Working Paper #15
Leslie-Davis Depletion Estimators

Basic Leslie-Davis Depletion Model

The key assumptions of a depletion model are:

1. All individuals have the same probability of being caught in a sample
2. The expected catch in a sample is proportional to sampling effort
3. The catch depends on the cumulative catch of preceding samples
4. All removals from the population are known
5. All additions to the population are known

$$CPUE_t = qN_0 - q\sum_{i=1}^{t-1} C_i$$

- This is a simple linear regression CPUE(t)=a +b K(t-1) where K(t-1) is equal the sum of catches up to t-1.
- In theory, the estimated total number of individuals in the population occurs when all of the individuals are captured.
- This corresponds to CPUE=0, so that the estimate of N_0 is simply equal to -a/b.

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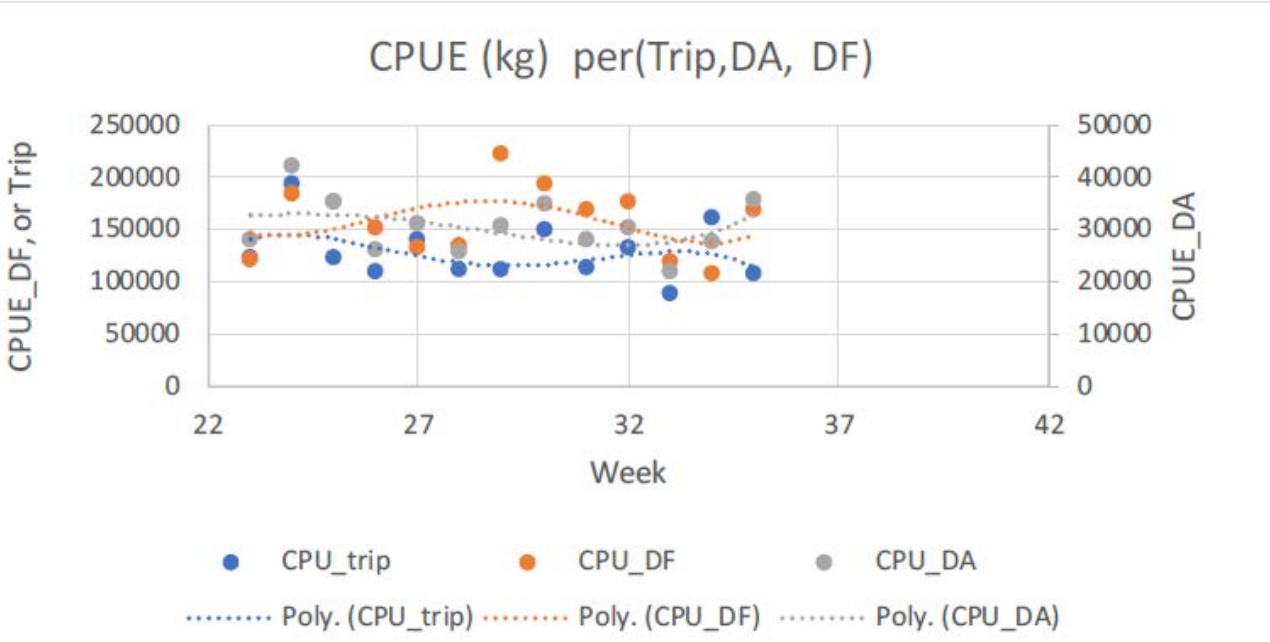
- Catches in weight were converted to catches in number by dividing the total catch by the estimated average weight.
- When weekly average weight samples were not available, average weights were borrowed from the next available week.
- Capture probabilities are applicable to individuals rather than biomass, all quantities in the Leslie Davis model were expressed in terms of numbers of individuals.

