Incorporating time-varying fishery catchability in assessment models for Atlantic herring (*Clupea harengus*)

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Clupea harengus, Atlantic Herring

Catchability, q

- the proportion of a fish stock captured by a unit of fishing effort

$$I_t = qN_t \qquad F_t = qf_t$$

- Fishery-independent indices: q often time-invariant

- Fishery- dependent indices (e.g., fishery CPUE): q often time-varying due to
  - Spatial and seasonal variation in q
  - Variation in fishing power (changes in gear, vessels, other technology)
  - Effects of management actions on fishing efficiency
  - Effects of changes in fishing behaviour on fishing efficiency
  - Effects of changes in fish behaviour on fishing efficiency – e.g., density-dependent q

Assessment models for Atlantic herring in the southern Gulf of St. Lawrence
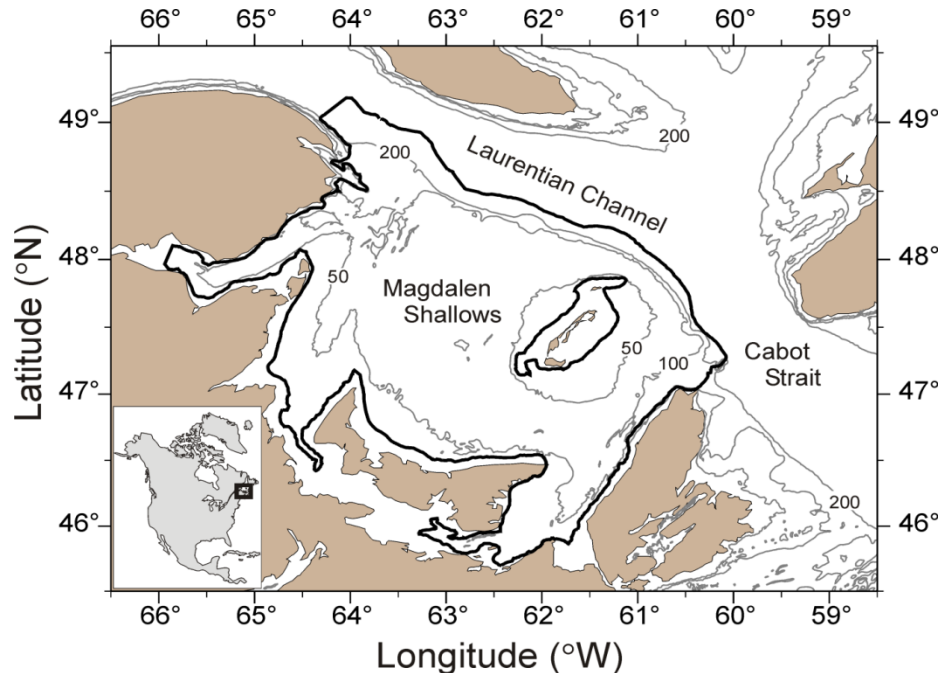
Spring Spawners

Single Population

VPA model
- Fishery CPUE
- Acoustic survey indices
- At low abundance

Fall Spawners

Three Populations, assumed unmixed after recruitment

VPA model
- Main index is Fishery CPUE
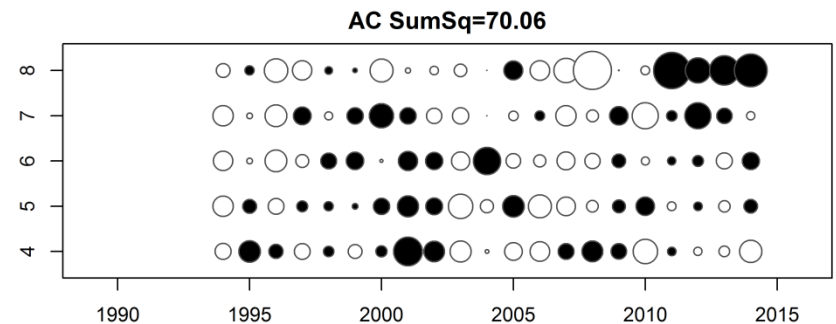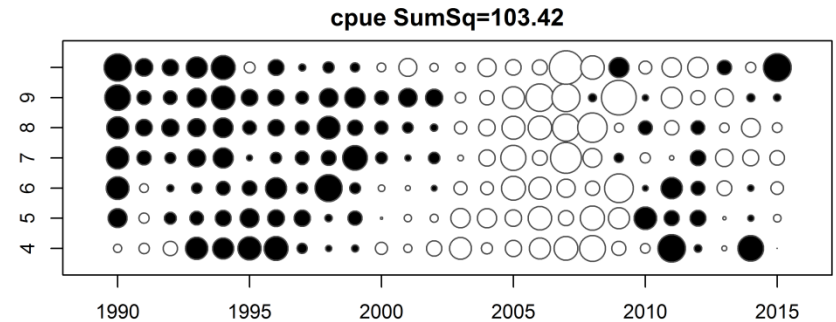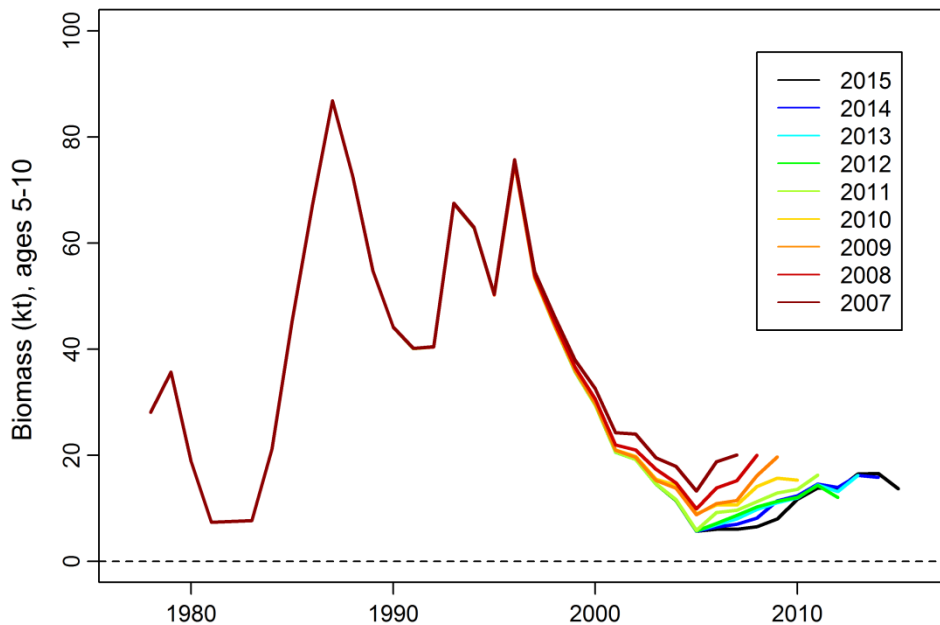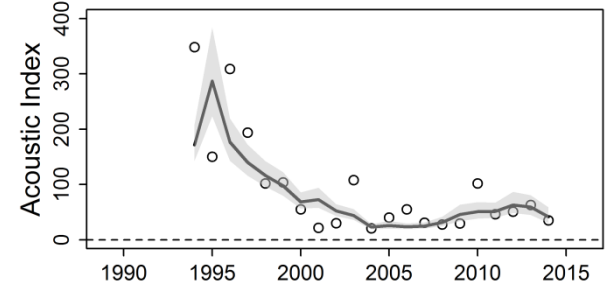- At relatively high abundance

