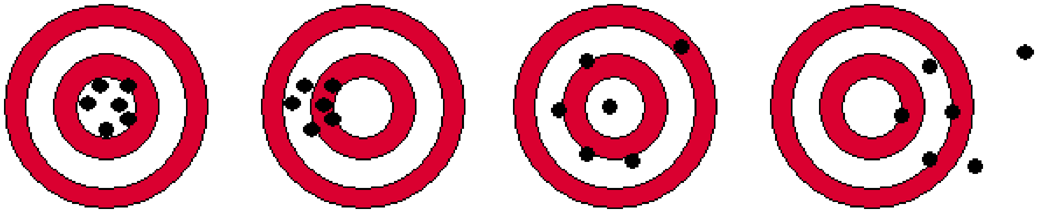

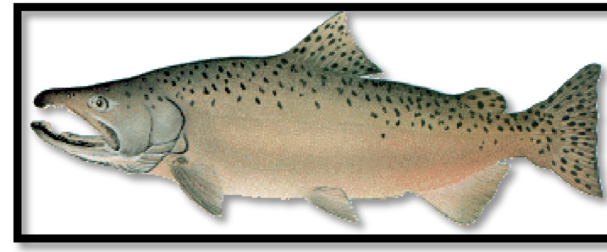

Understanding Productivity of Chinook Salmon: Comments on the Accuracy and Precision of Scientific Information

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Rudimentary Understanding

Production

Spawning Abundance

Productivity parameter

$$P_{by} = f(S_{by}, \varepsilon_{by} \mid \alpha, S_{EQ}, \sigma^2)$$

Process error ~ lognorm(0,σ^2)

Carrying capacity

Regress a paired time series of transformed <u>estimates</u> of P_{by} against S_{by} to estimate S_{EQ} and α

— Simple
— Can provide a "necessary" understanding
— Cause and effect in the function is obvious
— And it works … but with "problems"

“Problems” from Observational Studies

Model “Error” — Usually the best model can not be inferred from data

Process “Error” — Deviations from expected production can be serially related
— If ignored in analysis, productivity estimates can be biased

Observational “Error” — Information in data on productivity is related to the nature of past fishing
— The past may not be prologue to the future (“black swans”)

Measurement “Error” — Estimating P_{by} and/or S_{by} through sampling
— If uncertainty in S_{by} ignored in analysis, estimates of productivity can be biased high or low depending on history of exploitation in the data

Analytical "Solutions"

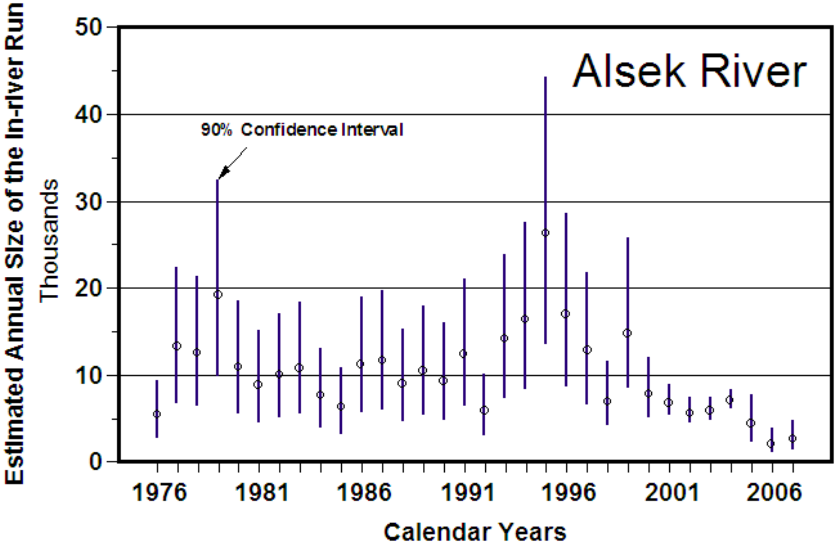
Process Error /Model Error — Add an autoregressive term(s) to the production function to account for serial correlations in process error

