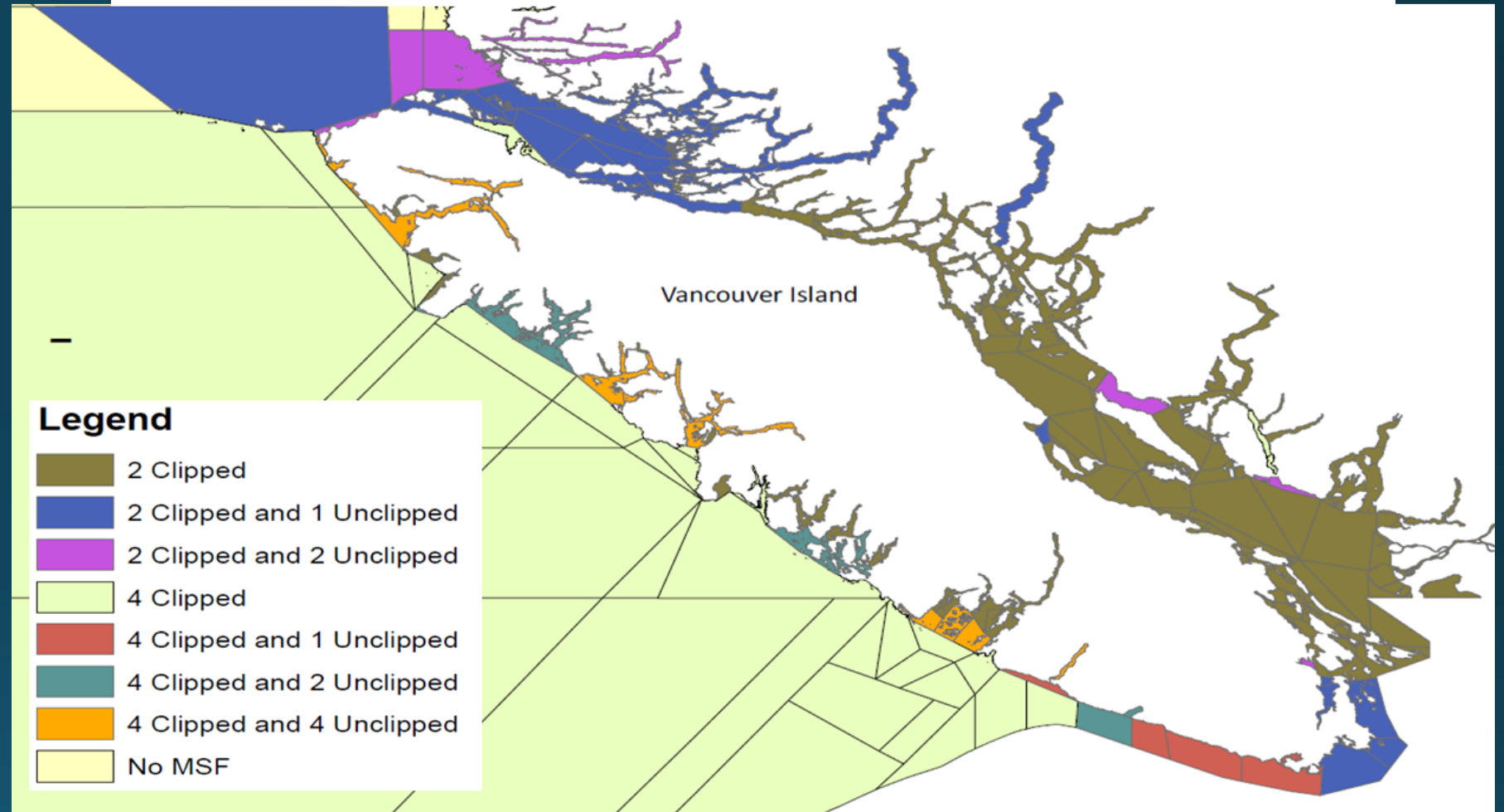
Hatcheries in study

- Analyzed DIT (CWT) data for 286 DIT groups
BC, WA coast, PS and Col. R. hatcheries
BYs 1998-2011
Return years 2001-2014



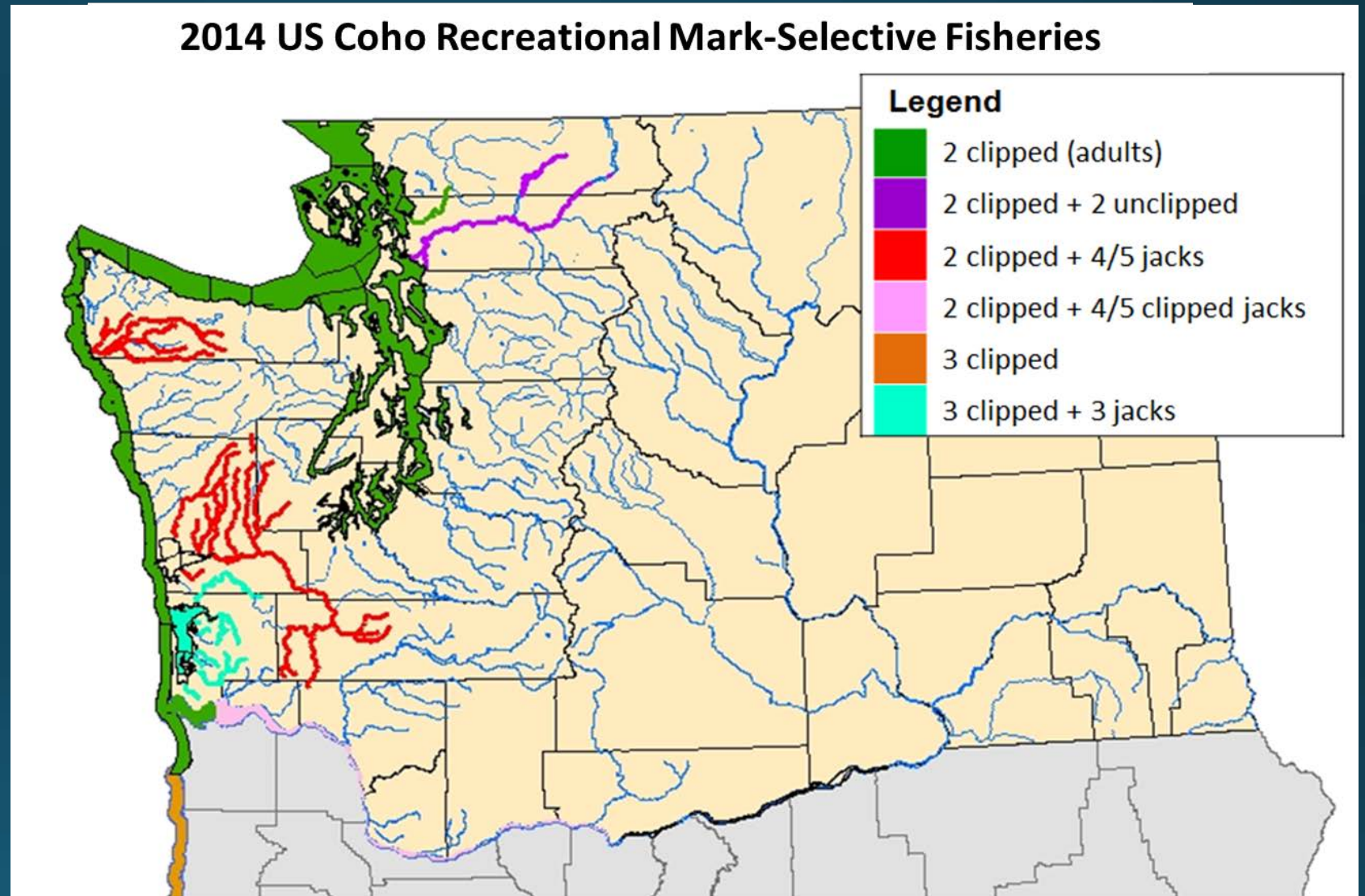
Fisheries

2014 BC Coho Recreational Mark-Selective Fisheries



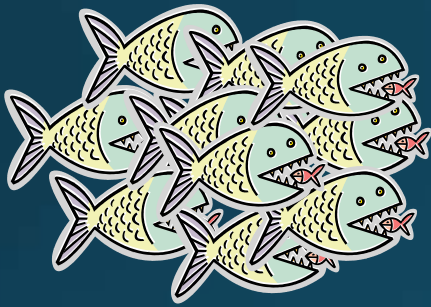
Mixed fishery – target marked, retain both marked (clipped) and some unmarked (unclipped)

