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Relative strength of four cohorts (2012-15) of Atlantic Cod, from nearshore surveys of demersal age 0 and 1 juveniles in Newman Sound, Bonavista Bay

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

We surveyed demersal age 0 and 1-year old Atlantic Cod (*Gadus morhua*) in the nearshore (<10 m deep) of Newman Sound, Bonavista Bay Newfoundland, during the 20-year period, 1995-2015. We used a seine net to conduct a qualitative assessment of the strength of these cohorts. Our assessment was based on comparisons with abundance of Atlantic Cod sampled at 6-12 sites, every two weeks from July until November, each year. Analysis of annual length frequency and abundance data indicated that age 0 Atlantic Cod settled into nearshore habitats in several distinct pulses, the first pulse arriving in early July in 2013 and 2015, but late in 2014 (i.e., September). Second and subsequent pulses followed the first by as much as a month and a half later, in each year. Strong pulse structure throughout the sampling period typically has resulted in the production of a strong cohort during previous survey years. The age 0 abundance in Newman Sound in 2013 and 2015 suggests that these two cohorts will also be moderate to strong, relative to other cohorts in the 20-year long time series. The 2013 cohort was the strongest in the 20-year time series in terms of mean abundance per set, timing of settlement, and strength of its recruitment pulse structure. Taking into account that two cohorts were sampled each year (as age 0 and age 1 individuals), this pre-recruit survey has shown that stronger than average cohorts were produced during each of the sampled cohorts of the four-year period (2012-15), compared with other cohorts during the 20 years of monitoring. At age 1, the 2014 cohort was far weaker than we had predicted based on their age 0 abundance alone. We suggest that a combination of smaller sizes of individuals in this cohort at the end of the growing season in November, due to late initial settlement (September 2014), and protracted low temperature conditions overwinter may have contributed to lower overwinter survival to age 1, for the 2014 cohort. We anticipate that 2014 will be numerically weak.

INTRODUCTION

Age 0 and 1-year old Atlantic Cod in the Northwest Atlantic Fisheries Organization (NAFO) Subdivisions 3K and 3L (Northeast Newfoundland Shelf) are distributed predominantly in inshore waters (Dalley and Anderson 1997). During autumn months within these inshore waters, age 0 cod are most common in depths less than 10 m (Methven and Schneider 1998). The Fleming surveys historically (i.e., 1959-64, Lear et al. 1980; 1992-97, e.g., Methven et al. 1998) sampled nearshore abundances of juvenile Atlantic Cod in this depth range with the objective of assessing relative numerical strength of adjacent cohorts. The working principle employed was that the relative strength of adjacent cohorts in the first years of life is carried through to subsequent age groups within that cohort over time (Schneider et al. 1997).

In autumn 1995, an investigation of the abundance of age 0 cod and their association with nearshore habitat types was initiated in Newman Sound, Bonavista Bay (Gotceitas et al. 1996). The 1995 study was followed by similar efforts in the years 1996-2015 (e.g., Gregory et al. 1997, 1999, 2002, 2004, 2006, 2017). These studies have collectively shown that the nearshore of Newman Sound is a nursery area for demersal fishes, including age 0 Atlantic Cod. In our study, we have continued to track the strength of temporally adjacent cohorts in Newman Sound, through the first two years of life.

In this study, we qualitatively assessed the relative strength of four cohorts (2012-15) of Atlantic Cod based on abundance of demersal age 0 and 1 in Newman Sound, Bonavista Bay in summer and autumn of three years (2013-15). We compared abundances of age 0 and age 1 Atlantic Cod to those in previous years (1995-2012). We have previously shown that interannual trends between the Newman Sound data and the larger geographic scale Fleming survey data are consistent (Methven et al. 1998; Gregory et al. 2002, 2004, 2006). We also suggest that during years of relatively high abundance, settlement occurs in more than one temporal pulse (Methven and Bajdik 1994; Grant and Brown 1998; Gregory et al. 2006, 2017) several weeks apart. The four cohorts examined in this report represented several of the strongest we have yet observed in Newman Sound during the past 20 years.

