Integrated Analysis

FISH 576 Winter 2025

What is integrated analysis?

- Combining many types of data into one joint likelihood.

Example:

L(data | parameters) =

  f(lengths | popn model, selectivity) *

  f(ages | popn model, selectivity) *

  f(indices | popn model, catchability, selectivity) *

 f(popn model | parameters)

Integrated Analysis Sub-Models

- **Population Model**
  - **Recruitment, mortality, growth**
  - **Age and/or size structured**
- **Observation Model**
  - **Derive expected values for data**
- **Likelihood-based Statistical Model**
  - **Probability of observing the data given the model (e.g., multinomial ages, lognormal index)**
- **Algorithm to search for parameter set that maximizes the likelihood**
  - **Auto-Differentiation Model Builder (ADMB)**
- **Cast results in terms of management quantities**
- **Propagate uncertainty onto confidence interval for management quantities**

Why Integrated Analysis?

- Predecessor is statistical catch-at-age, which requires complete time series of quality catch-at-age and index data. Often not available, so:
  - Truncate time series to shorter period; losing contrast
  - Create catch-at-age from inadequate data sources;
  - Switch to biomass dynamics model with simple parameters linked to population r & K
- Integrated Analysis can:
  - Span data-poor historical periods and data-rich era(s)
  - Compare expected values to wide variety of data types
  - Link to population dynamics through spawner-recruitment

Why Integrated Analysis?
Data available only for some years
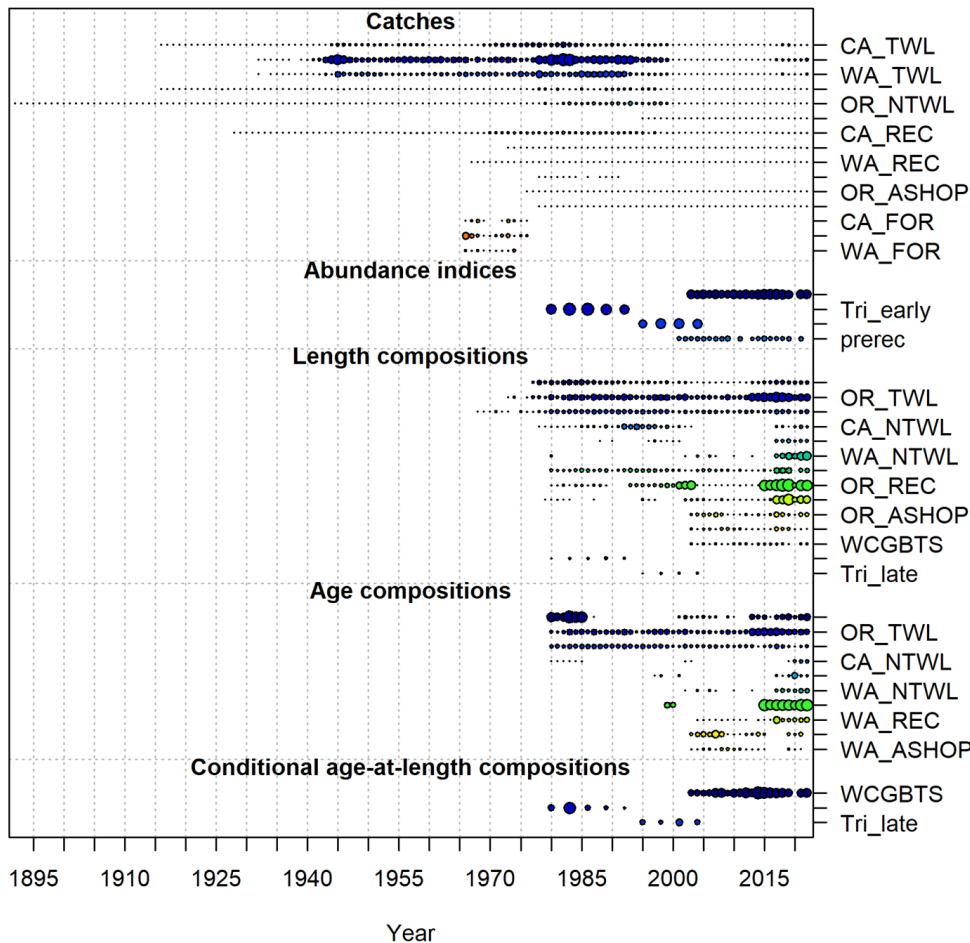
Data availability for canary rockfish