Fisheries



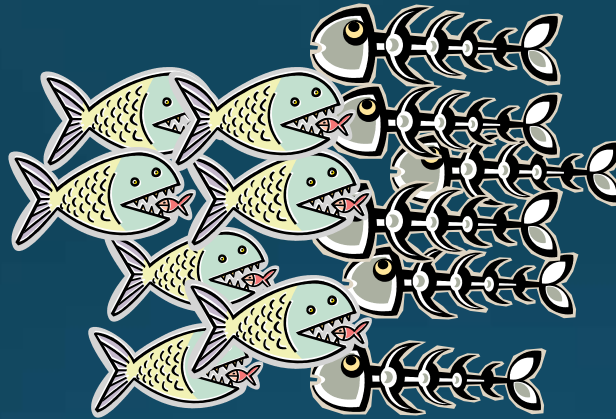
Mixed fishery – target marked, retain both marked (clipped) and some unmarked (unclipped)

In the beginning...

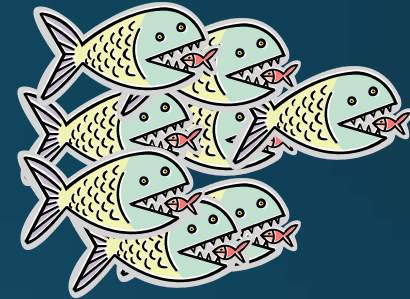


Pre-
fisheries

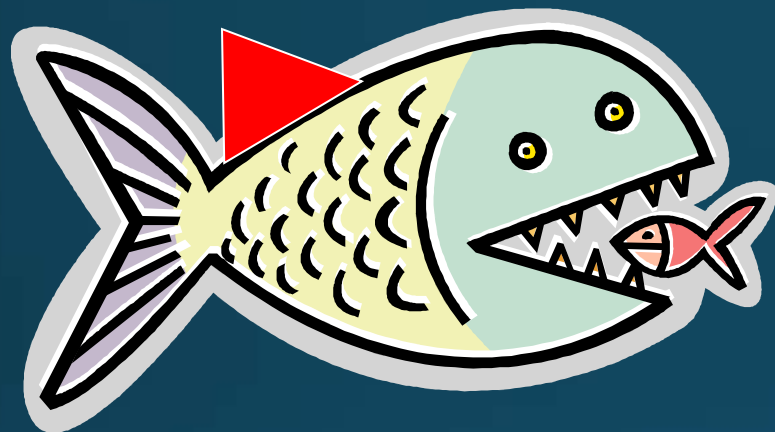
Releases,
recruits to
fishery



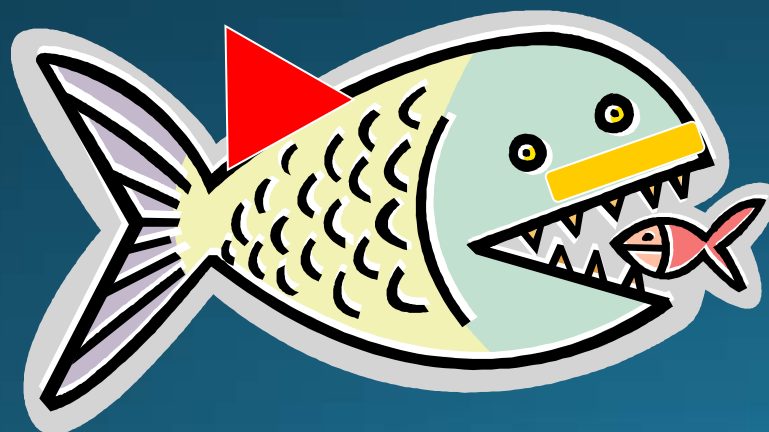
Fisheries



Escapement

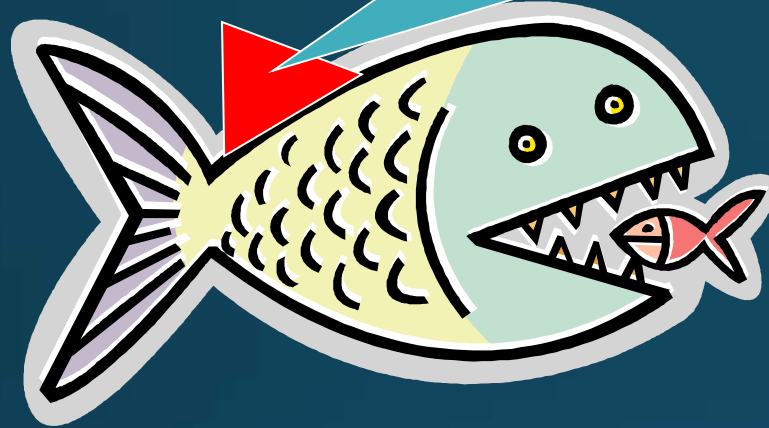


CWT

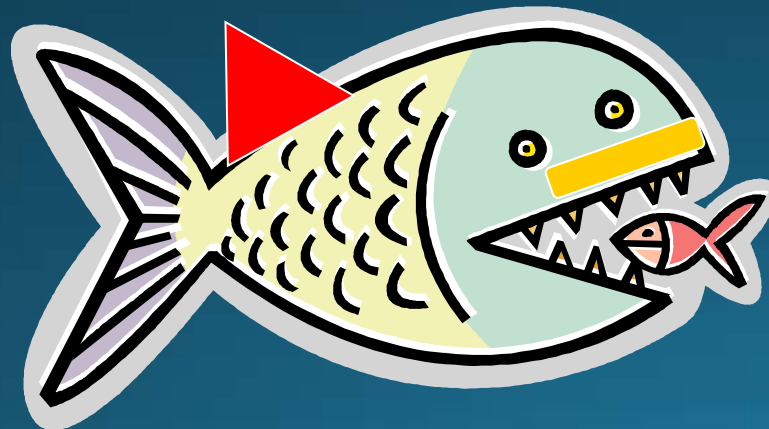







Adipose Fin

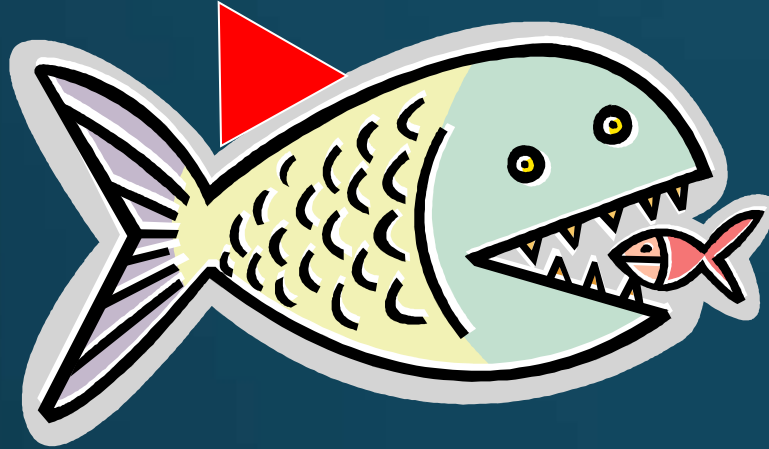


CWT

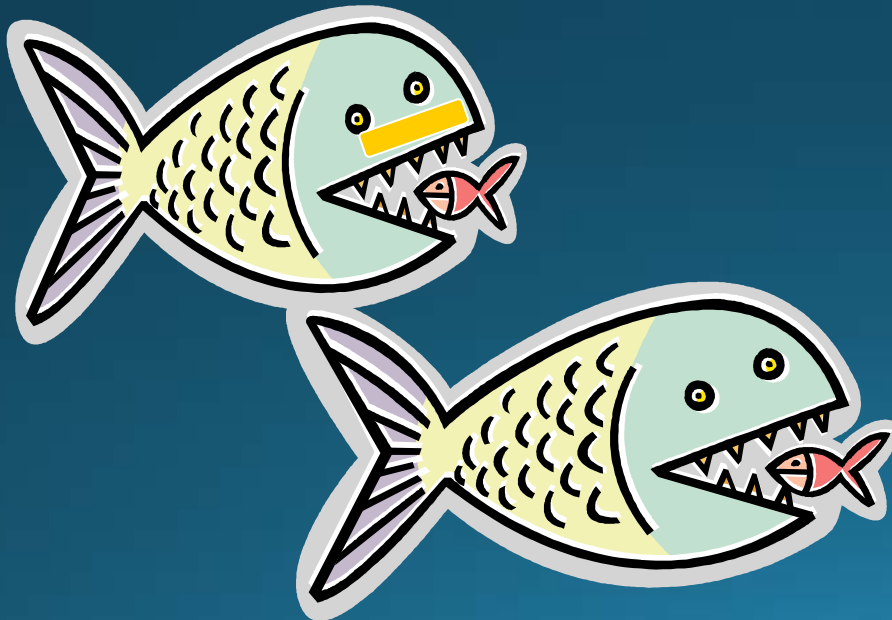


**Because all fish treated the same,
we assumed..**