METHODS

Newman Sound seine sites (Fig. 1) – described in Gregory et al. (1997) – were selected on the basis of sampling logistics. We used seasonal catch data from all 12 of our primary study sites, sampled every two weeks from July to November each year. Fish samples were collected using a 25 m beach seine – wings, belly and codend consisted of 9 mm stretch mesh; 24.4 m headrope, 26.2 m footrope. Aluminium poles – 75 cm long and 25 mm diameter – one on the end of each wing served to maintain the spread between the headrope and footrope. The net was deployed from a 6 m boat at a distance of 55 m from the shore, and then retrieved by two individuals standing 16 m apart on the shore. The seine was pulled along the bottom and sampled the lowest 2 m of the water column. Deployed in the manner described, the net sampled approximately 880 m^2 of the bottom.

All fish collected were identified and counted. Juvenile cod were loosely assigned to age groups in the field based on previously established age-length relationships in Newfoundland waters in late autumn (age 0: $\leq$10 cm SL [standard length], age 1: 10 to 20 cm SL, and age 2: 20 to 30 cm SL - Dalley and Anderson 1997) and adjusted as necessary for age 0 and age 1 fish by examination of otolith microstructure in 1996 and 1997 (Gregory et al. unpublished data) and refined by examination of length frequency trajectories within each season.

RESULTS AND DISCUSSION

The period 2013-15 has produced above average strength cohorts when compared among all others in the 20-year Newman Sound time series 1995-2015 (Fig. 2). The 2013 cohort was the single strongest among those sampled since the implementation of the 1992 cod moratorium, and the 2006 cohort remains the lowest during the series. During the most recent decade, five cohorts (2007, 2012-15) were relatively strong compared to adjacent ones, as age 0 individuals (Fig. 2). High densities of age 0 were consistently followed by higher than average densities at age 1 the following year, for most cohorts (Fig. 2), but not in all cases (e.g., 2014 cohort). Similarly, low density years as age 0 were succeeded by low densities of age 1 individuals the following year in most instances (e.g., 2003-06 cohorts), again with exceptions (e.g., 2000 and 2010).

Age 0 cod abundance has been a qualitative indicator of cohort strength among years. Directional change in age 0 density between adjacent years matches similar changes in age 1 in over 75% of cohorts (Fig. 2). Although qualitatively consistent (i.e., age 0 abundance reflects age 1 abundance the following year), high interannual variability in age 0 to age 1 mortality makes age 0 abundance a poor predictor of age 1 abundance with any precision among Newman Sound cohorts (Fig. 3). However, Newman Sound age 1 abundance and age 3 abundance from Inshore SPA (Sequential Population Analysis) have been positively and highly correlated (r^2 =0.803; p=0.0026) for 1995 to 2003 cohorts (Fisheries and Oceans Canada [DFO] 2006).

Age 0 Atlantic Cod settle into nearshore habitats in several distinct pulses each year caused by unique combinations of offshore and onshore wind events throughout the summer and autumn months (Ings et al. 2008). The implications of multiple settlement pulses on the cohort strength of Atlantic Cod and other gadid species was explored by Ings et al. (2008). Although mortality rates between age 0 and 1 have proven difficult to predict, annual pattern of early settlement (e.g., late-July or early-August) followed by a complex structure of settlement pulses, has appeared consistently favourable to the production of a strong cohort. Our data from 2013-15 (Figs. 4-6) suggest that a complex and temporally extended pulse structure observed during 2013 and 2015 (e.g., two or more strong modes; Figs. 4 and 6) may signal relatively good recruitment years, compared to years with a simple or weak pulse structure (e.g., only one mode or multiple weak modes). The 2014 cohort, although abundant as age 0 individuals, settled late in the season (in September, Fig. 5), resulting in individuals entering winter smaller than usual. These individuals likely experienced high overwinter mortality resulting in the 2014 cohort being underrepresented as age 1's (Figs. 2, 5 and 6). The 2013 and 2015 cohorts showed evidence of three strong settlement pulses about one month apart, indicating relatively strong cohorts, during our 20-year time series. Weak abundance years (e.g., 1996, 2001, 2003-04; Gregory et al. 2006), in which settlement to the nearshore is often late (i.e., late-August and even into early-September) and accompanied by few, numerically weak pulses, typically do not produce strong cohorts.