Spring Spawner VPA model

Traditional model
 – time invariant *M* and *q*

Severe lack of fit:
- Strong retrospective pattern
- Very poor fit to the Fishery CPUE index (but reasonable fit to the acoustic index)
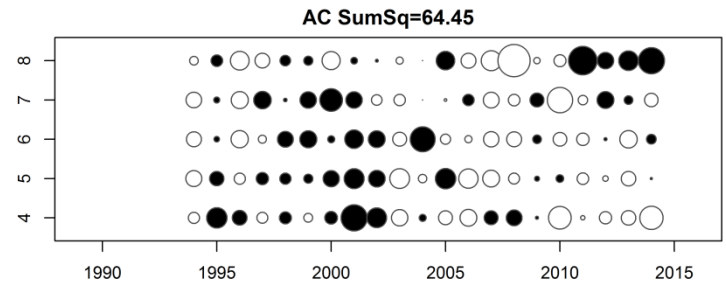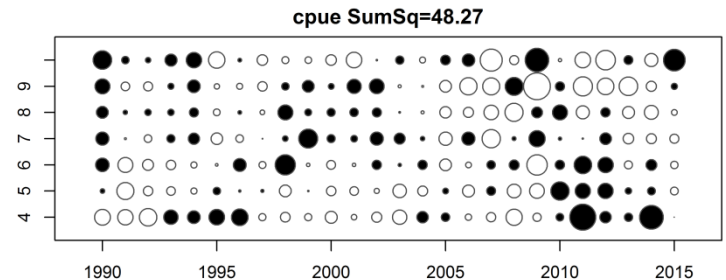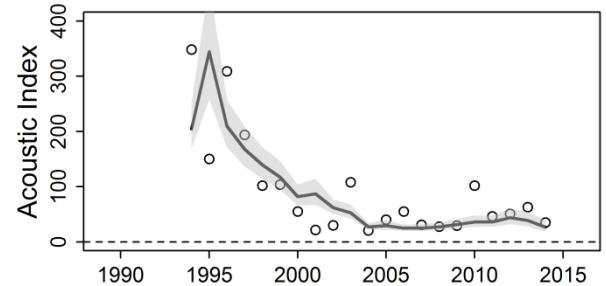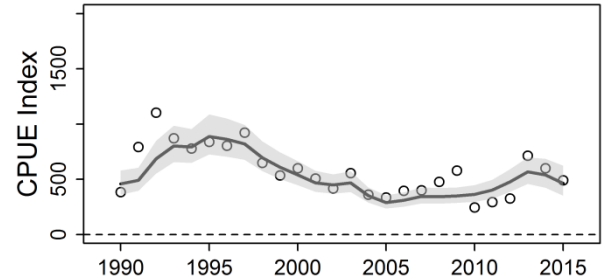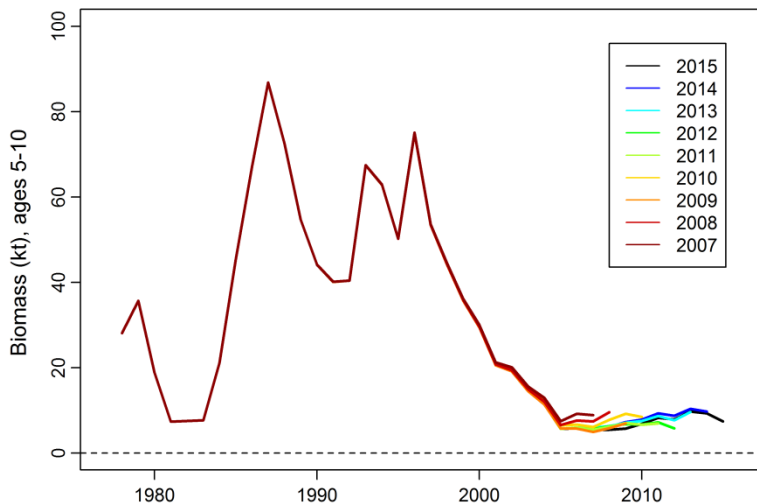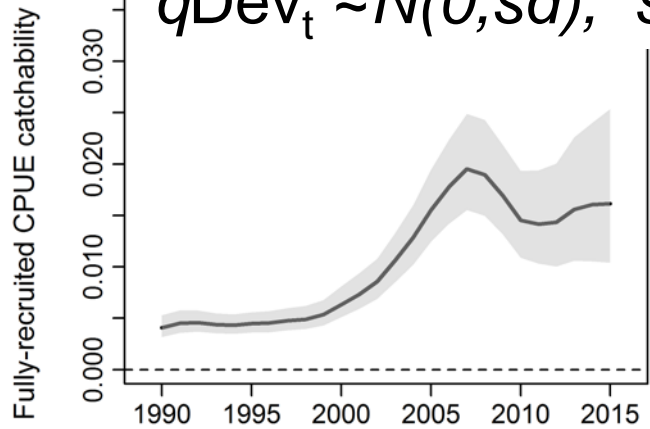
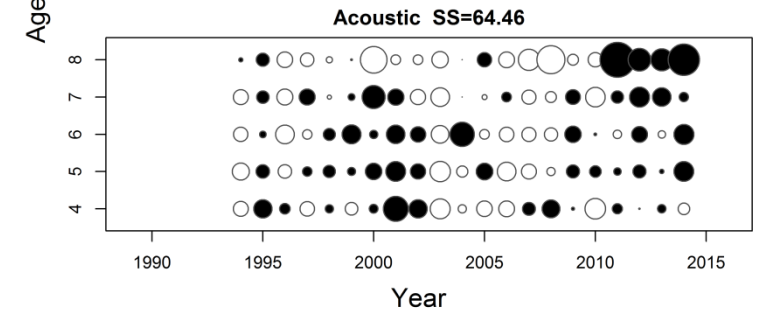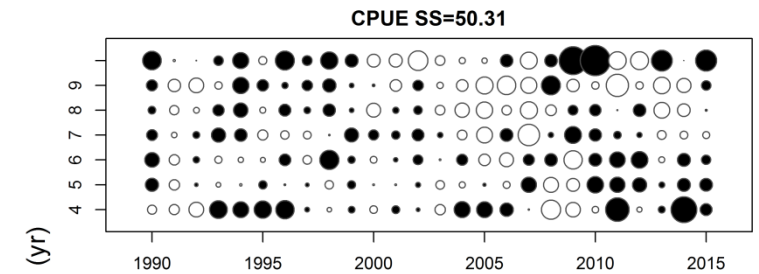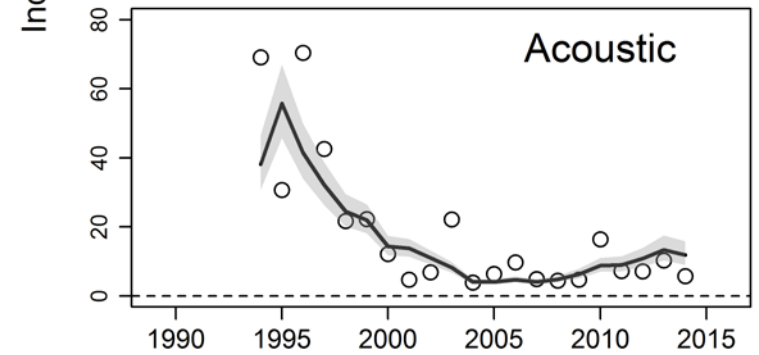## Non-stationarity in *M* or *q*?
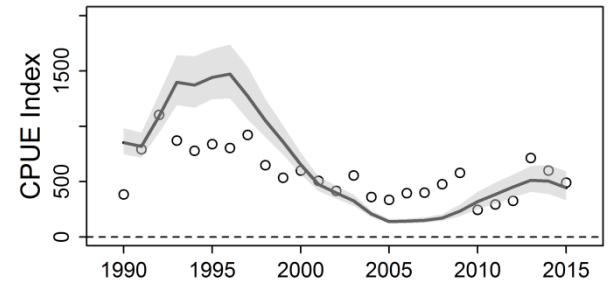
Spring Spawner VPA model