	Hatchery ER		Wild ER
Fishery 1	10%		= 10%
Fishery 2	10%		= 10%
Fishery 3	2%		= 2%
Fishery 4	3%		= 3%
Escapement	75%		= 75%



UNMARKED



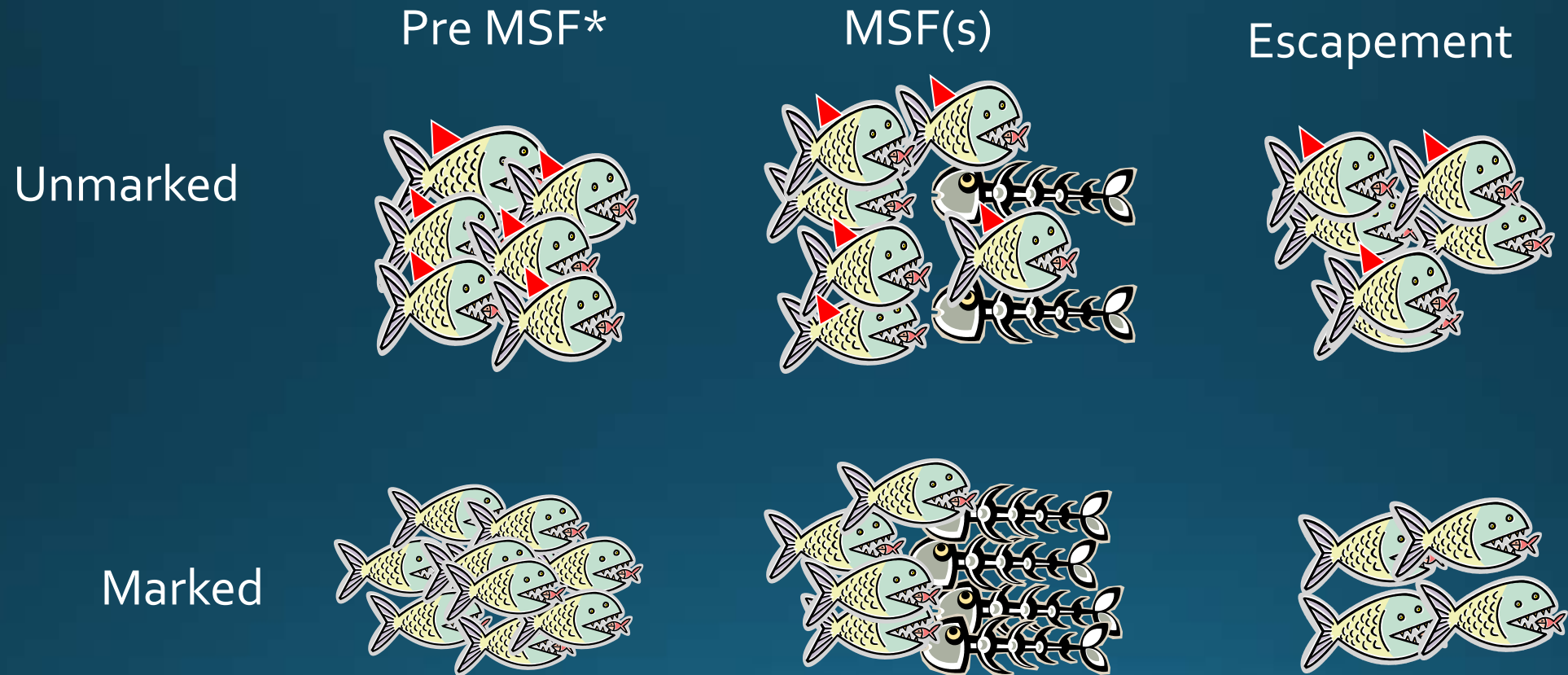
MARKED

Mass
Marking
(MM)

*Let's mark
all hatchery
fish!*

Uh-oh...

Let's go fishing, but keep only marked fish...

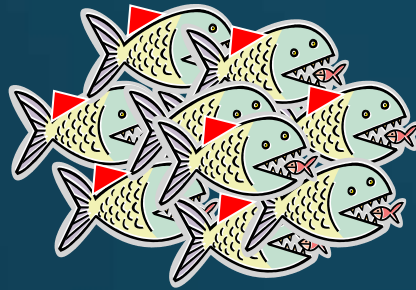


* Releases, recruits to fishery, NSFs

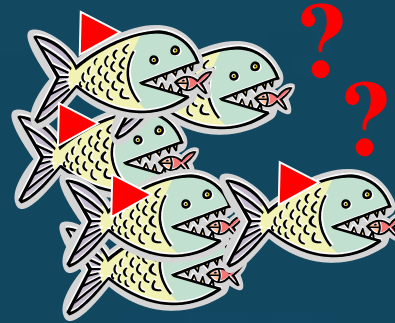


Unmarked

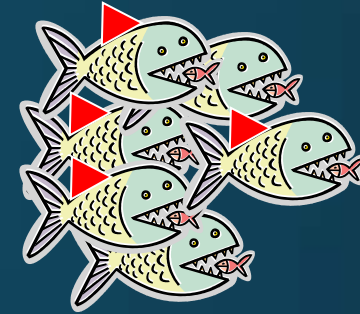
Pre MSF



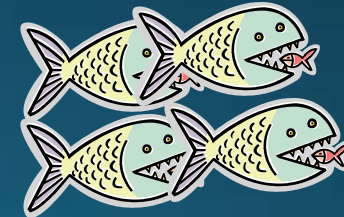
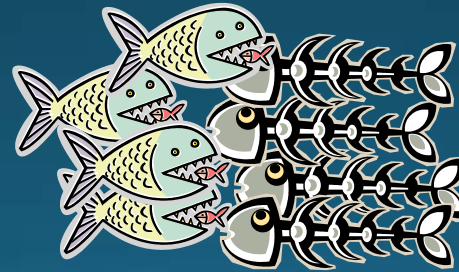
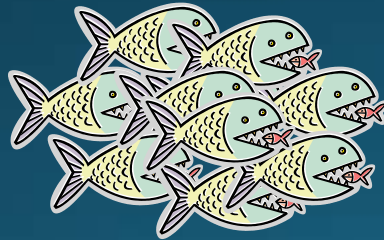
MSF(s)