A similar pulse structure is also generally observed over spatial scales covering multiple embayment’s along the northeast Newfoundland coast, and do not appear unique to the vicinity of individual nursery areas such as Newman Sound. Similar recruitment patterns occur annually at widely separated sites along the northeast Newfoundland coast (Methven and Bajdik 1994; Grant and Brown 1998) suggesting that these observations reflect broader geographic phenomena. We investigated this pattern further in 2007 by conducting a protracted juvenile fish beach seining program in Smith Sound, Trinity Bay as well as our annual Newman Sound effort (Gregory and Morris, unpublished data); the size patterns of the settlement in the two locations was similar, suggesting that similar settlement dynamics were at play over wide geographic areas and isolated patterns may not be unique to each embayment. From genetic evidence, we also know that different stock components contributed differentially to each of these pulses in 1999 (Beacham et al. 2000). However, it remains to be determined if individual stock components contribute only to a single settlement pulse in Newman Sound. Size-selective mortality factors can be reasonably expected to affect differential survival among different recruitment pulses (Sogard 1997). The mortality rates of age 0 have been highly variability – 0.5-11%$\cdot d^{-1}$ – among pulses across cohorts, as calculated from pulse-specific abundance data 1995-2005 (Gregory et al. 2006).

Based on the results of described here for 2012-15, within the context of our 20-year dataset, we make the following conclusions:

- the 2012 cohort will likely be modest to high compared to all others 1995-2012.
- the 2013 cohort will likely be strong compared to all others in the previous 20 years.
- the 2014 cohort will be weak due to apparent poor overwinter survival from age 0 to age 1, despite its strong showing as age 0 in 2014; and,
- the 2015 cohort will be relatively high compared to others in the past decade, based on age 0 results.