Time-varying fishery q

$$q_{1990} = qInit, \qquad q_t = q_{t-1}\, e^{qDev_t}$$

$$qDev_t \sim N(0, sd), \quad sd = 0.1$$

Spring Spawner SCA model

Time-varying fishery *q*
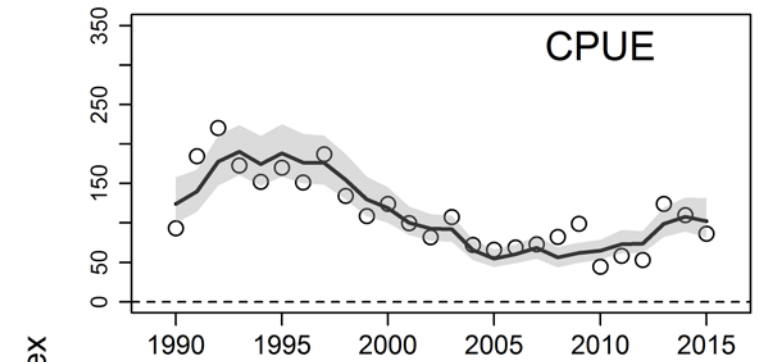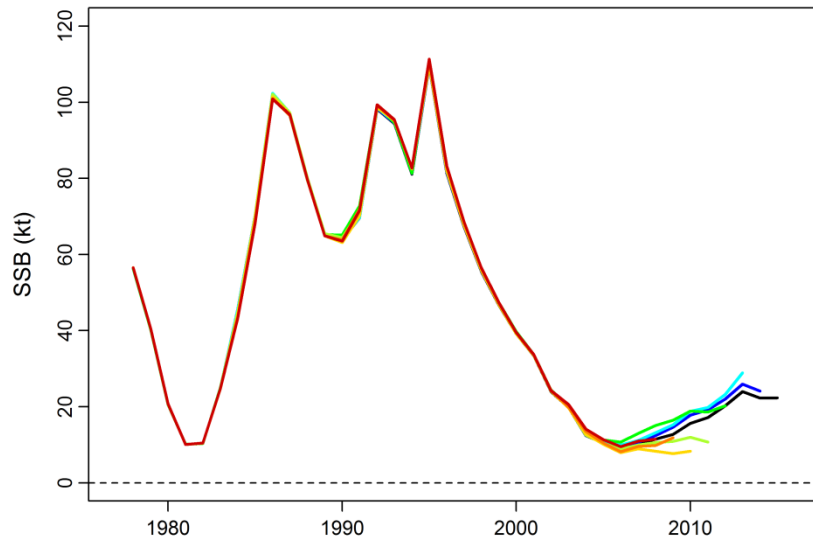