Escapement



Marked



Imapcted ability for marked hatchery fish ER to represent naturally spawning ER

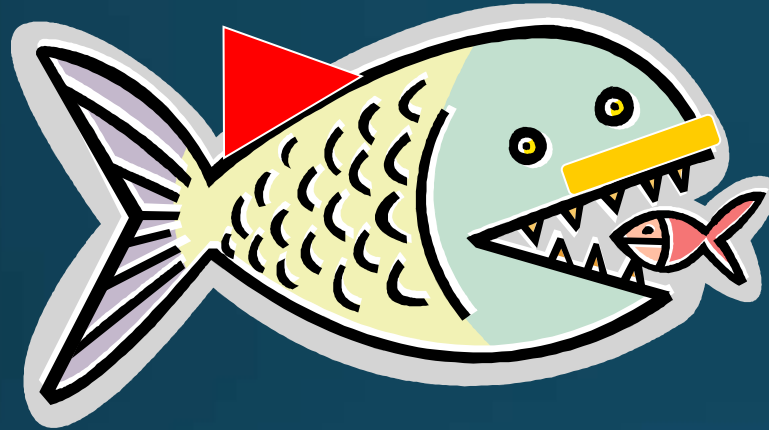
	Hatchery M ER	Hatchery U ER	Wild ER
MSF Fishery	10%	?	?
NSF Fishery	10%		
MSF Fishery	2%	?	?
MSF Fishery	3%	?	?
Escapement	75%		

*MM and MSF
Impact
can be
viewed as
Information
Impact*

Double Index Tag – DIT

- A tool to assess potential impacts by MSFs on information
 - Differential ERs on marked, hatchery fish and the naturally spawning stock
 - Use DIT to estimate unmarked ER
- Consists of
 - Group of Marked fish and Unmarked fish
 - Both groups have CWTs (hence “double” – M&T or U&T)

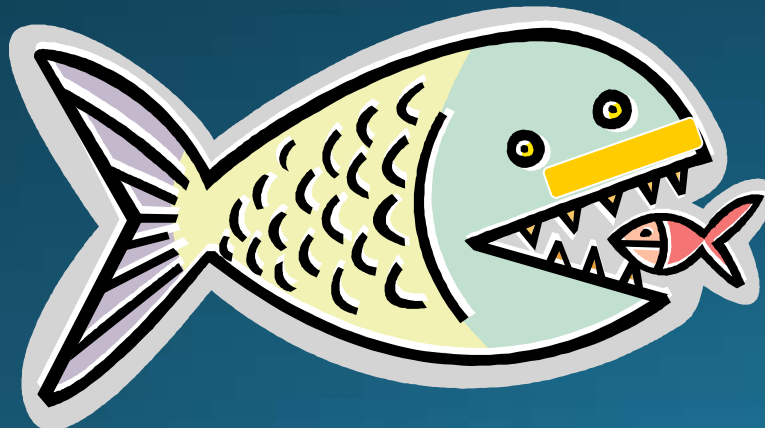
Unmarked & Tagged



Unmarked & CWT

U

Marked & Tagged



M

Marked & CWT

*Still have that pesky visual
sampling problem...*

How do we determine if there was an MSF impact with DIT?

- Look at release and returns numbers of marked and unmarked fish
- In relation to assumption that MSFs are the only source of return differences



Assumptions: make DIT informative

- Marked and unmarked groups are identical except for mark status
 - Rearing and release methods are the same
 - Sampling and handling at escapement are the same
- *No differential mortality except for that due to MSFs*



DIT group – 2 important quantities

- Relative return rates marked and unmarked fish – p_m and p_u , respectively
- Ratio of unmarked to marked fish - U/M or λ

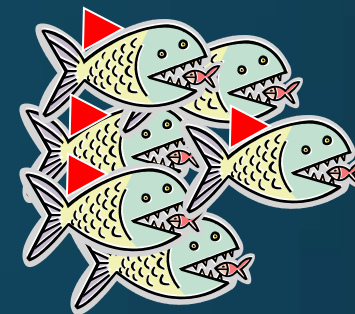
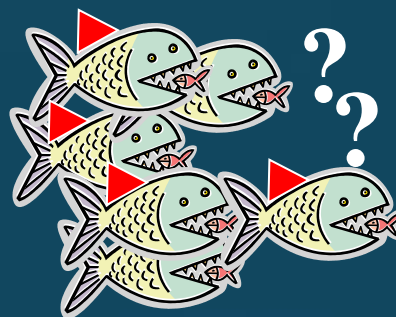
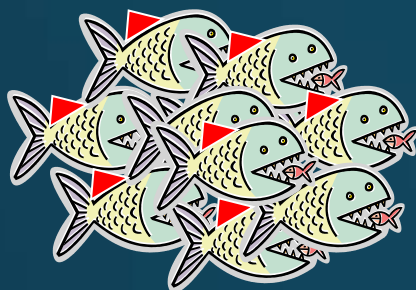
Get comfy with both – we will be using them a lot!

Pre MSF or
Release

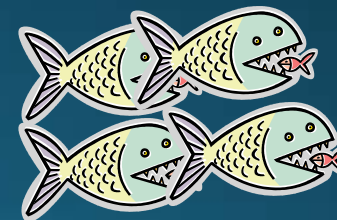
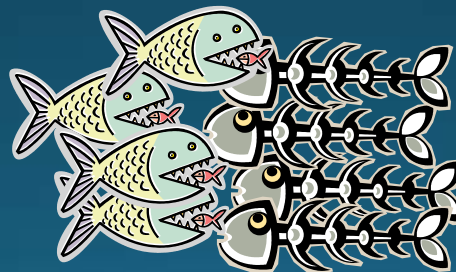
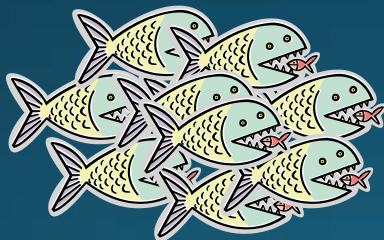
MSF (S)

Escapement

Unmarked



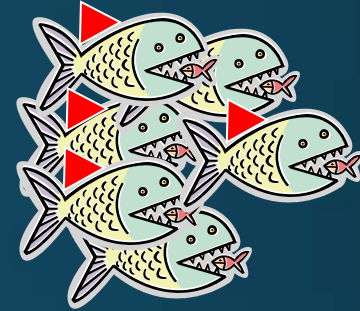
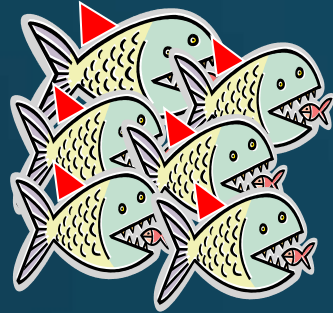
Marked



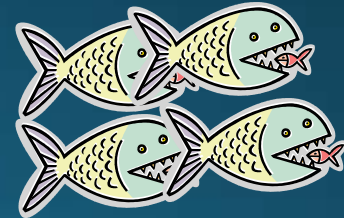
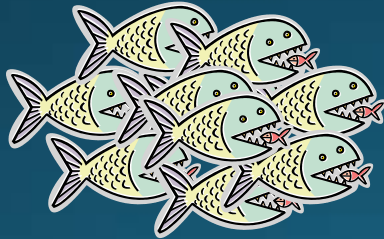
Release

