Variation in life history traits, and signs of recovery in a collapsed marine forage fish species

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Introduction

- In marine ecosystems, forage fish transfer energy from primary producers and convert it into food for top predators [1]. Therefore, even modest declines in forage fish populations can have ecosystem-level impacts [2].
- Forage fish are small-medium sized fish with a short life span that reach maturity early and have high fecundity [2]. These life history traits result in high population growth rates.
- After a population collapse, individuals are released from competition and, thus, are predicted to have more available energy to allocate toward reproduction, thereby allowing the population to grow quickly
  - Higher inter-annual variability in life history traits also are predicted after a collapse, as there are fewer individuals in the population to buffer the impacts of environmental factors [3].
- As a population continues to recover, pre-collapse tends in life history traits, typically start to reappear.

Study Species

- Capelin *(Mallotus villosus)* is the key forage fish species on the Newfoundland and Labrador Shelf (NAFO Divisions 2J3KL; Fig. 1).
- Capelin in this region are commercially fished for their roe (eggs) prior to spawning during the summer in coastal regions.
- This capelin population collapsed in the early 1990s [4], which was associated with an anomalous cold-water event.
- Immediately after this collapse, capelin had smaller body size, earlier age at maturity, and delayed spawning (~3 weeks) (Fig. 2).
- Since collapse, the inshore roe fishery continues and the population continues to be monitored for signs of recovery.

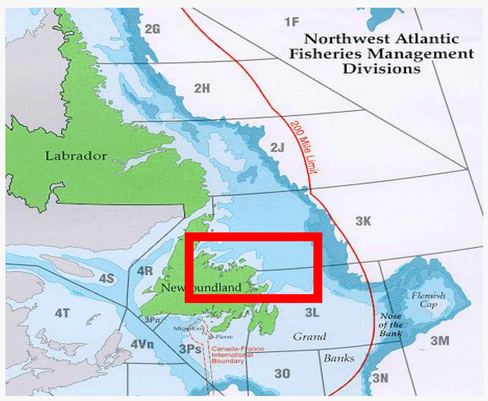

Figure 1. Map of region occupied by capelin on the Newfoundland and Labrador Shelf (NAFO Divisions 2J3KL; modified from. https://www.dfo-mpo.gc.ca). The box indicates the study area on the northeast Newfoundland coast.

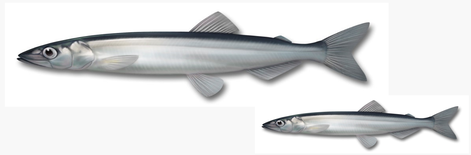

Figure 2. Capelin *(Mallotus villosus)* decreasing body size post-collapse. Modified from https://www.dfo-mpo.gc.ca

Objective

Investigate the status of the Newfoundland capelin population after collapse (post-1991) to determine if the population is showing signs of recovery.

Predictions

Table 1. Predictions of life history traits in forage fish before a population collapse and during recovery

Life history trait	Pre-collapse	Post-collapse	Recovering
Body size	Moderate	Small	Increasing
Age of maturity	Later	Earlier	Delaying
Spawning time	Earlier	Later	Advancing
Area occupied	High	Low	Increasing
Life history trait variability	Low	High	Decreasing

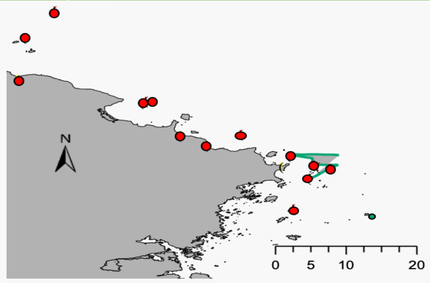

Figure 3. Map of the study area on the northeast Newfoundland coast, indicating capelin spawning sites (red dots) and hydroacoustic survey (green line).

Methods

- Multiple samples of capelin (sample = 200 fish) were collected at spawning sites (Fig. 3) through July – August 2009-2020.
- Spawning sites were monitored every 1-3 days to determine the number of spawning sites used and the first date of spawning in the study area.
- A hydroacoustic survey (Fig. 3) was conducted weekly throughout July-August in each year to quantify capelin biomass in the study area.

Results

Body size: was low post-collapse, showed signs of recovery (2013-2014), but then decreased after 2015.

Age at maturity: earlier age at maturity post-collapse (2-3 years old) relative to pre-collapse (3-4 years old).

Timing of spawning: later and more variable timing of spawning post-collapse relative to pre-collapse. Later spawning is associated with lower body size (Figs. 4, 6).