ACKNOWLEDGEMENTS

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FIGURES

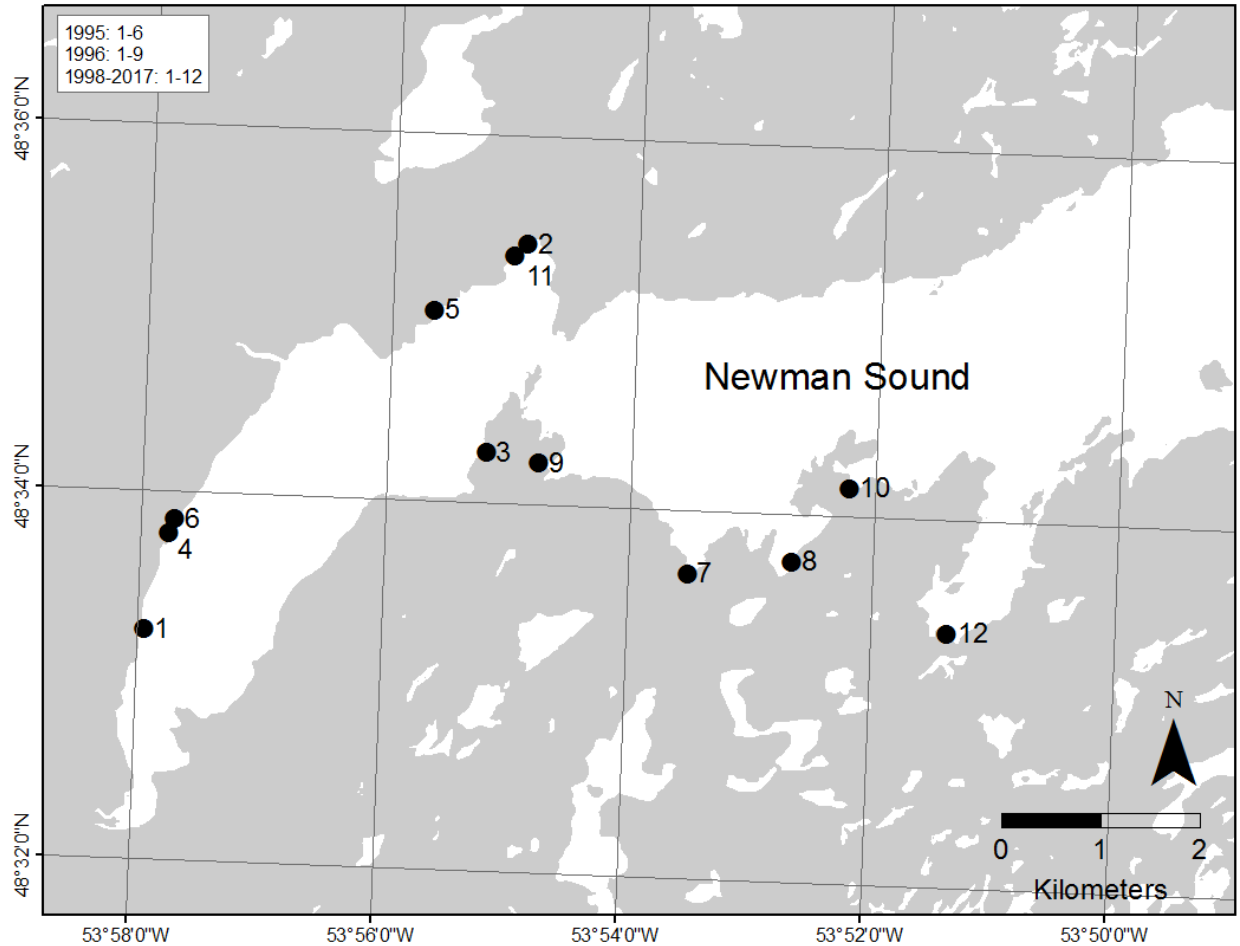

Figure 1. Location of nearshore sampling sites in Newman Sound, Bonavista Bay July to November 1995-2015.