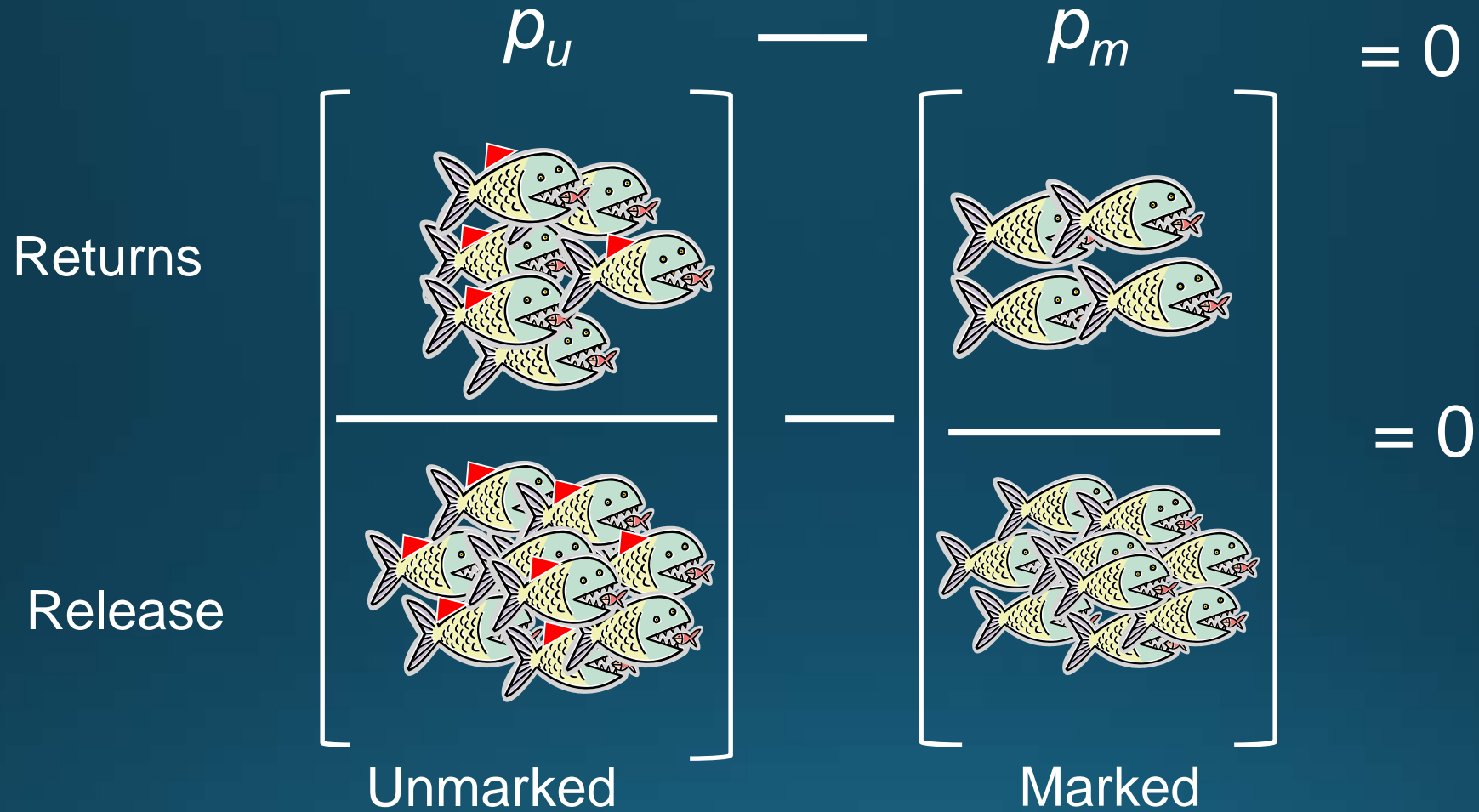
Escapement
(Returns)

Unmarked



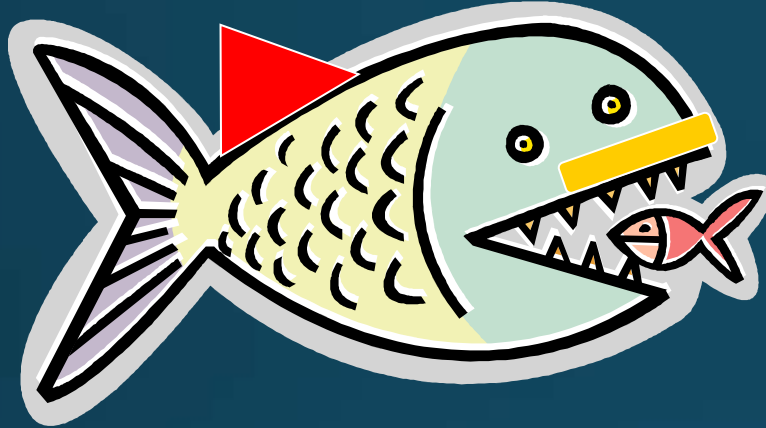
Marked





1st metric for total impact – Difference the proportion of returns out of releases

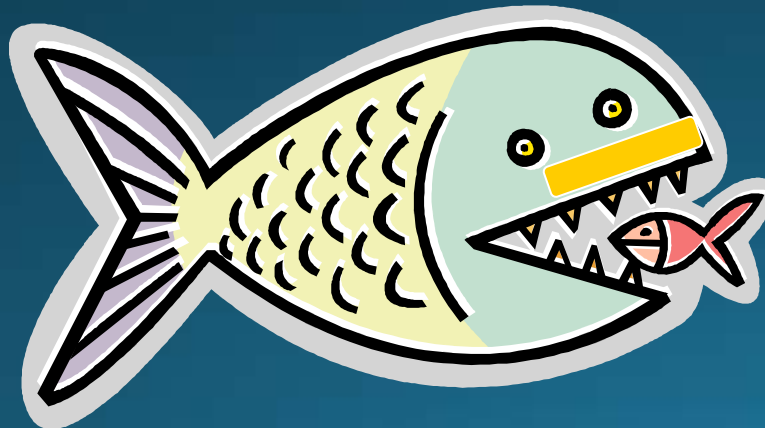
Unmarked (U) & Tagged



Unmarked & CWT

$$\frac{U}{M} = \lambda$$

Marked (M) & Tagged



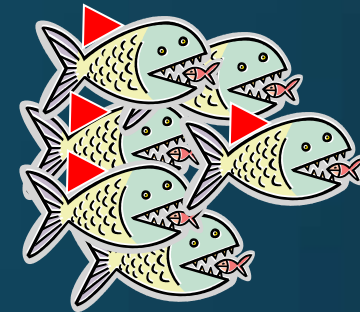
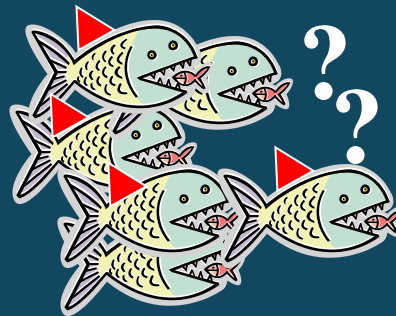
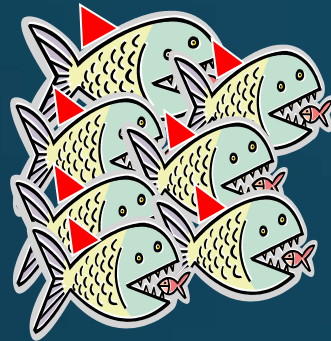
Marked & CWT

Pre MSF

MSF (S)

Escapement

Unmarked

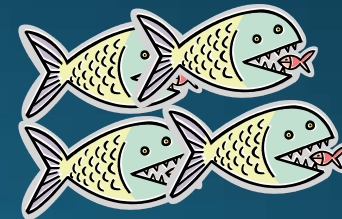
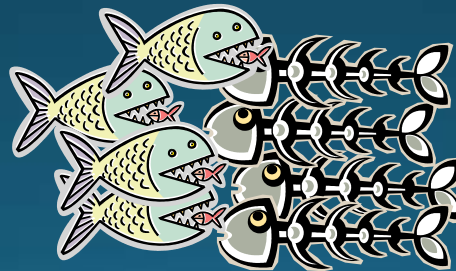
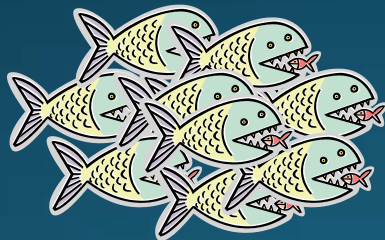