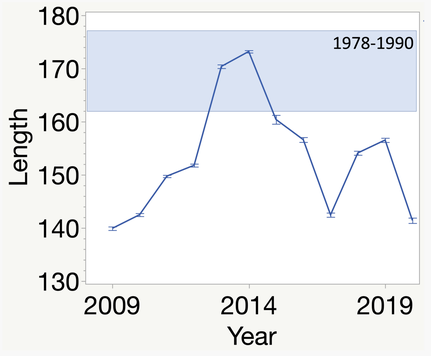

Figure 4. Mean (± SE) length (mm) of spawning capelin in the study area, with the range of mean lengths pre-collapse indicated in blue [5]. $R^2 = 0.405$. Data presented are correlated with similar data from other regions (r = 0.636).

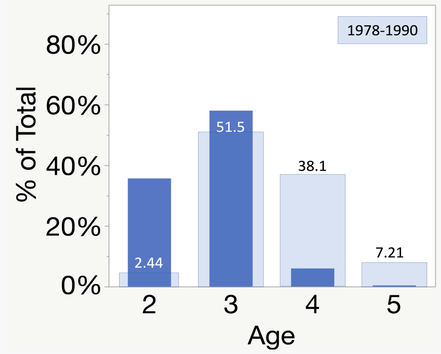

Figure 5. Mean proportion of individuals in each age class post-collapse 2009, 2011-2014 (dark) and pre-collapse 1978-1990 (light) [6].

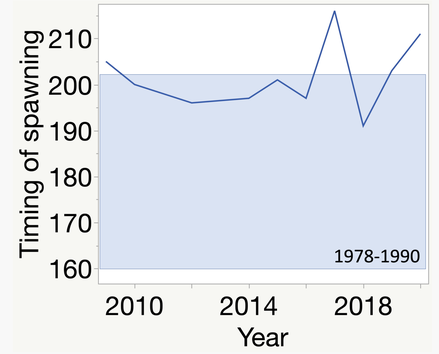

Figure 6. Mean spawning times (day of year) post-collapse with the range of mean times pre-collapse indicated in blue [5]. $R^2 = 0.046$. Data presented are correlated with similar data from other regions (r = 0.214).

Other indications

- We predicted that a collapsed population would occupy fewer spawning sites because they should select the most favourable spawning sites to ensure high reproductive success [7]. A recovering population would increase the number of sites used as abundance increases (Fig. 7).
- Although forage fish populations infrequently reside near the carry capacity of their environment, increasing body size with increasing abundance indicates that the capelin population is not experiencing density-dependent growth that is more typical at pre-collapse population sizes (Fig. 8)

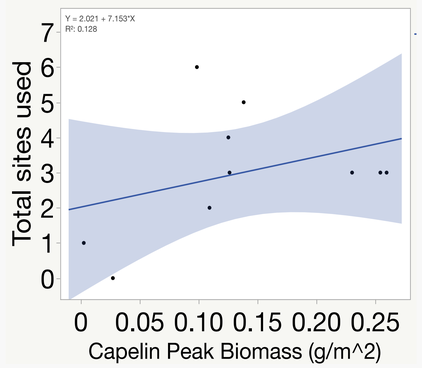

Figure 7. Number of sites used with increasing capelin biomass. $R^2 = 0.128$. Data presented are correlated with similar biomass data from other regions (r = 0.358).

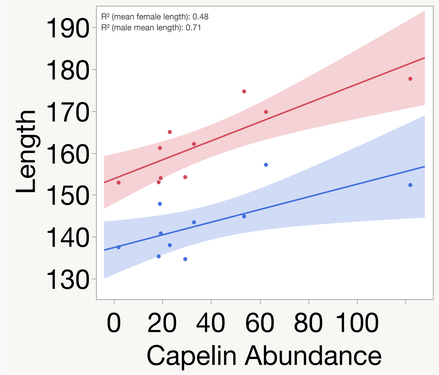

Figure 8. Mean female (blue) and male (red) length (mm) with increasing capelin abundance. R^2 male = 0.710; R^2 female = 0.480. Data presented are correlated with similar length and abundance data from other regions (r male = 0.843; r female = 0.693).

Conclusion

- Still showing life history traits (body size, age at maturity, timing of spawning) that are similar to immediately post-collapse.
- Increased variability in body size and timing of spawning further suggests a lack of recovery.
- The trend of increasing number of spawning sites used with increasing abundance suggests that the population is not near the carry capacity of the environment. This is further supported with increasing length and abundance.

Citations

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