IA – SCAA Comparison

- SCAA is built around use of fishery catch-at-age
- IA is a broader and more flexible concept
  - Biological characteristics of catch can be represented by size composition, weight composition, or composition data-free
  - Multiple fleets routinely included
  - Alternative information sources (e.g. tag-recapture, environmental indices)
  - More modeling of processes possible (growth, size-selectivity, ageing imprecision and bias, spatial dynamics, predation)

Bring Model to the Data

- **Do not transform data to meet rigid model structure**
- **Do add processes to the model to develop expected values for diverse, lightly processed data**
  – Improves understanding of processes
  – Allows simultaneous use of more types of data
  – Statistical properties of data are preserved and transferred to variance of final model results

Fundamental Processes

- Population
  - Production: Recruitment
  - Mortality: M and F
  - Visibility: Catchability and Selectivity
  - Location and Movement
- Individual
  - Growth
  - Maturation and Fecundity

Integrated Analysis Output
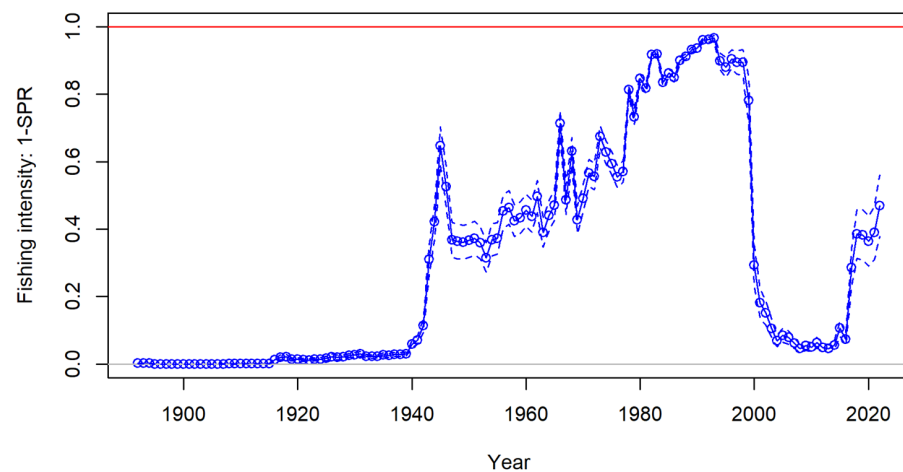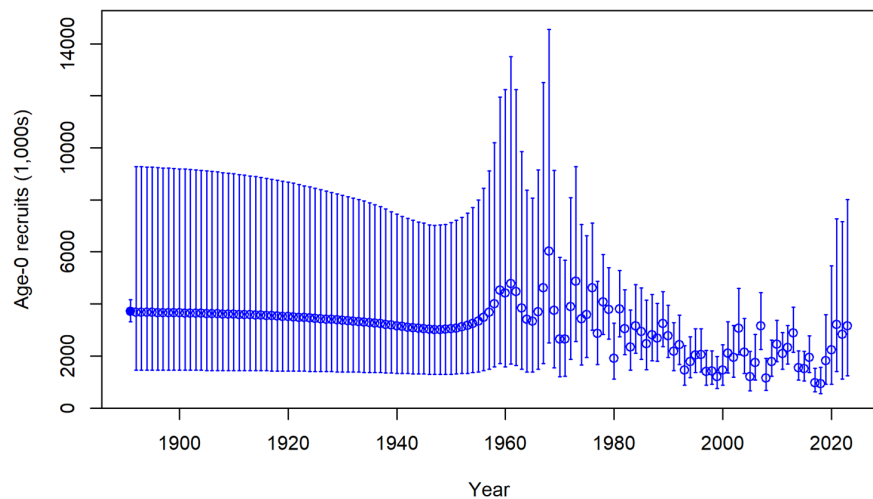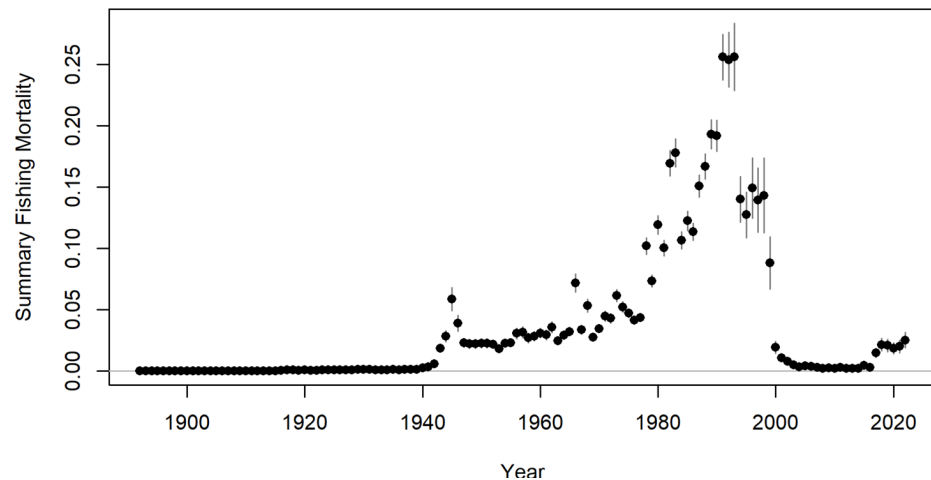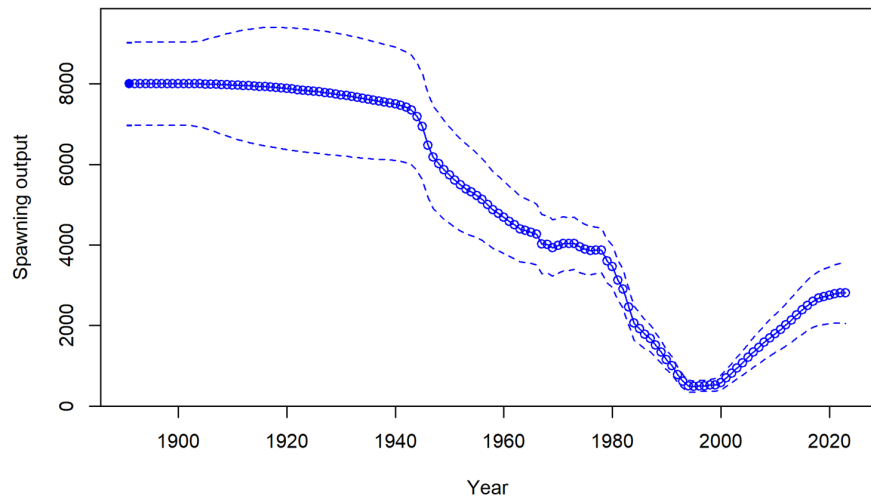
IA: No Magic Bullet