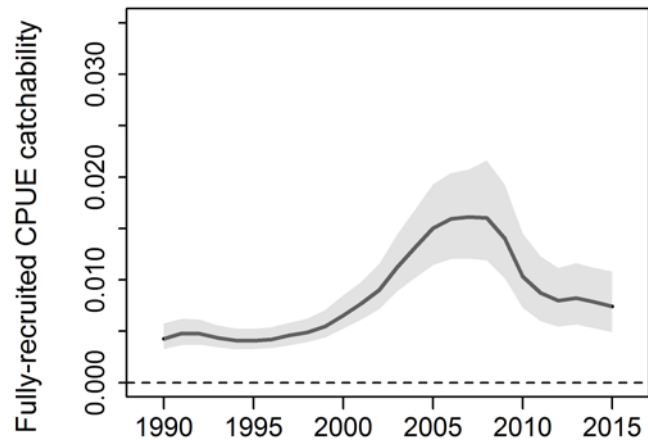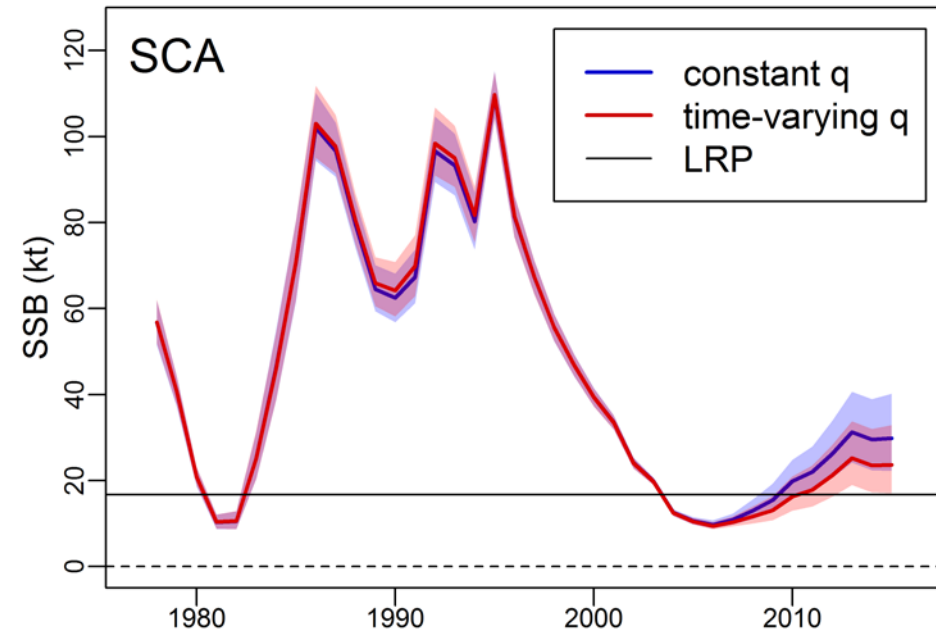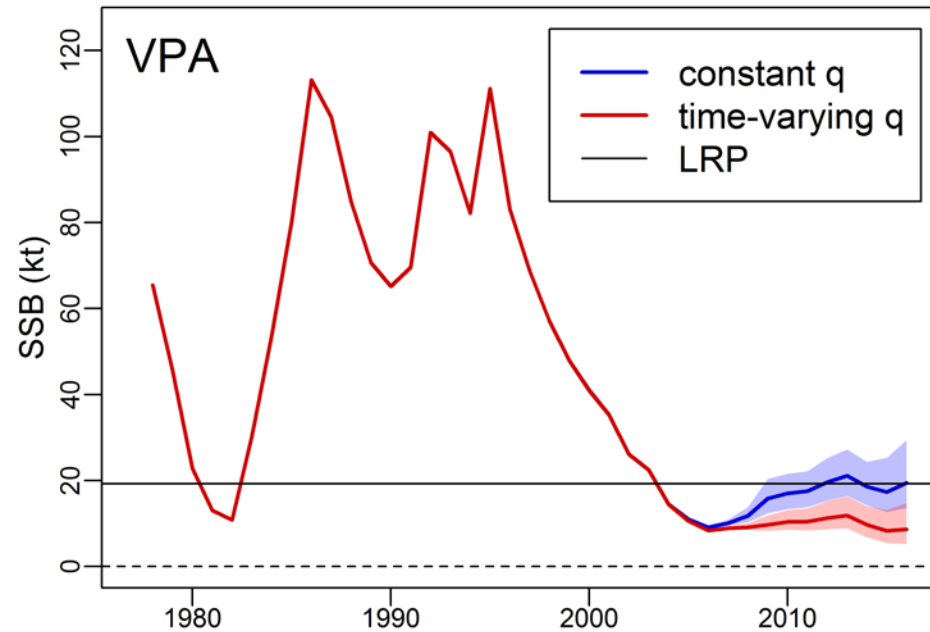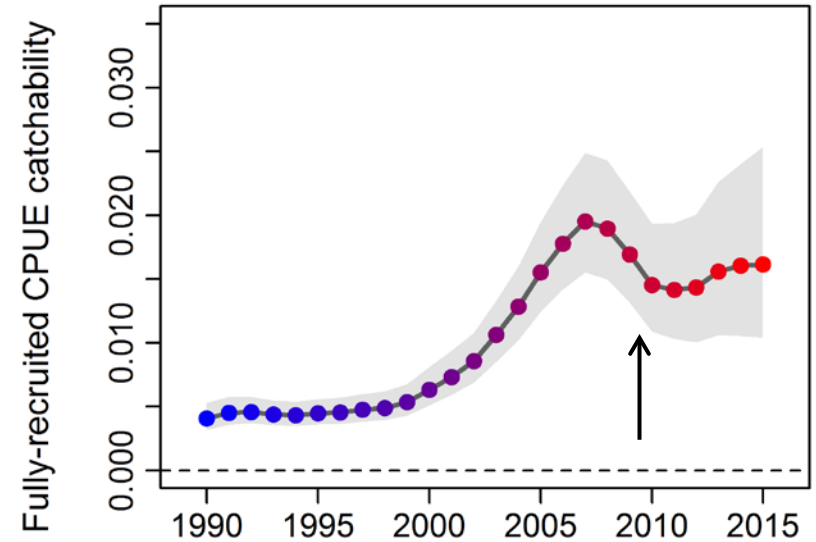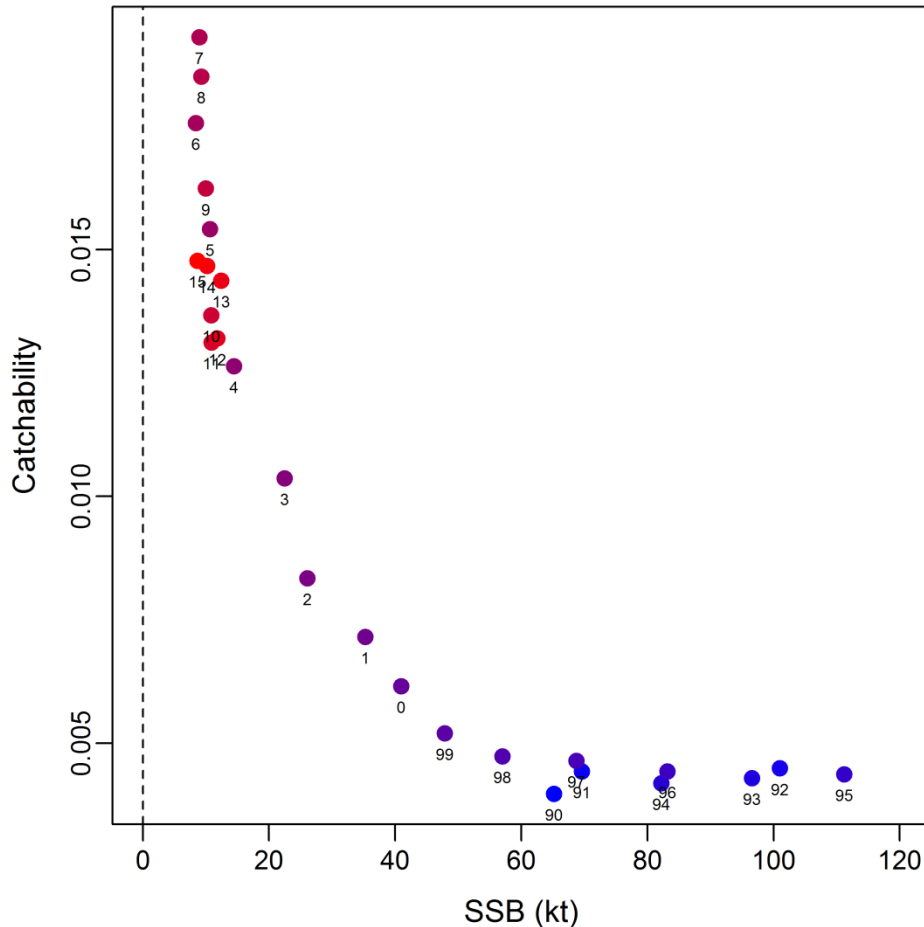
Spring Spawner Models