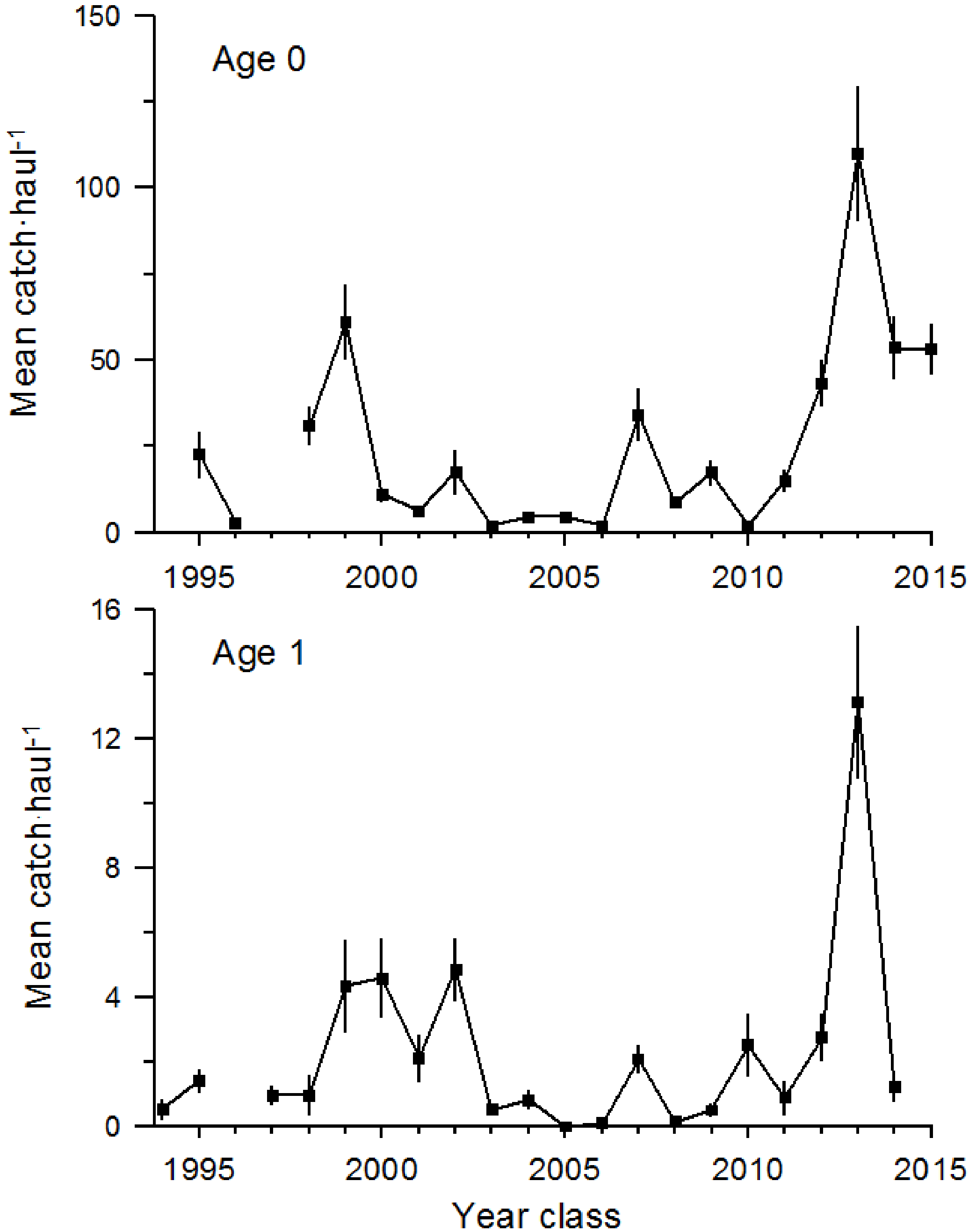

Figure 2. Mean age 0 (top panel) and age 1 (bottom panel) Atlantic Cod caught annually by beach seine in Newman Sound, Bonavista Bay, 1996-2015 (bars are +/-1 SE; n=105-132 seine sets/year).