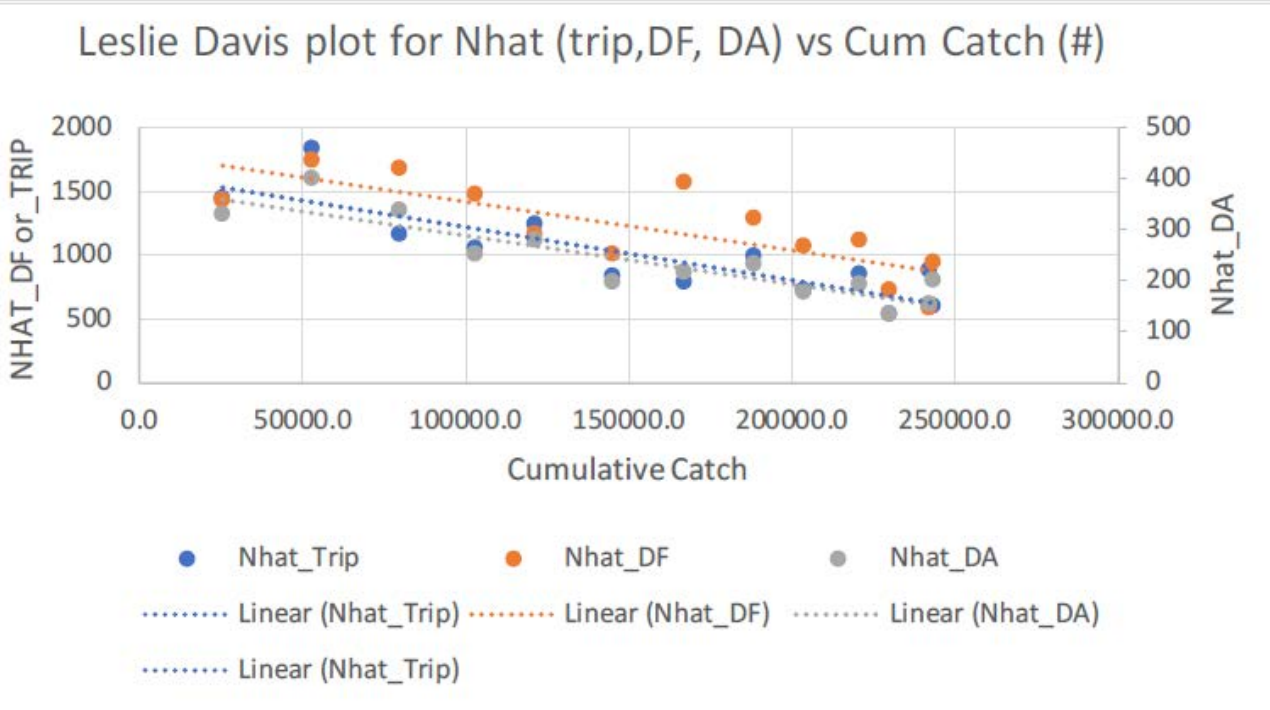
Working Paper #15 Leslie Davis Depletion

- **EXPECTATION:**
  - In a closed population subject to depletion only from harvesting one would expect CPUE to decrease continuously.
- **RESULTS:**
  - This occurred in only 4 of the 19 years, notably in 1998, 2010, 2017 and 2018.
    - Three of these years were judged by fishermen as excellent harvest years (1998, 2017, 2018).
    - The Leslie Davis model appeared to fit reasonably well in these years with average R2 exceeding 0.7 for all models.
  - The proportion of the variance explained by total removals was about 50% in 2011 and 2016. In all other years, the R2 values were below 0.22 and in many cases near zero.
  - From a broad overview, the model would be judged acceptable statistically in 4 of the 19 years, marginal in 2 years, and unacceptable in the remaining 13 years. In seven years the Leslie Davis model had positive slopes for at least one of the CPUE measures, resulting in negative population estimates.