- time-varying q – more pessimistic view of stock status, especially with VPA

- VPA - more pessimistic results than SCA

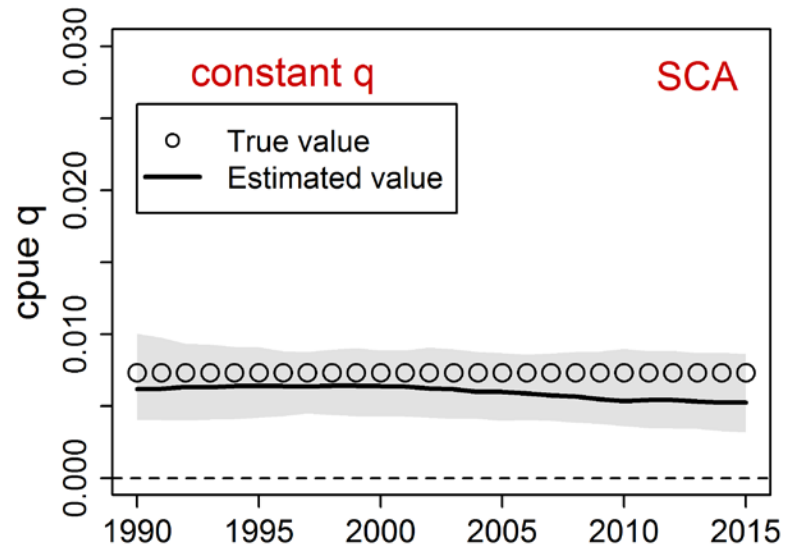# Causes of changes in fishery *q* of Spring Spawners?

Density-dependent: *q* increases as SSB declines below 60,000 t.

Decrease following management measures to reduce fishing efficiency.

Interesting if true – simulation tests of time-varying *q* models
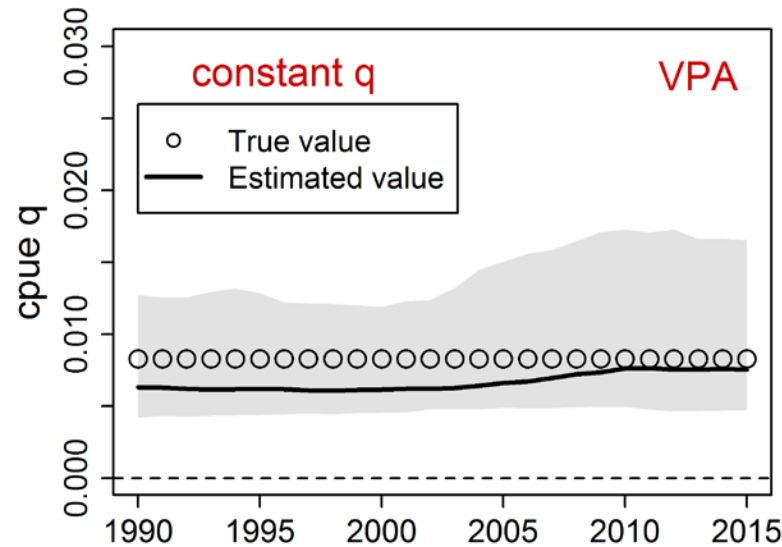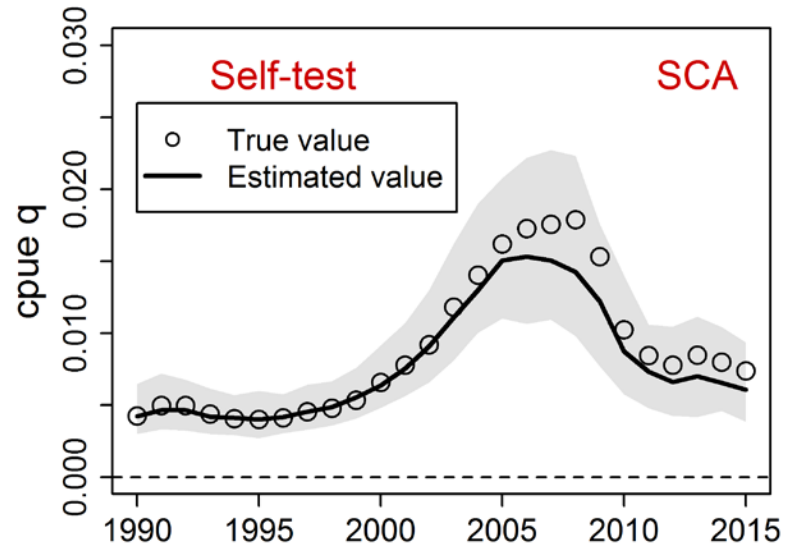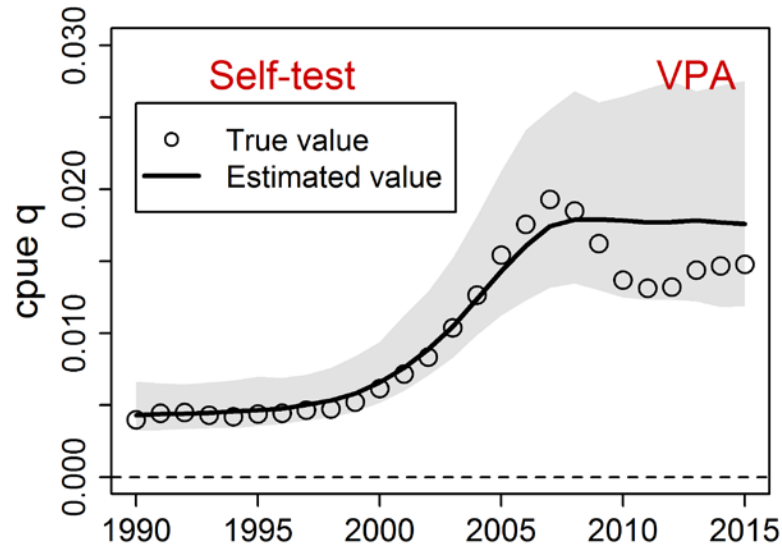
Fall Spawner VPA model