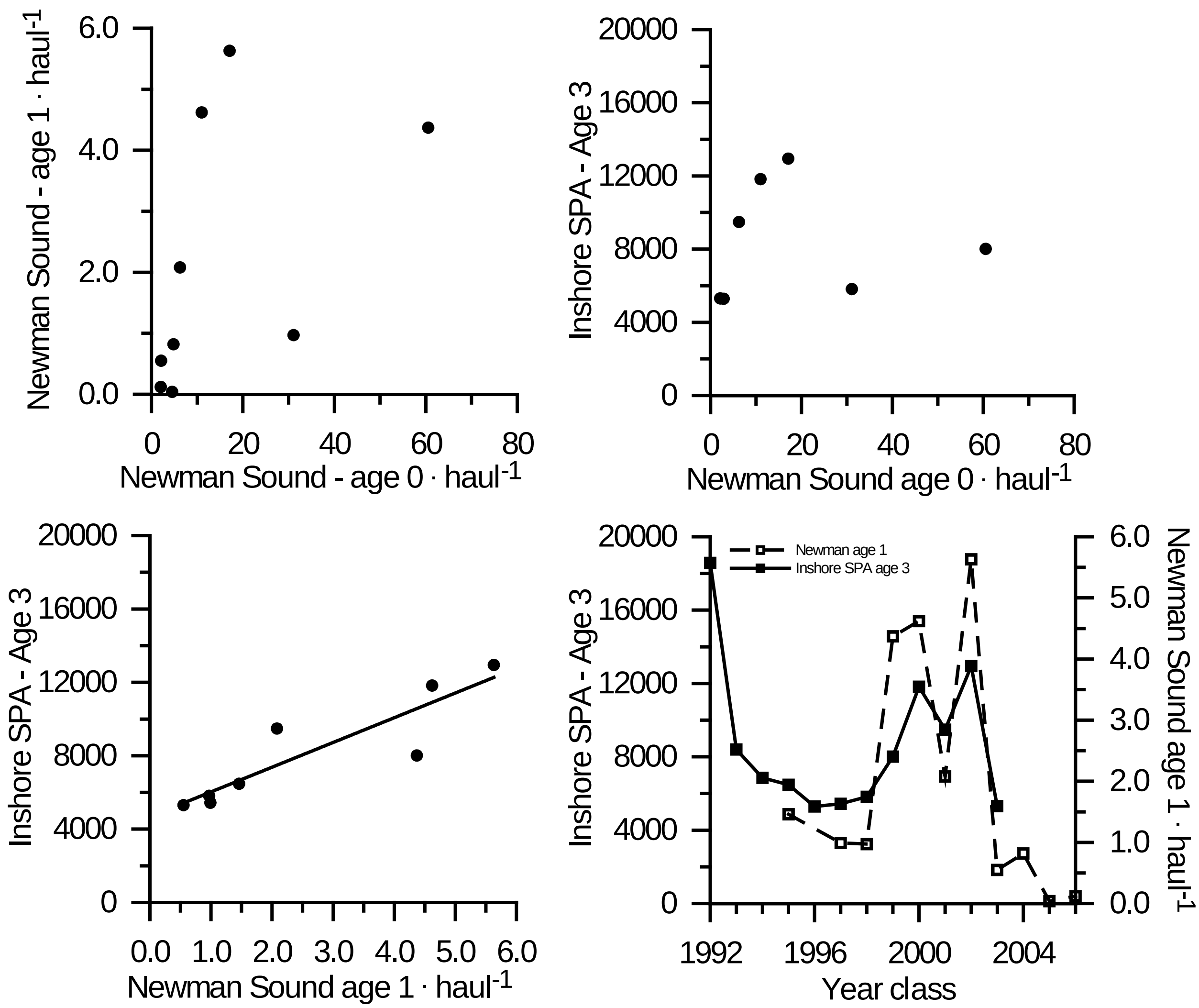

Figure 3. Age 0 and 1 Atlantic Cod caught by beach seine in Newman Sound Bonavista Bay, 1996-2007, and numerically compared to the inshore Sequential Population Analysis (SPA) for age 3 (DFO 2006).