Observational Error — Use *a priori* information from other stocks to compensate for lack of specific information (i.e., habitat based model of Lierman et al. 2010) to provide information on α (productivity) for lightly exploited stocks

Measurement Error —

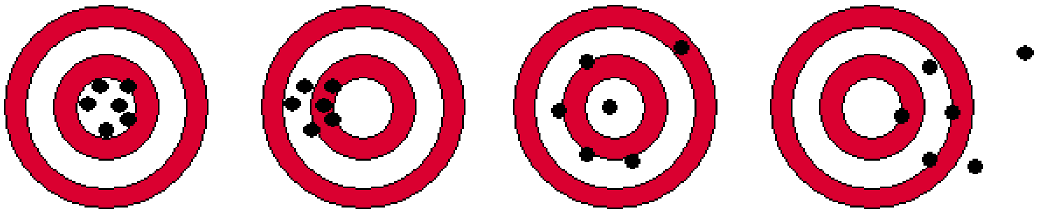
— Avoid biases in estimates of P_{by} and S_{by} from "opportunistic" sampling

— Use estimated variances for these statistics when estimating productivity



Accuracy (bias) and Precision (variance)

Precision is mostly a matter sample size and is expressed as a variance



Accuracy is almost entirely due to how samples are taken, i.e., implementing a sampling design and using a specific method of "sampling"

- **Most statistical methods for estimation are based on the primary sample being a randomly selected sample**
- **Most biological sampling is <u>not random</u>, but is <u>systematic</u> at best, and at worst <u>opportunistic</u>**

Estimating Spawning Abundance S_{by}

Estimates of Escapement:

	Accuracy	Precision
Weirs	Very Good	Very Good, estimable
Towers	Somewhat Depensatory, Bias not correctable w/o independent info	Very Good, estimable
Sonars	Somewhat Depensatory, Depends on Coverage, Depends on Species ID, Biases not correctable w/o independent info	Very Good, estimable
Capture-recapture (traditional,PBT,CWT,telemetry)	Moderately Good, biases correctable w/o independent info	Moderately Good, estimable
Surveys (aerial, foot, swim)	Very Depensatory, Problems w/ Coverage, Problems w/ Species ID, Biases not correctable w/o independent info	Very Poor, not estimable w/o independent info

Estimating Production: Step 1a

Estimates of Terminal Catch:

	Accuracy	Precision
Fish Tickets	Very Good	Very Good
Permit Systems	Very Good	Very Good
Creel Surveys	Moderately Good but can be prone to: —Avidity Bias —Length-of-stay Bias	Moderately Good
Household Surveys	Moderately Good, but can be prone to: —Non-response bias —Prestige bias —Recall bias —Strategic bias	Moderately Good
Logbooks	Moderately Good, but can be prone to: —Non-response bias —Prestige bias —Recall bias —Strategic bias	Moderately Good

Estimating Production: Step 1b

Incidental and targeted catches of Chinook salmon outside terminal areas requires stock identification plus a discount for catches of immature salmon

Catches in non-terminal areas should be transformed into Adult Equivalents, otherwise estimates of production of mature salmon will be inflated (biased)

Estimates of Incidental Catch:

	Accuracy	Precision
Fish Tickets	Very Good	Very Good
At-Sea Catch Sampling	Moderately Good	Moderately Good
Capture-recapture (CWTs,Otoliths,Excision)	Moderately to Very Good	Moderately to Very Good
Stock Indentification (GSI,contaminants,pathogens, morphometry)	Good for Major Stocks in a Catch, Poor for Minor Stocks	Good for Major Stocks in a Catch, Poor for Minor Stocks

Estimating Production: Step 2

Production by definition is the sum of mature fish in a brood year reaching the terminal area, or that would have reached sans fishing

Estimating production requires estimating each annual run by age, then summing across years within a brood