Modelled as 3 populations (which may mix at recruitment)
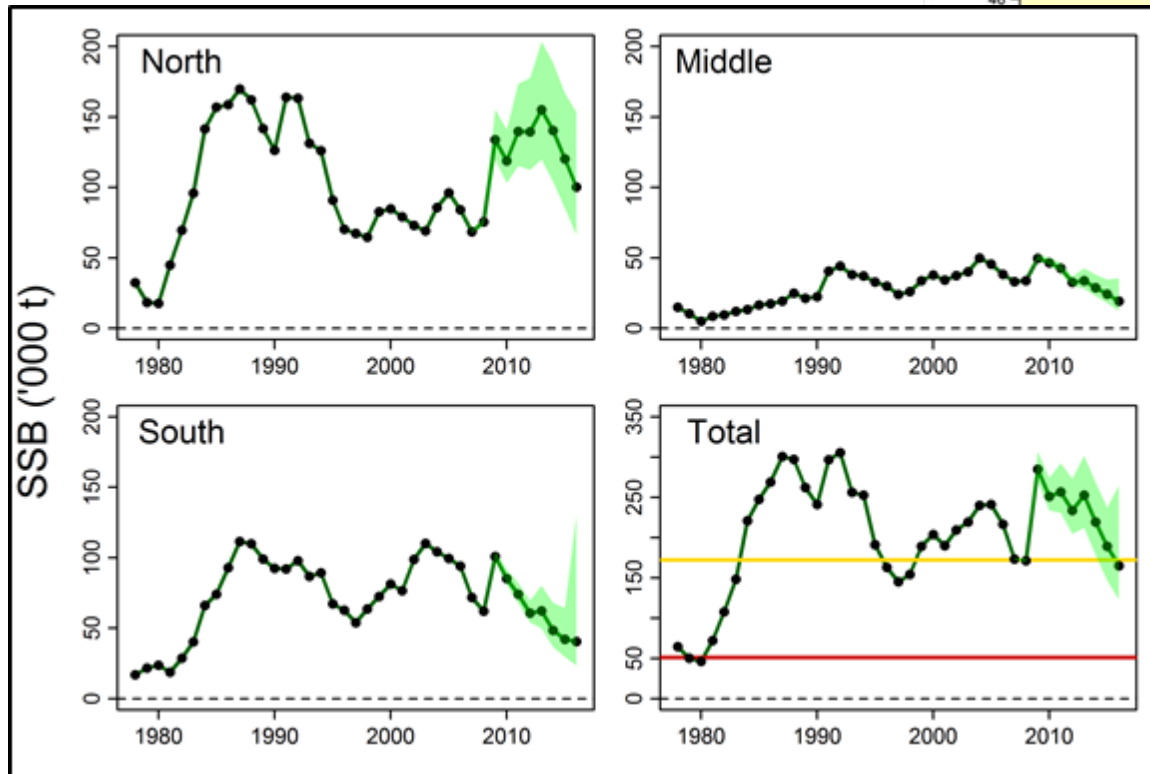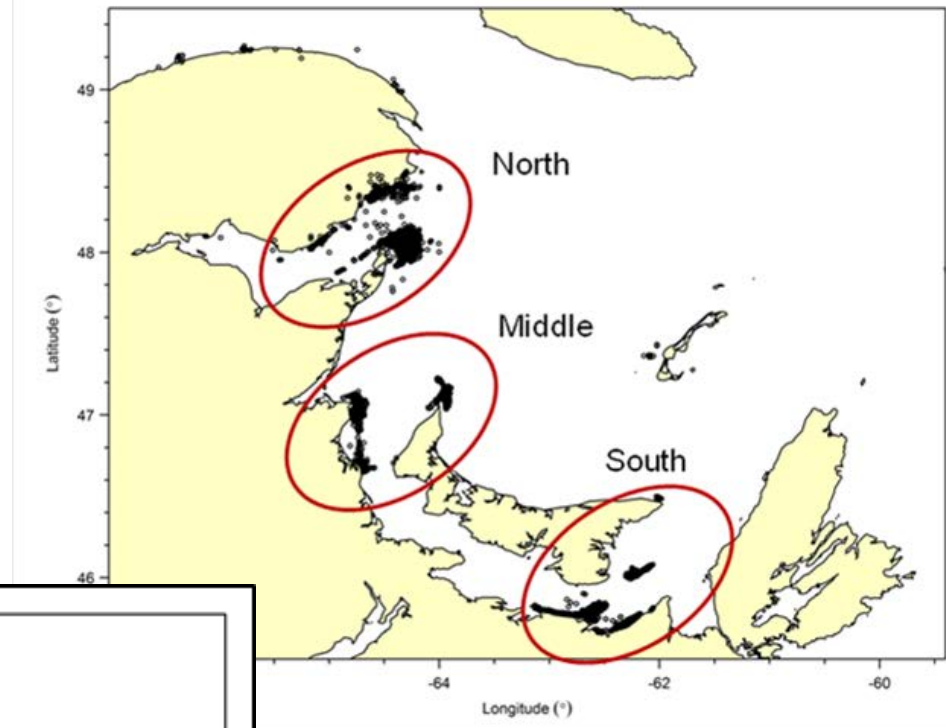
Fall Spawner VPA model – fit to the fishery cpue index