1998—GOOD

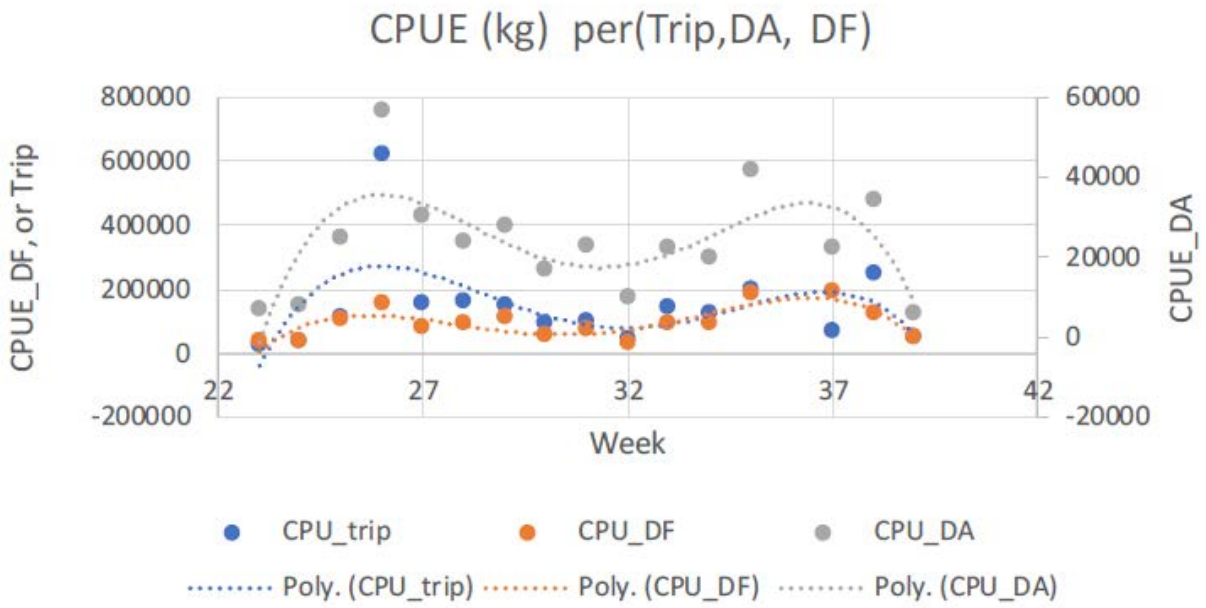
CPUE	Per Trip	Per Day Absent	Per Day Fished	Average	Max/ Min
R-square	0.7269	0.8041	0.6161	0.7157	1.31
Slope	-0.0041	-0.0009	-0.0038	NA	0.23
Nhat (millions)	395	404	474	424	1.20