- Allows many kinds of data, but data does not assure contrast
- Allows many processes to be investigated, but cannot magically remove confounding
- Fixing parameter values for some processes (M) will tighten confidence intervals by excluding some alternative explanations for the data
- Result probably will have more variance than result from a simpler model – that's good

History of Integrated Analysis

- Fournier & Archibald (1982) provided explicit consideration of errors and use of auxiliary information.
- CAGEAN (Deriso et al 1985) - 10s of parameters
- Stock Synthesis (Methot, 1989) -10s to 100s of parameters; FORTRAN & numerical derivatives
- AD Model Builder (late 1980s) - Computer software to build your own IA, 10s to 1000s of parameters. www.admb-project.org
- MULTIFAN-CL (1998) - 1000s of parameters (age and size, tag recapture, movement)
- ASAP (Legault& Restrepo, 1998). A flexible forward age-structured assessment program.
- Coleraine (Hilborn, Maunder et al, 2000) – comparable to ASAP
- CASAL (Bull et. al 2004; New Zealand) C++ algorithmic stock assessment laboratory); age and size structured, tag recapture, movement
- GADGET (Begley & Howell, 2004) Globally applicable Area-Disaggregated General Ecosystem Toolbox
- Stock Synthesis 2 (Methot, 2005) – ADMB-based; size & age based model with spatial structure, gender and growth-morphs
- SS3 – numerous improvements and expanded use over decades
- 2010s: newer models like SAM and WHAM developed in TMB instead of ADMB to support random effects among other benefits
- 2019: CAPAM workshop on the creation of frameworks for the next generation general stock assessment models https://capamresearch.org/Next-Gen-SAM