Constant *q*

Time-varying *q*
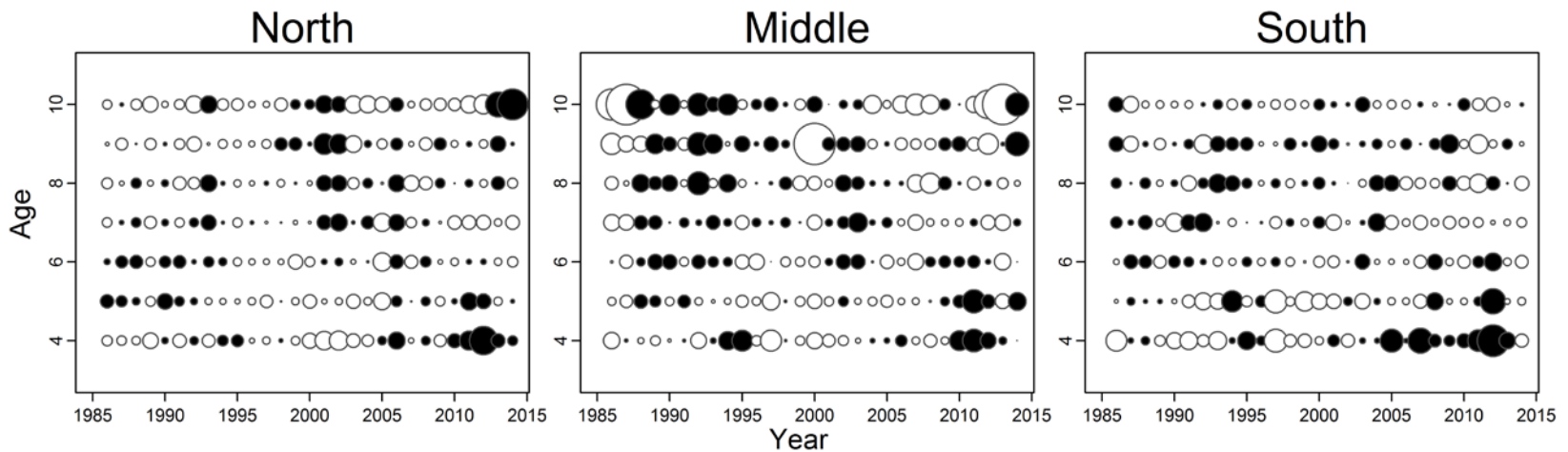
Fall Spawner VPA model – time-varying fishery *q*
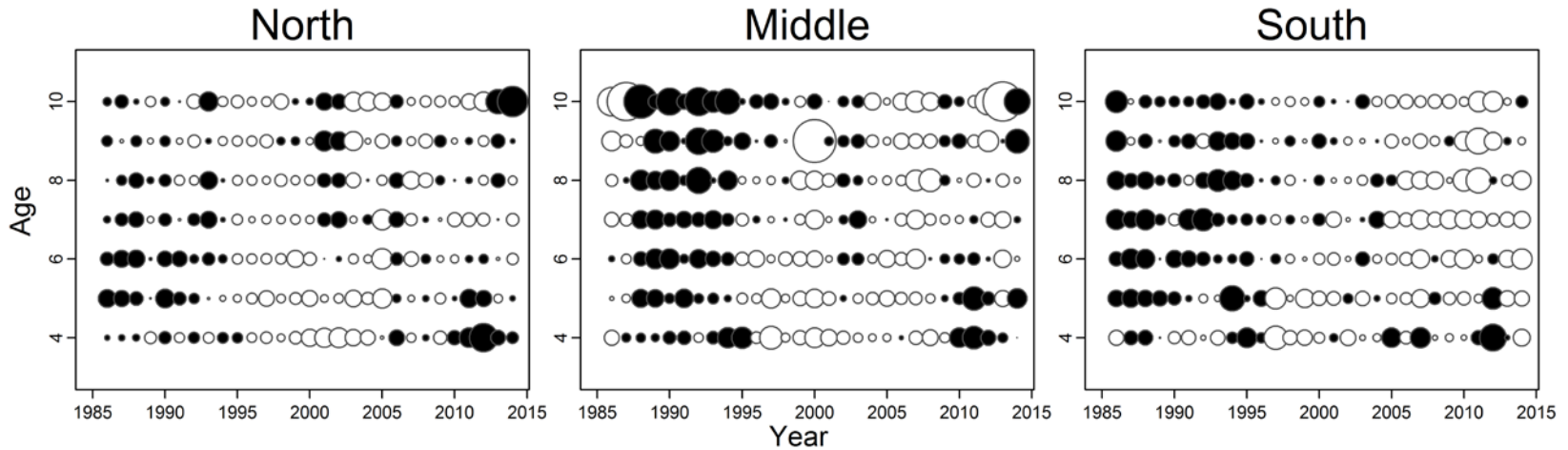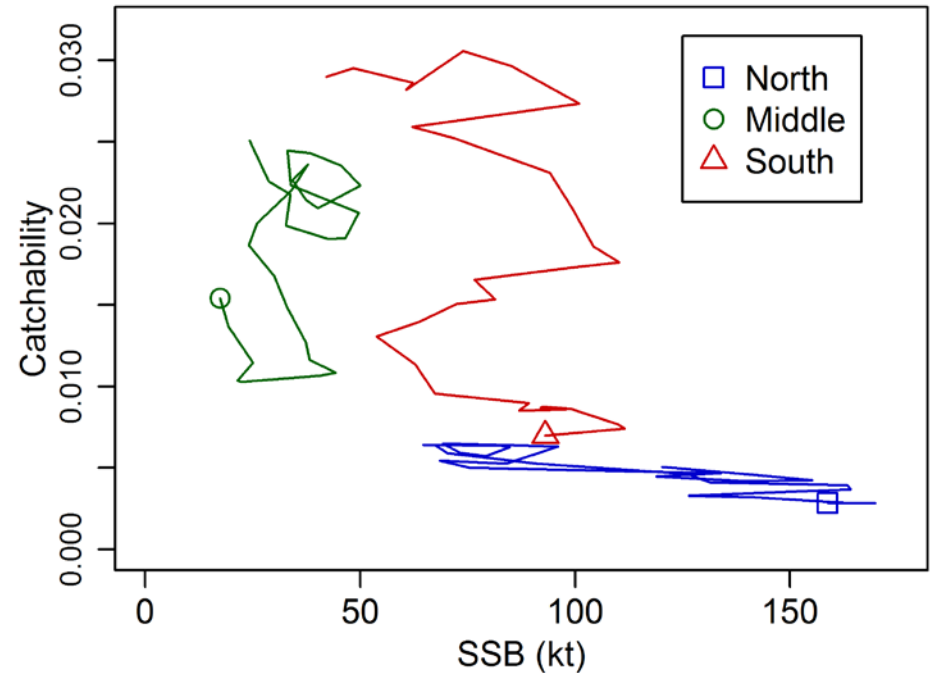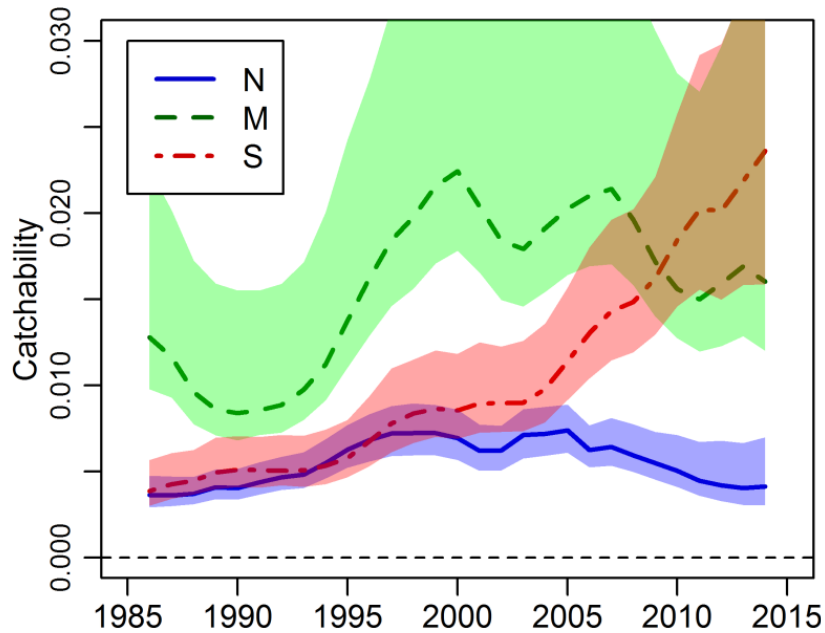