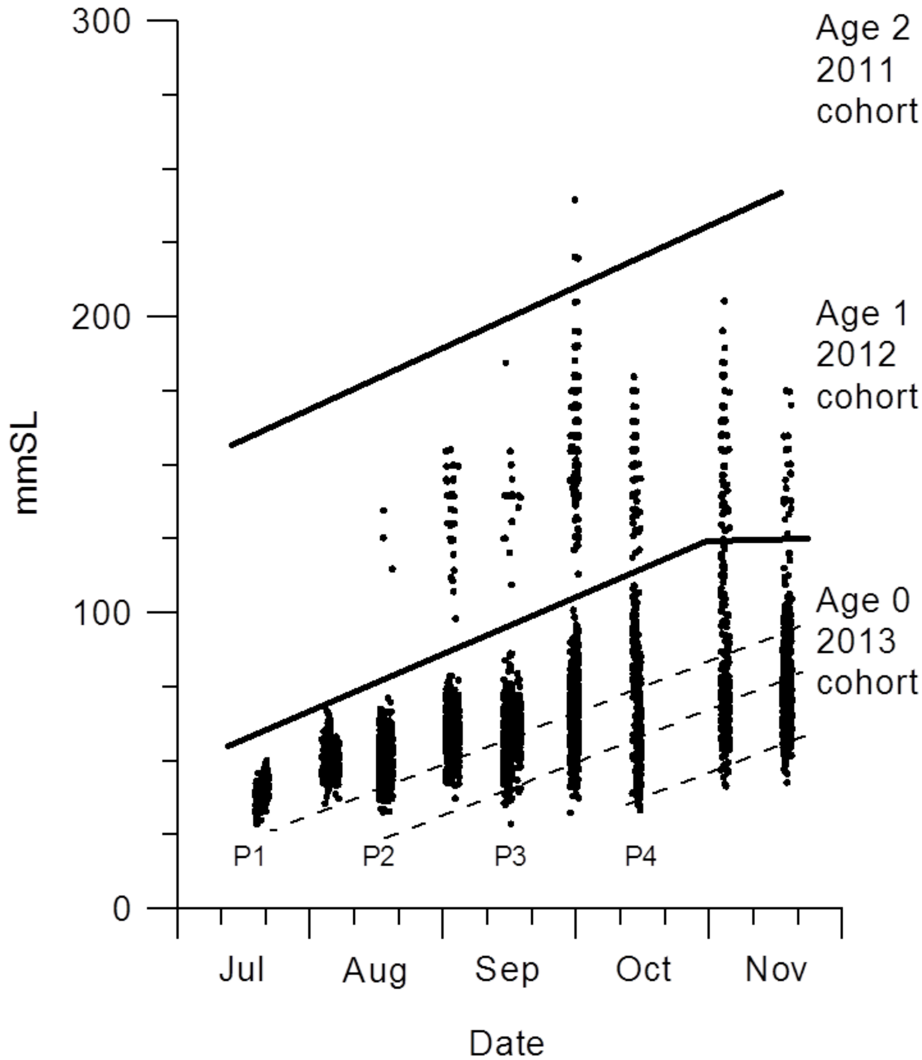

Figure 4. Sizes of Atlantic Cod captured by beach seine in Newman Sound, Bonavista Bay, July-November, 2013 and their potential age and recruitment pulse structure.