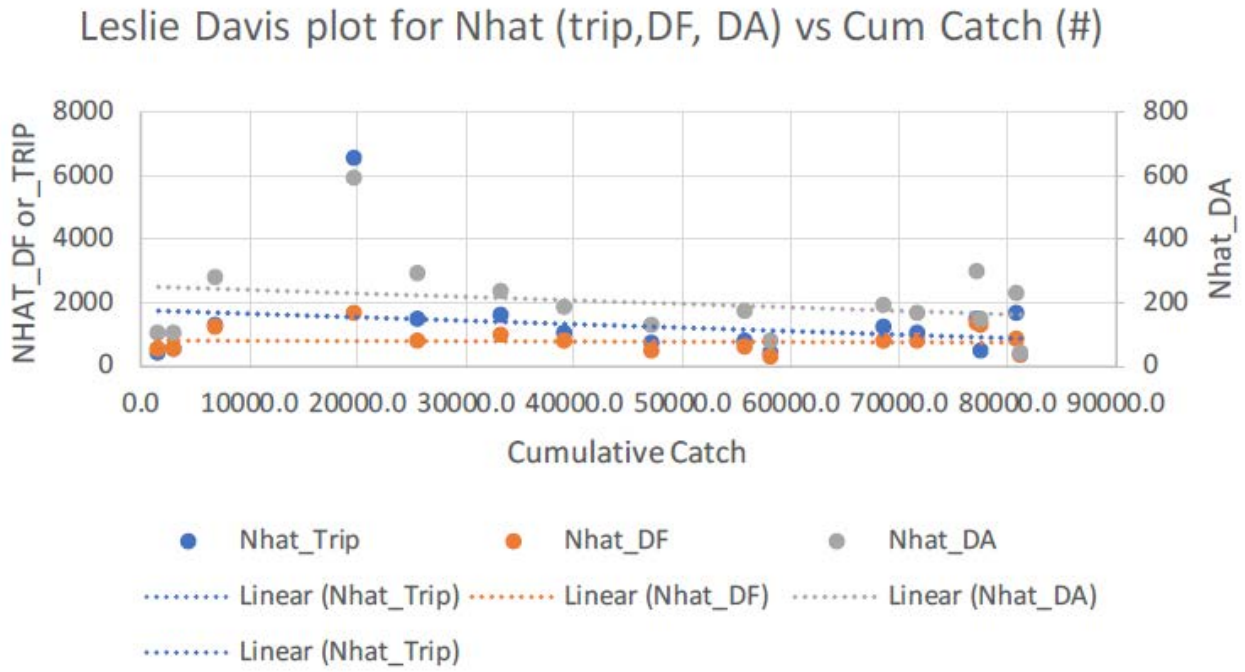




1999—BAD

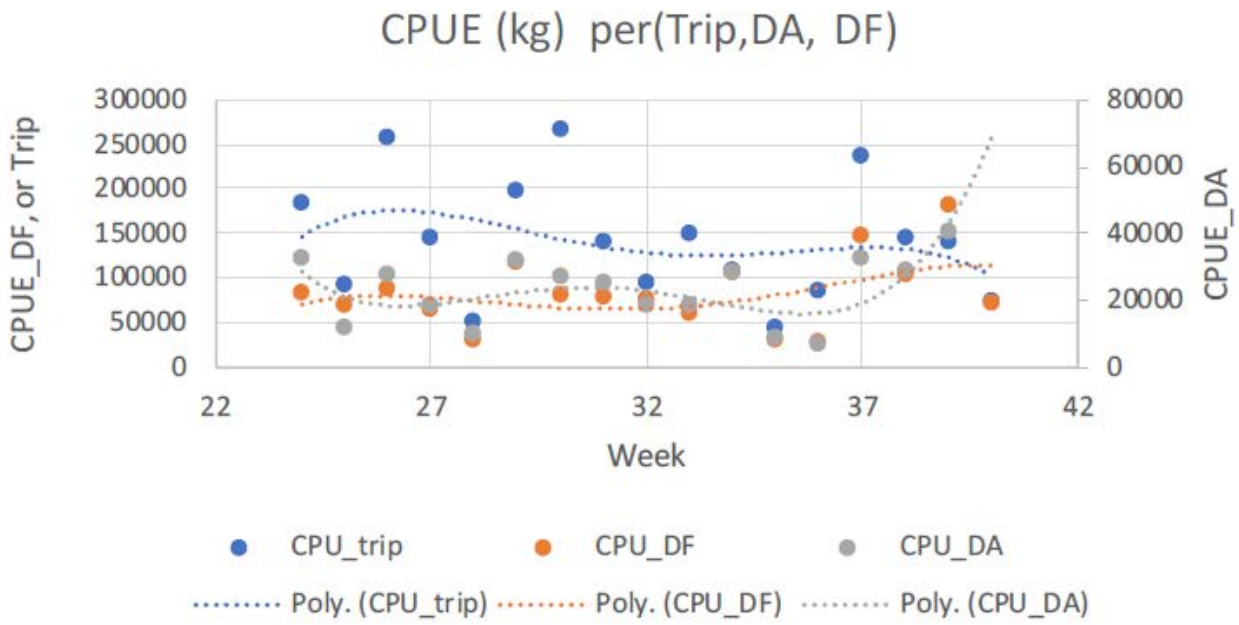
CPUE	Per Trip	Per Day Absent	Per Day Fished	Average	Max/ Min
R-square	0.0470	0.0562	0.0009	0.0347	61.36
Slope	-0.0110	-0.0011	-0.0004	NA	0.04
Nhat (millions)	161	232	1,931	775	11.98