Variation in *q* is mostly density-independent

May be related to changes in the behaviour of fish or fish harvesters:

- Harvesters in the South (but not in the North) indicate important changes in their fishing behaviour in recent years
- Grey seal abundance has been increasing exponentially and harvesters report changes in herring behaviour in response to the presence of seals

Fall Spawners – effect of time-varying *q* on estimates
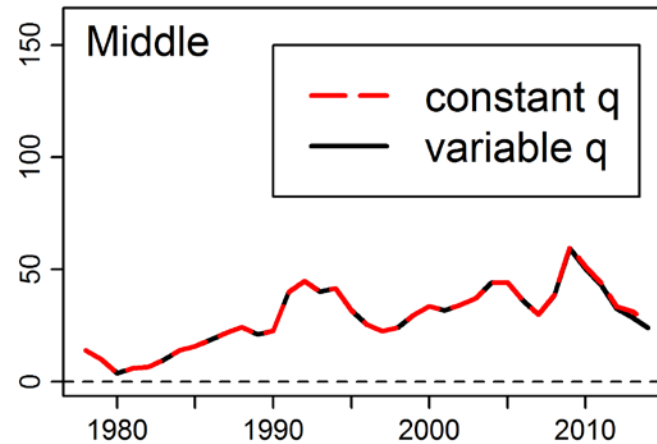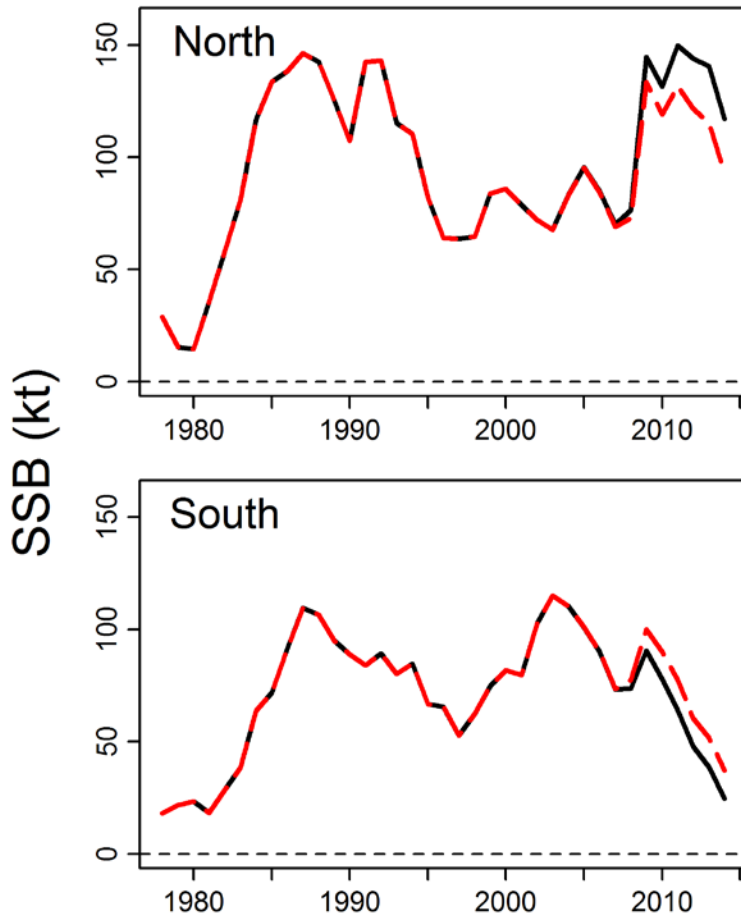
- Recent estimates of SSB are higher in the North and lower in the South when time-varying q is taken into account

- This difference may be important given the status of the South population

Conclusions

- Evidence of time-varying q for fishery cpue indices of both spring- and fall-spawning stocks of herring

- Apparent causes differed between stocks

- Strong evidence for density-dependent q for the depleted spring spawning stock

- Failure to account for time-varying q can lead to incorrect conclusions on stock status (e.g., spring VPA)

- Based on simulation tests, both SCA and VPA models were able to identify time trends in q in most instances

- VPA and SCA estimated similar trends in population biomass, though the SCA estimates were more optimistic in recent years.