Sampling both escapement and terminal catch is required

Estimates of Size/Age/Sex:

	Accuracy
Live Weirs	Unbiased with systematic/stratified sampling
Carcass Weirs	Biased towards small/younger/male Chinook salmon
Gillnets	Depending on mesh size, material, and where fished, could produce unrepresentative sample and biased estimate
Seines	Depending on where fished, could produce unrepresentative sample and biased estimate
Fishwheels	Biased towards small/male salmon
Carcass Surveys	Biased towards large/older/female Chinook salmon
Electrofishing	Biased towards large/older/female Chinook salmon
Catch Sampling	Depending on logistics, could produce unrepresentative sample and biased estimate

Better Understanding of Productivity (perhaps)

$$\varepsilon_{\text{by}} = \text{g}(\text{X}_{1,\text{by}}, \text{X}_{2,\text{by}} \ldots \text{X}_{\text{k},\text{by}}, \lambda_{\text{by}})$$

Factors that are correlated w/production

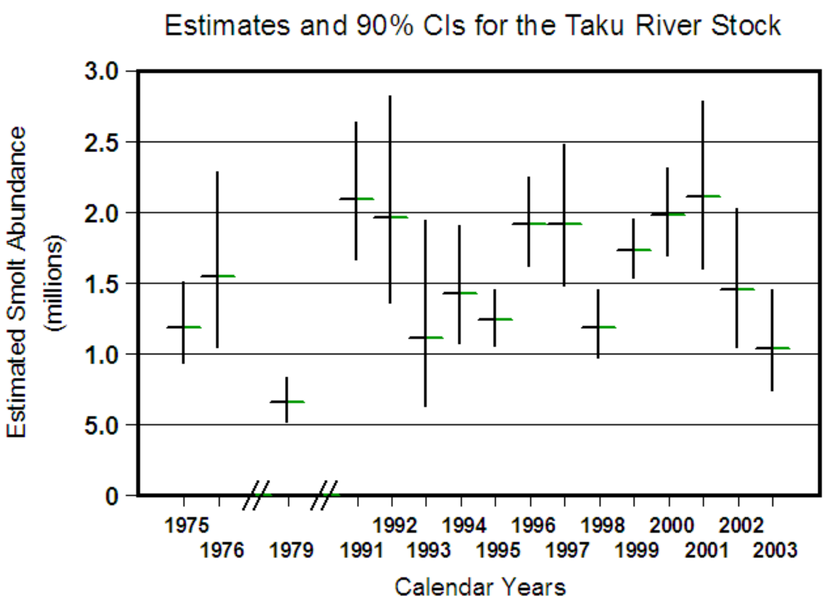
Remaining process error ~ lognorm(0,δ^2) where $\sigma^2 > \delta^2$

$$\text{P}_{\text{by}} = \text{h}(\text{S}_{\text{by}}, \text{X}_{1,\text{by}}, \text{X}_{2,\text{by}} \ldots \text{X}_{\text{k},\text{by}}, \lambda_{\text{by}} \mid \alpha, \text{S}_{\text{EQ}}, \boldsymbol{\Theta}_{\text{X}}, \delta^2)$$

- **More Complex**
- **Can provide "sufficient" understanding**
- **Cause and effect of factors is not obvious**
- **And it <u>can</u> work … but with difficulty**

Estimating Smolt Abundance

Estimates of smolt abundance can be used to clarify inferences on what factors, freshwater or marine, influence production



Estimates of Smolt Abundance:

	Accuracy	Precision
Weirs	Very Good to Very Poor depending on fraction of migration intercepted	Very Good, estimable
Multi-year Capture-recapture	Moderately Good Robust to some biases because mixing occurs over years Biases often <u>detectable</u>, but not <u>correctable</u> w/o independent info	Moderately Good, estimable
In-season Capture-recapture	Very Good in small streams Very Poor in moderate/large rivers because mixing must occur in hours Biases often <u>detectable</u>, but not <u>correctable</u> w/o independent info	Moderately Good, estimable
Sonars	Somewhat Depensatory, Depends on Coverage, Depends on Species ID, Biases <u>not correctable</u> w/o independent info	Very Good, estimable