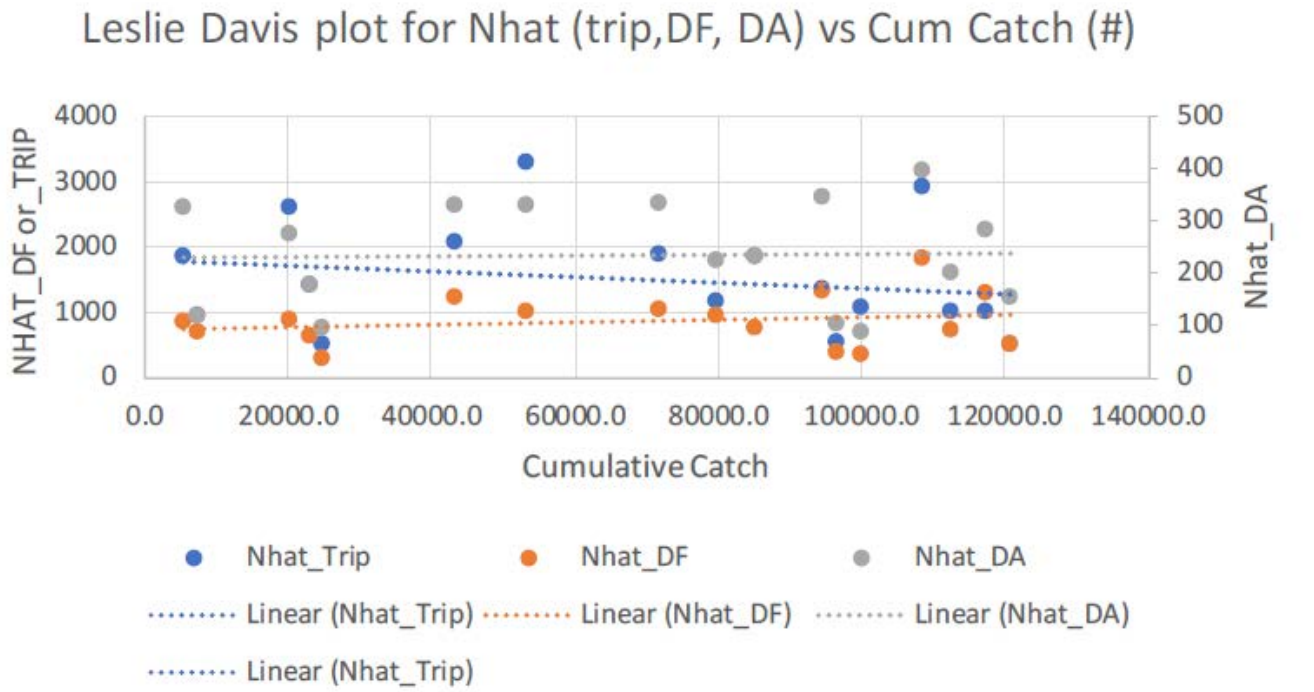




2000--UGLY

CPUE	Per Trip	Per Day Absent	Per Day Fished	Average	Max/ Min
R-square	0.0455	0.0011	0.0367	0.0278	40.72
Slope	-0.0044	0.0001	0.0019	NA	-0.43
Nhat (millions)	413	-2,730	-382	-900	-0.15





Working Paper #15
Leslie-Davis Depletion--Conclusions

- Nothing works reliably
- Seber (1973, p. 298) cautioned:
  - “A plot of Yi vs xi will provide a rough visual check on the adequacy of the regression model, including the assumption of constant variance. However, such graphical evidence should not be taken as final, for a straight-line fit is still possible in some situations, even when the assumptions do not hold. For example, a linear model is still possible even with natural mortality or migration taking place.”
- Results suggest that the violations of assumptions of the Leslie Davis model overwhelm any simple application of the model.
- Variations in temporal timing of migrations and interannual variations in growth may be primary factors underlying lack of model fit.
- Simulations may be helpful for illustrating behaviors (see paper).