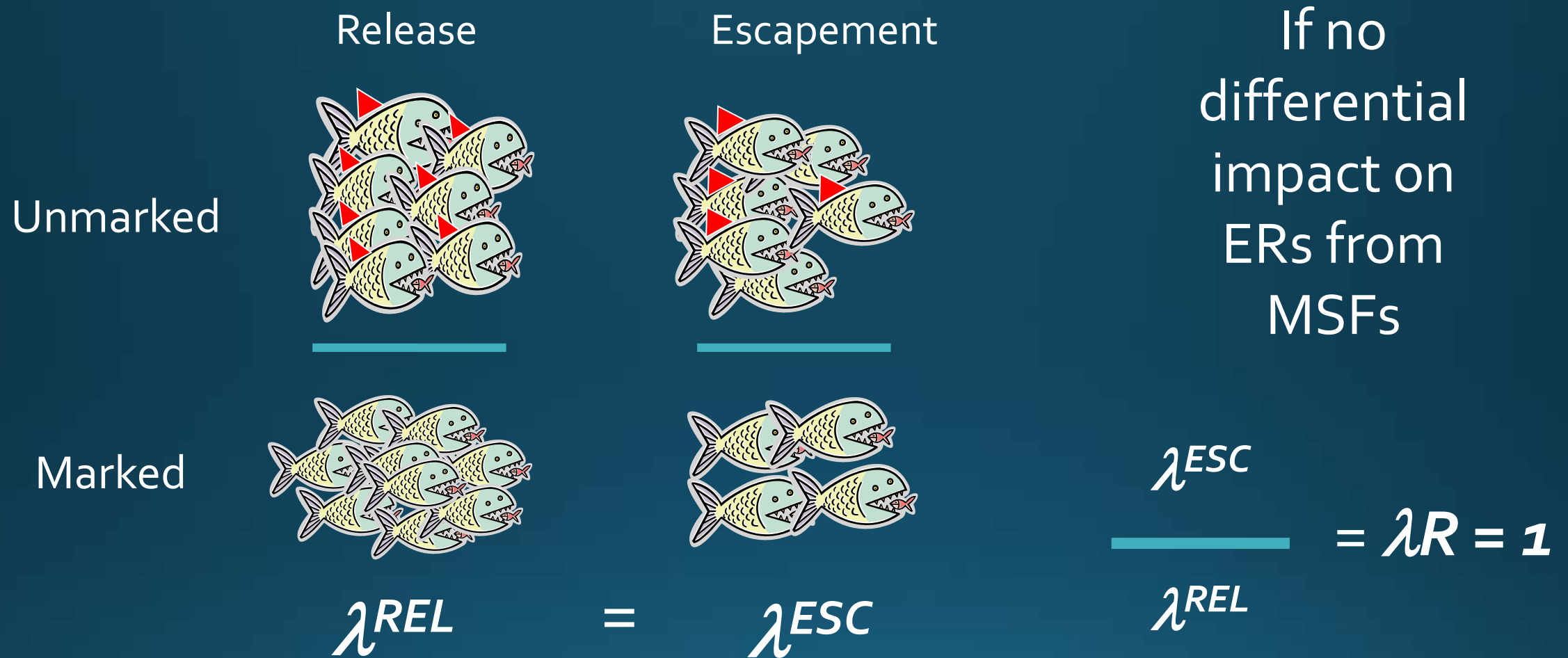
λ^{REL}

λ^{SF}

λ^{ESC}

Marked





- A metric for total impact AND
- Quantity to estimate Unmarked fishery mortalities



DIT – Detect a total MSF impact? [Section 2]

- Conducted 286 tests on Metric 1 ($p_u - p_m$)
- 286 confidence intervals on Metric 2 (λR)
- Results
 - 48% of Z- tests were significant, 87% of which were positive ($p_u - p_m$)
 - 76% of the 286 λR values were ≥ 1
 - Negative z-statistics and/or $\lambda R < 1$ may indicate sampling and/or data quality issues

Not the important part...

DIT pair – Detect total impact? [Section 2 & 7]

YES ! DIT can be informative that marked and unmarked fish had different ERs ...

...Under the following conditions

- Returns of both marked and unmarked groups > 1000 fish
- 33% of marked CWT recoveries occurred in MSFs

This is the important part, and we'll see it again

Yes, we can detect a difference in return rates, but...

- Have not developed the “So what?”
 - Difference of concern - biological/management
 - How often we want to detect that?
 - Speaking to the Type 2 errors and detectable differences
- A “next step” that involves bigger audience

Estimating unmarked mortalities [Section 3] (and unmarked ERs)

- Different ERs for marked and unmarked fish. Now what?

$$ER^U = \frac{\text{Unmarked CWT All Fisheries}}{\text{Unmarked CWT All Fisheries} + \text{Unmarked CWT Escapement}}$$

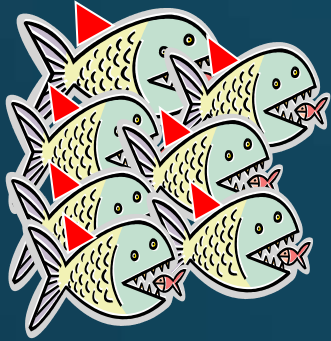
BUT Don't recover tags from unmarked fish in

- Visually sampled non-selective fisheries
- Incidental mortalities in MSFs

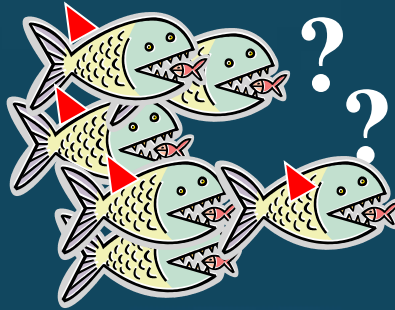
What's the information in DIT on stock/cohort specific unseen mortalities?

Unmarked

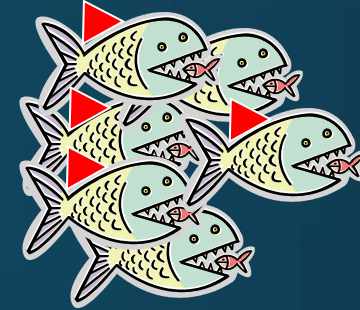
Release



MSF



Escapement



λ^{REL}

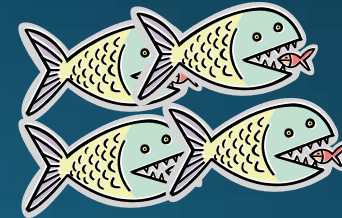
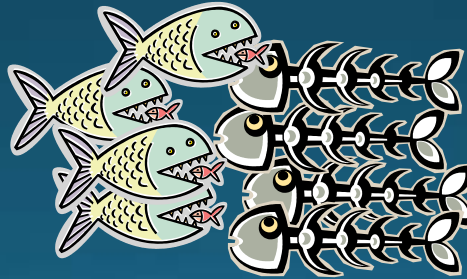
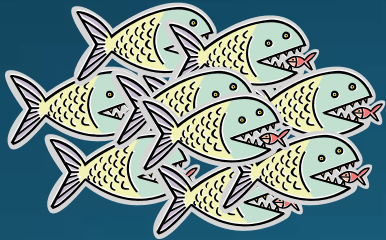
<

λ^{MSF}

<

λ^{ESC}

Marked



Use the information in the ratio of unmarked to marked fish in the DIT pair to estimate unmarked mortalities