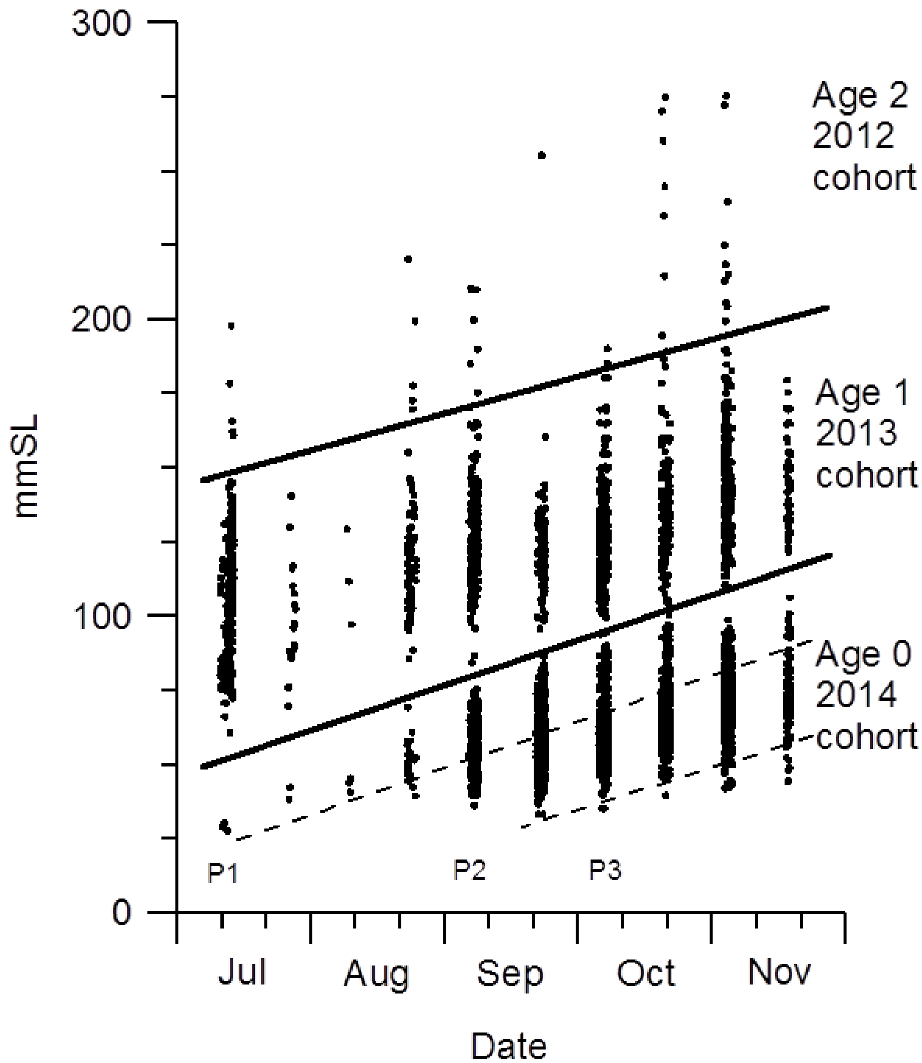

Figure 5. Sizes of Atlantic Cod captured by beach seine in Newman Sound, Bonavista Bay, July-November, 2014 and their potential age and recruitment pulse structure.

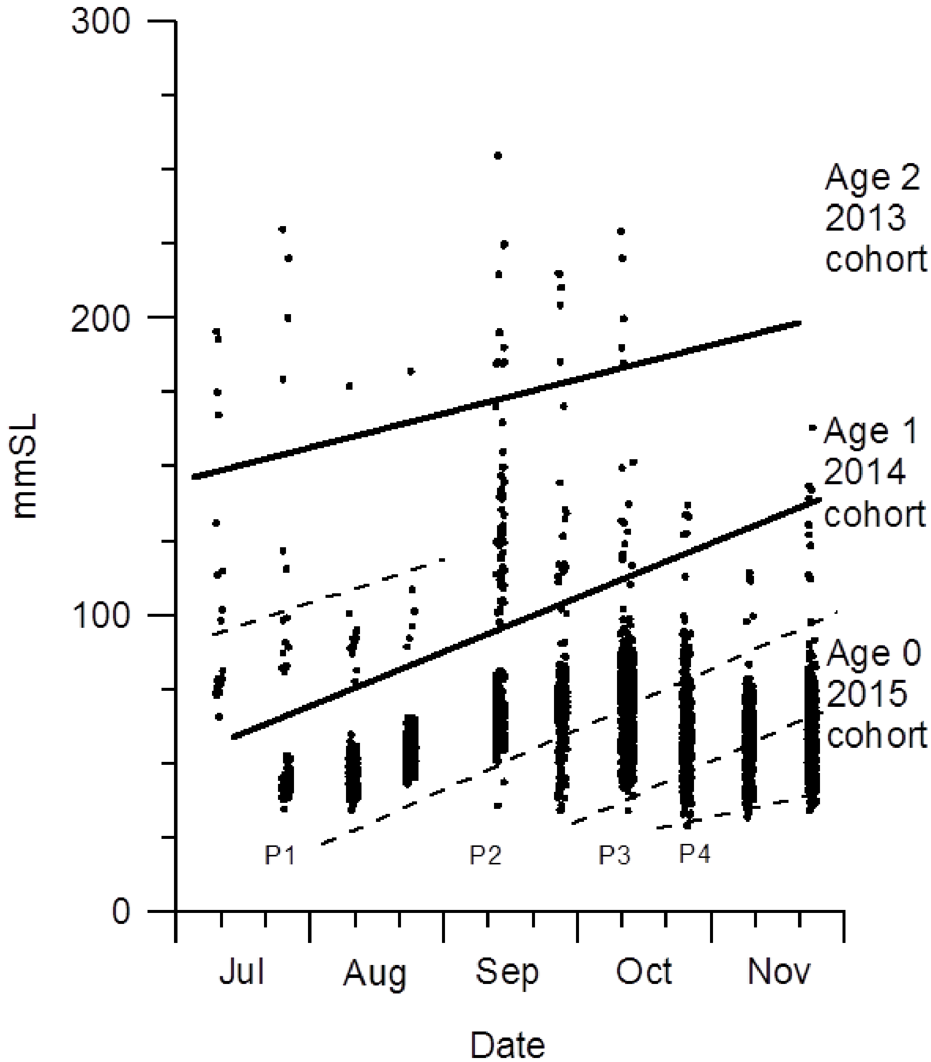

Figure 6. Sizes of Atlantic Cod captured by beach seine in Newman Sound, Bonavista Bay, July-November, 2015 and their potential age and recruitment pulse structure.