Cause-and-effect Links between Factors and Productivity: An Example

"Hypothetical" Hypothesis: Nutritional stress from competition has reduced productivity of Chinook salmon

1) **Nutritional stress slows body growth while Chinook salmon are at sea;**
2) **Slower body growth slows the rate of maturation;**
3) **More time maturing exposes immature fish to more natural mortality; and**
4) **Productivity is therefore lowered.**

If hypothesis is true:

— **Average age of returns in a brood year; and**
— **Body growth**

would be related inversely to abundance of competitors

Hypothesis Test involving Body Growth

Procedure: Compare variation in estimates (indices) of the abundance of competitors against variation in the average distance between annuli on scales taken from mature Chinook salmon

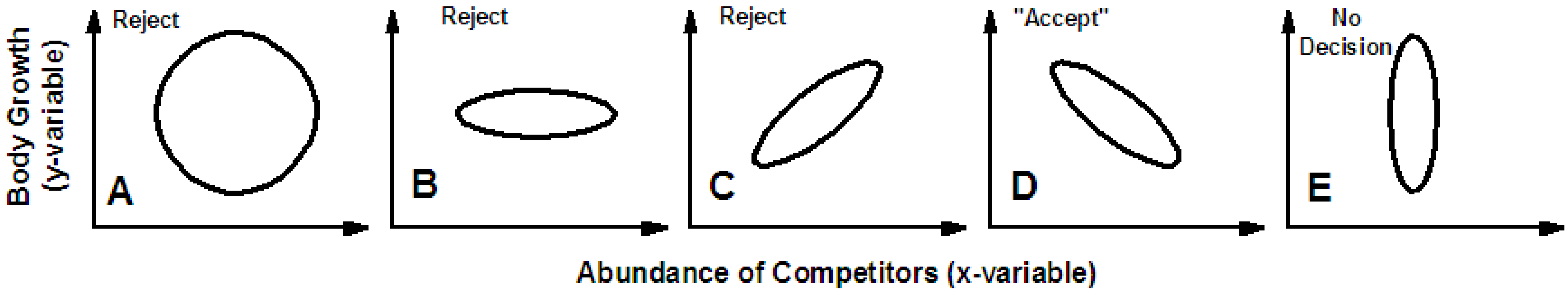
Reject hypothesis when:

“correlation” weak and variation great in both variables (A); or
“correlation” weak and variation great only for x-variable (B); or
“correlation” is positive and variation great for both variables (C).

“Accept” hypothesis for further scientific investigation when:

“correlation” is negative and variation great for both variables (D).

No decision when variation is small for the x-variable (E)



Consequences of Inaccuracy when Testing Hypotheses Concerning Body Growth

Sampling scales from just escapement, or from just catch, risks a false result when sampling and/or management imbue "apparent" body growth with false trends, such as when:

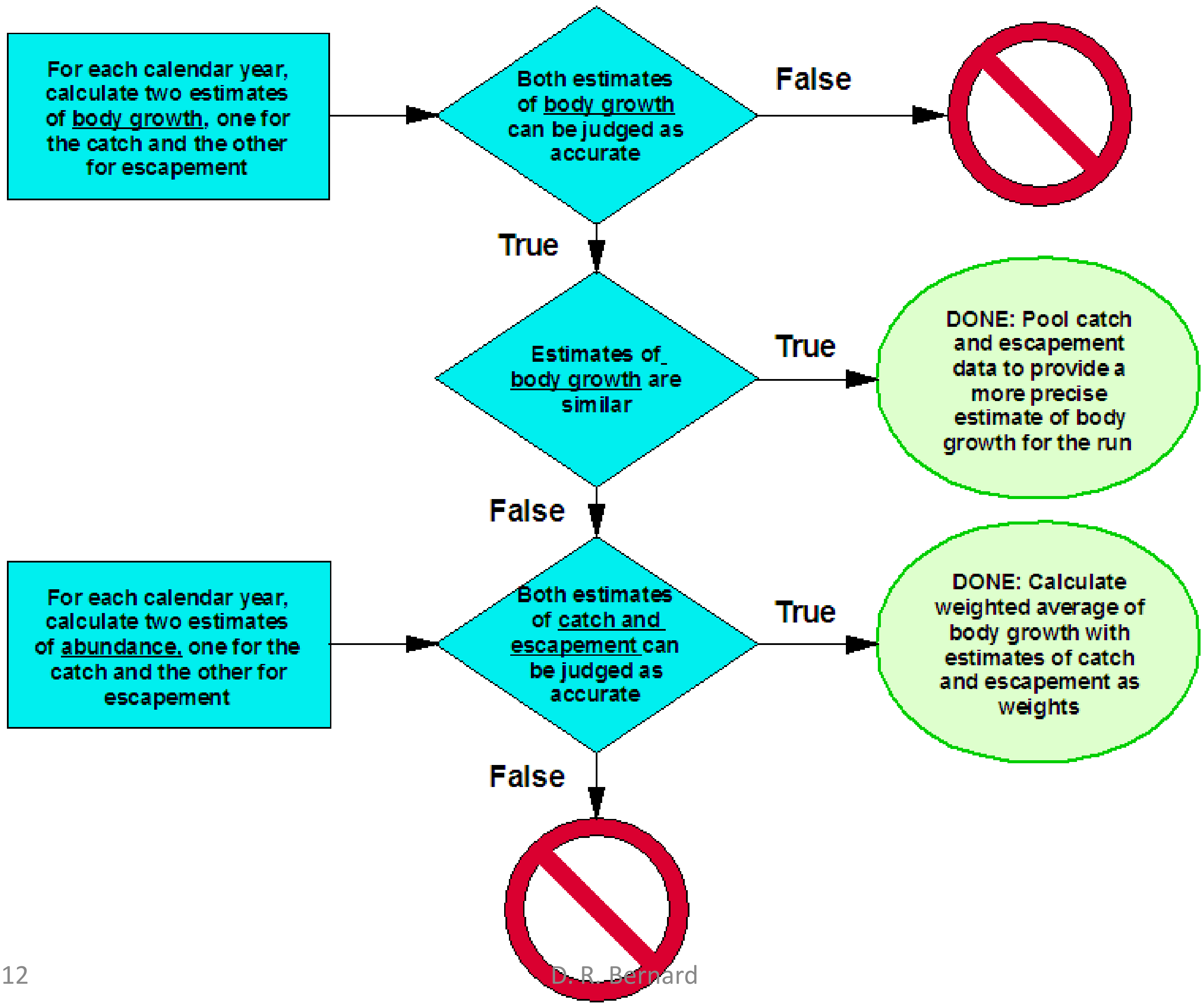
Shift over the years in capture gear used to sample:

— escapement (say fishwheels to carcasses surveys)
— catches (say mesh size changes as gillnet fishery begins to target Chinook salmon

Increasing or decreasing trend in exploitation rates (say due to a lowering or raising of an escapement goal) by a size-selective fishery

Trends in the allocation of catches under an FMP between two fisheries with different selectivity (say between a small-mesh gillnet and a hook-and-line fishery)

Remedy: Use Statistics for the Run



Final Comments

When investigations are based on observational studies, data $\geq$ information

Recognize the opportunistic nature of stock assessment and adjust

Understand the potential of methods, sampling gears, and fishery management to produce biased estimates, even if applied correctly, and adjust

If inferences about productivity of Chinook salmon are to be believed, estimates behind those inferences must be shown to be likely accurate:

- **— The pedigree of estimates should be thoroughly researched, and if found wanting, the estimates should not be used to investigate productivity**
- **— But if used, the belief in the accuracy of these estimates should be justifiable**


Example of a “Black Swan”