Paired ratio method - *Unmarked mortalities* (U^{MSF})

Calculate U^{MSF} for a CWT group i , to use in ER estimates

$$U_i^{MSF} = M_i^{MSF} * \lambda * sfm$$

Expanded
Marked
Fishery
CWT
Recoveries

$\frac{U}{M}$
 $(\lambda^{\text{Release}})$


Release
Mortality
Rate

Estimating Unmarked ERs [Section 3]

- Assumptions:
 - λ is an unbiased estimate of the λ in the MSF
 - s_{fm} is known with certainty
 - All marked fish are retained (Mark retention error = 0)
 - Unmarked fish are not encountered on multiple occasions in the MSF
 - All fish in a DIT pair can be adequately represented as a single population

Estimating Unmarked ERs – Results [Section 3]

- Small difference in estimated ER^U when using λ^{Rel} vs λ^{Esc}
 - ER^U calculated from λ^{Esc} (PR λ^{Esc}) was 40% higher, on average
 - Paired ratio (PR) method will produce adequate estimates of ERs
 - Use of λ^{Rel} or λ^{Esc} will depend on fishery location
 - PR method used for comparisons with FRAM ERs
(FRAM model – used by Coho TC, PSC. Does not use CWTs)
- YES – there is information in a DIT pair to estimate unseen, unmarked mortalities and calculate ER^U



Estimating U^{MSF} and ER^u - Single Index Tag (SIT)

[Section 4]

- Marked and tagged group *only*
- Assume $\lambda = 1$, and calculate U^{MSF} and ER^u as before
(Method in report a bit more involved, but this is basically it)
- Other assumptions
 - Legal sized marked fish not released
 - If successive small MSFs, λ does not change (much)
 - ERs in NSFs equal between marked and unmarked fish
 - *sfm* unbiased and known without error



Estimating ER_u - Single Index Tag (SIT)

[Section 4]

- Good correlation between SIT ERs and paired ratio ERs ($PR\lambda^{Esc}$)
 $r=0.96$
 - $PR\lambda^{Esc}$ is the maximum bound on ER
- SIT ERs were less than $PR\lambda^{Esc}$ 75% of the time
 - Average [DIT – SIT]: -0.14 to 0.131
- *As a cost-saving measure, SIT may be an adequate alternative for some hatcheries when expected total ERs < 40%*

Comparing FRAM (CoTC-PSC) to Paired Ratio ERs (DIT) [Section 5]

- Compared DIT-ER to FRAM-ER for marked and unmarked fish
 - Paired ratio estimates of total ER
- Estimates of U (unmarked mortalities) include drop-off mortality
- Only age 3 fish used in analysis
- Comparison metrics included
 - Differences between DIT-ERs and FRAM-ERs for marked and unmarked groups
 - Scatter plots of DIT-ER to FRAM-ER for marked and unmarked groups



Comparing FRAM to Paired Ratio ER - Results

- BC and Col. River – Pre-Terminal fishery ER
- Puget Sound and WA Coast - Pre-Terminal + Terminal (Total) fishery ER
- Correlations between DIT-ER and FRAM-ER
 - $r = 0.65$ for marked groups; $r = 0.69$ for unmarked
 - Lower than SIT vs PR (0.96)
- Differences in DIT-ER and FRAM-ER varied by hatchery
 - Unmarked fish - FRAM-ERs higher (58%)
 - DIT-ERs > FRAM-ERs more consistently at higher exploitations for both groups

Comparing FRAM to Paired Ratio ER (DIT): Differences

- FRAM relies on average stock distributions and harvest patterns from CWT groups released during a reference base period (1986-1992)

	FRAM	DIT
Unmark Retention Error	YES	NO
Mark Recognition Error	YES	NO (= o)
Multiple Encounters (for a fish)	YES	NO

Comparing FRAM to Paired Ratio ER (DIT):

- DIT may inform FRAM estimates of ERs because based on current data
 - Fisheries may have changed substantially over time
 - Highs and lows ERs are not averaged



Components of a DIT program – what makes DIT informative

- Hatchery
 - Rearing and release conditions for both group equal
 - Marking and tagging support
 - Adequate release size of each component – marked and unmarked
 - Sampling at return - Electronic tag detection (ETD), 100% of return preferred
- Fisheries
 - ETD of all landed fish in all fisheries
 - Estimates of encounters and retained fish in all fisheries
 - Ability to identify catch by fishery regulation
- Accurate, accessible release and recovery information

Regional analysis [Section 6]

- Reviewed DIT programs by region on basis of components
 - Release sizes – adequate for recoveries (> 1000)?
 - Tag recoveries
 - Fisheries - % caught in MSFs vs Non-selective fisheries (NSF)
 - Sampling - % recoveries ETD vs visual, for each group
 - Total ERs
 - Assess quality of information from DIT groups
 - Potential biases and uncertainties in estimates
 - Coverage of stocks



Putting it all together – findings, recommendations [Section 7 and 9]

- DIT and its ability to be informative as a tool
 - Assessing if MSF impacts exist for a stock
 - Estimating U^{MSF} and ERs where we have impacts (or think we do)
- Fishery sampling -recommendations
- Selective fishery mortality rates (*sfm*) and data quality issues
- Reliable alternatives to DIT?
 - SIT
 - FRAM ERs - information from DIT relative to FRAM

Evaluation of estimation methods

[Section 7.1]

- Paired Ratio method [Section 3.2]
 - Uses ratio of unmarked to marked fish (λ), marked encounters, and s_{fm} to estimate
 - Unmarked mortalities in MSFs
 - Exploitation Rates of unmarked fish
- Reliable method when assumption were met
- Estimates will be bracketed by λ^{Rel} (low) and λ^{Esc} (high)

DIT programs and fishery sampling

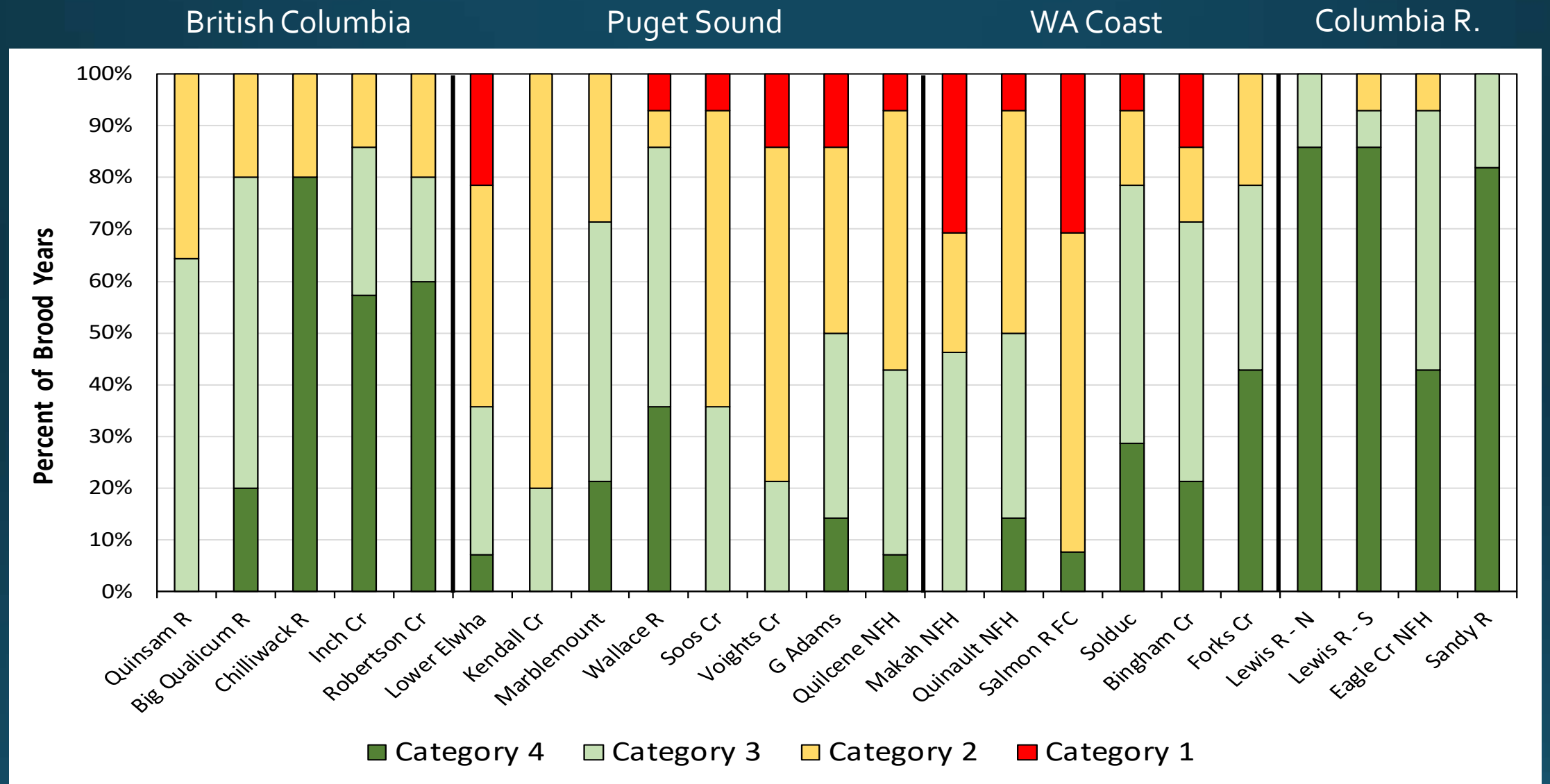
[Section 7.2, 7.3, and Section 2]

