RESEARCH ON DATA AND METHODS FOR ONCE-THROUGH COOLING IMPACT ASSESSMENT

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Research Overview

- Identify life history types for use as “indicator species”
- Conduct sensitivity analysis of impact assessment methods
- Review cumulative impact studies
- Focus of this presentation: sensitivity analysis of three demographic assessment methods for selected life history types

Introduction to Sensitivity Analysis

- Most CA once-through cooling impact assessments do not express egg and larval losses in terms of fish

- Main reason: lack of life history data needed to implement models and resulting uncertainty in model outputs

Introduction (cont'd)

- Despite uncertainty, a measure of absolute losses of larvae expressed as fish can play an important role in impact assessment:
  - provides a standardized measure of absolute loss
  - facilitates comparisons among species, years, facilities
  - helps communicate losses to the public
  - needed for economic benefits analyses
  - provides a screening-level measure of relative magnitude of loss to determine which species require more detailed analysis

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Objectives of Analysis

- Determine which life history parameters contribute most to variability (uncertainty) in outputs of demographic models for indicator species

- Determine data collection needed to reduce uncertainty

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Adult Equivalents

- Adult Equivalent Loss (AEL) Model
- Expresses entrainment as equivalent number of organisms at a particular age (e.g., age 1)
- Requires age-specific cumulative survival rates between the age of entrainment and age of equivalency
- Uncertainty about survival rates translates into uncertainty about estimates of equivalent fish

Fecundity Hindcasting

- Fecundity Hindcasting (FH)
  - Expresses losses in terms of the number of females that would produce the number of organisms killed (equivalent spawners)
  - Requires cumulative survival rate between the egg stage and the age at which entrainment occurs and expected lifetime fecundity

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Fecundity Hindcasting (cont'd)

- Uncertainties about age-specific fecundity (eggs/female) and age-specific total mortality translate into uncertainty about expected lifetime fecundity

- Uncertainty about total mortality rates and expected lifetime fecundity translate into uncertainty about estimates of equivalent spawners

Foregone Fishery Yield

- Similar to AEL and FH but include multiple ages and consider the proportion of entrained organisms that would have been harvested had they survived
- Parameters also include age-specific survival rates but, in addition, also include age specific fishing mortality rates and age specific weights
- Output: “yield per recruit” ratio (YPR)

Approach

- Conducted sensitivity analysis of models using Monte Carlo analysis
- Monte Carlo analysis uses statistical sampling techniques to determine a "probabilistic approximation" to model solution
- Conducted comprehensive literature search to select representative life histories and to develop range and central tendency of parameter values
- For Monte Carlo analysis, ranges were defined to be symmetric around the central tendency (median) value

Approach (cont'd)

- Conducted a sequence of distinct Monte Carlo calculations:
  - Type 1 > all parameters were fixed at the median value
  - Type 2 > all parameters were determined by random sampling from the range of parameter values
  - Type 3 > all parameters were fixed at the median value except for a single parameter that was determined by random sampling from the range of parameter values

Approach (cont'd)

- Type 1 model runs provided a point estimate of the result statistic
- The SD of the Type 2 runs was interpreted as a measure of the overall uncertainty in the point estimate from the Type 1 run.

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Approach (cont'd)

- The results of the Type 2 and Type 3 runs were further characterized as a coefficient of variation (CV), defined as the ratio of the SD from the model run relative to the point estimate from the Type 1 run
- The final CV ratios for each Type 3 run were interpreted as indicators of the relative contribution of uncertainty in the variable parameter to total model uncertainty

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Life Histories Evaluated

- **Northern anchovy** - commonly entrained, short lived and highly fecund, can be a close surrogate for other forage species, commercially important

- **Gobies and blennies** - Ecologically important forage species, data-poor life history parameters, locally abundant in bays and estuaries, high frequency of entrainment

- **California halibut** - Ecologically important predator species, use bays and estuaries, commercially and recreationally important

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Life Histories Evaluated

- **Dungeness crab** - complicated early life history, can be a close surrogate for commonly I&E crab species
- **Rockfishes** – long lived & fecund, stocks very depressed from historic levels, commercially and recreationally important
- **Surfperch** - Unique life history (i.e., vivipary), commonly entrained recreationally important

Results

- Total uncertainty, expressed as the CV (SD divided by point estimate), was smaller using the Age-1 Equivalent approach for anchovies, blenny, and crab.
- For goby and halibut, total uncertainty was smaller using the Fecundity Hindcast approach.
- For the Foregone Yield approach, total uncertainty for anchovy and halibut was very similar to the results using the Age-1 Equivalent approach. Uncertainty for crabs, however, was substantially greater.