- Determined significant impacts from MSFs
 - Z-test for difference in return proportion ($p_u - p_m$)
 - 95% CI on λR (does interval include 1?)
 - Z-test of estimated marked and unmarked ERs [Section 3]

Assessment categories for each DIT program – least to most informative

- 1. Tests Counter to expectations (marked returns higher) - ?
- 2. Tests not informative (no significant difference in any test)
- 3. 1 or 2 tests show MSF impacts – Somewhat informative
- 4. All 3 show MSF impacts - Informative

DIT program assessment



DIT programs [Section 7.2]

What are commonalities for brood years in categories 3 and 4?
Where DIT was most informative?

- *Returns to escapement sampling ~ 1,000 or more from both groups*
 - *Release numbers, Survival, Exploitation rates*
- *At least 33% estimated marked CWT recoveries expected to occur in MSFs*

Fishery sampling for CWTs - The problem

Visual Sampling – Only those fish with a mark (clipped fish)

Because that what was used to signify tagged fish

In NSFs, unmarked DIT CWTs not recovered

Electronic Tag Detection (ETD) – all fish sampled for a CWT, marked and unmarked

If all fisheries had ETD – we could make full use of DIT.

Fishery sampling [Section 7.3]

Where DIT was most informative?

- *ETD and sampling programs for at least 80% of fishery CWT recoveries for marked component*
 - *That pesky visual sampling problem we talked about...*
- *No more than 5% of estimated CWT recoveries for marked component occur in mixed-regulation fisheries*
- *No more than 5% of estimated CWT recoveries for unmarked fish occur in visually sampled NSFs*

Comparison of DIT to Post-season FRAM ERs

[Section 7.4, Section 5]

- Correlation between DIT-ER and FRAM-ER
 - $r = 0.65$ for marked groups; $r = 0.69$ for unmarked groups
- Mean difference: -5% to $+5\%$
- FRAM: averages stock-fishery-time strata ERs during a base period.
 - More appropriate to compare mean ERs rather than year to year variability
 - DIT methods may have the ability to pick up finer scale ERs
- Consistently poor correlation between ER estimates for some hatcheries

Selective fishery mortality rates (*sfm*) and data quality

[Section 7.5]

- Biases and uncertainties in release mortality rate estimates (*sfm*) – effect U^{MSF} and ERs
 - Bias estimates
 - Add uncertainty to estimates
 - Effect any tests of impacts based on these quantities
- Conduct sensitivity analysis to further examine this issue
 - Particularly cases where results of tests do not make sense

Data quality [Section 7.5]

- Issues related to identification of the proper set of CWT data required to conduct analysis became apparent early
 - DIT groups from a hatchery not identified in RMIS
 - Identification of which codes to use becomes problematic
 - Timeliness of reporting recovery information
 - Fishery where recovery occurred – not attributed to MSF (ad-clip selective field)
 - Need to address potential data quality issues such as missing fishery and recovery information
 - Potentially limits who can conduct DIT analysis

Recommendations – Informative DIT

To increase the probability that DIT groups will be informative on presence of significant MSF impacts to ER estimates of unmarked fish

- Combination of release numbers, survival, and expected ERs lead to at least 1000 hatchery returns each component
- At least 33% of all estimated CWT recoveries in MSFs
- ETD in place for at least 80% of fishery recoveries
- No more than 5% of recoveries in mixed-regulation fisheries
- No more than 5% of unmarked recoveries in visually sampled NSFs

Recommendations – ER estimates

- Paired Ratio method to estimate ERs from DIT data
- SIT method may be adequate for estimating relatively low ERs (e.g., $< 40\%$) and if release sizes and survival rates are conducive to producing precise estimates
- Sensitivity analysis examining changes in ERs from changes in *sfm* and to uncertainties in *sfm* estimates

Recommendations – FRAM and DIT

- Differences between post-season Coho FRAM and DIT-based ERs vary by stock.
 - *Generally good correspondence between DIT and FRAM ER estimates from many hatcheries, several hatcheries where correspondence is very poor*
- FRAM account for effects of average base-period ERs that are a key component of the models
- CWT-based estimates of ERs, estimate sampling variance (uncertainty) It is unreasonable to assume that the point estimates of annual ERs produced by the Coho FRAM are accurate and without error.

Recommendations - FRAM and DIT

- Post-season estimates of ERs should not be based solely on post-season Coho FRAM. For fishery planning purposes
 - Estimates of ERs should be accompanied by indications of confidence levels
- Precautionary management principles would indicate that buffers or bias corrections for error should be considered and routinely employed as a best practice.

Recommendations – DIT Programs

Provide relatively consistent, reliable, and relatively precise estimates - The Keepers

British Columbia region

Inch Creek Hatchery

Puget Sound region

Marblemount Hatchery

Wallace River Hatchery

Soos Creek Hatchery

George Adams Hatchery

Quilcene National Fish Hatchery

Recommendations – DIT Programs

The Keepers (continued)

Washington Coast region

Quinault National Fish Hatchery

Solduc Hatchery

Bingham Creek Hatchery

Forks Creek Hatchery

Columbia River region

Lewis River Hatchery – north-migrating group

Lewis River Hatchery – south-migrating group

Sandy River Hatchery

Recommendations - DIT Programs

- *Potential issues, decreasing effectiveness and require further review to determine if these issues can be addressed or if the DIT program(s) should be discontinued:*

British Columbia region

Quinsam River Hatchery

Puget Sound region

Lower Elwha Hatchery

Kendall Creek Hatchery

Washington Coast region

Makah National Fish Hatchery

Salmon River Fish Culture

Recommendations – Hatchery Programs

- *The results for the following DIT program(s) are mixed and difficult to categorize or have an insufficient number of years of data to make a determination:*

British Columbia region

Big Qualicum River Hatchery

Chilliwack River Hatchery

Robertson Creek Hatchery

Puget Sound region

Voights Creek Hatchery

Columbia River region

Eagle Creek National Fish Hatchery

Acknowledgments

- *Marianna Alexandersdottir (NWIFC, Retired)*
- *Robert Conrad (NWIFC, Retired)*
- SFEC members
- Coho Technical Committee

Questions?