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Results: Crabs

- Uncertainty for crabs was much greater than for fish for all three modeling approaches.
- This stems from large uncertainties in survival rates for larval and age 0 life stages.
- Decreasing uncertainty about these parameters could substantially reduce total uncertainty for these crab species.

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Results: AEL Model

- Evaluation of the sensitivity of the uncertainty to individual model parameters indicated that larval mortality was the most sensitive parameter for each species using the Age-1 Equivalent approach.

  - Expected because larval stages dominate entrainment losses. Literature also indicates substantial uncertainty regarding larval survival for most species.

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Results: AEL Model (cont'd)

- Simulations using uncertainty in larval mortality, alone, generated uncertainty ranges 83-99% as large as the total uncertainty indicated by varying all parameters in the Monte Carlo analysis.
- <u>Egg, age-0, and age-1 mortality was less important</u> in explaining modeled uncertainty.

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Results: larval mortality

- Assuming entrainment losses were accurate +/- 30% yielded uncertainty bounds of a generally similar magnitude to, but slightly lower than, those generated by uncertainty in larval mortality.
- Consequently, improving the precision of estimates of larval survival will only yield tangible improvements in total model uncertainty if the uncertainty in entrainment loss estimates is less than +/- 30%.

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Results: Fish Fecundity

- Evaluation of the sensitivity of the uncertainty to individual model parameters indicated that lifetime fecundity was the dominant source of uncertainty for the four fish species.

- But for crabs, larval mortality was the largest source of uncertainty.

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Results (cont'd)

- Improved estimation of lifetime fecundity (fecundity-at-age; adult survival) would provide valuable improvements in the precision of estimates.
- Because empirical estimation of lifetime fecundity may be more tractable than estimating larval survival for many species, this may be a more feasible approach to reducing uncertainty.

Recommendations

- If Age-1 Equivalent or Foregone Yield models are used, model uncertainty may be reduced by gathering improved, and potentially locally-specific, information regarding larval survival rates.
- However, improving the precision of estimates of larval survival will only yield tangible improvements in total model uncertainty if the uncertainty in entrainment loss estimates is less than +/- 30%.
- Therefore, we recommend that future studies include statistical estimation and reporting of precision of annual total losses.

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Recommendations (cont'd)

- Use of the Fecundity Hindcast approach may offer greater opportunities for reducing model uncertainty because improved estimates of lifetime fecundity would provide valuable improvements in model precision.
- These variables may be more amenable to empirical estimation for many species than larval survival.

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Recommendations (cont'd)

- Uncertainty about crabs is substantially larger than for the modeled fish species. Because entrainment rates of crab larvae can be very large, additional research should focus on these species if uncertainty is to be reduced meaningfully.

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Recommendations (cont'd)

- In developing parameter set for a given species:
  - Focus additional field sampling on collecting data for uncertain parameters that have greatest influence on variance in output
  - "Fix" values of parameters that have little influence on model output
  - Use "life history balancing" (Horst, 1975; Goodyear, 1978; PSEG, 1999) to evaluate reasonableness of the population growth rate implied by the life history values used
    - E..g., assume population is at equilibrium (zero growth) over long-term or use a known growth rate

Recommendations (cont'd)

- Place priority on sensitive life history types with large entrainment and high public value
  - Public values for fishery species relatively well known
  - But most losses are forage species
  - Public values for these species need to be determined

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Concluding Remarks

- Important to characterize uncertainty for any assessment method
- When uncertainty is well-characterized, can identify options for reducing uncertainty
- In general, uncertainty greater for higher levels of biological organization (populations, communities, food webs)

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Concluding Remarks

- Tradeoffs among uncertainty and ecological relevance
- Impact assessment requires iterative approach: starting with least uncertainty and moving to increasingly relevant levels of biological organization as appropriate

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Impact Assessment Tradeoffs

Entity	Response Time	Ambiguity	Difficulty of Measurement	Relevance for Ecosystem
individual	short	low	low	less direct
population	↓	↓	↓	↓
community				
ecosystem	long	high	high	more direct

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