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Is There Mixing of American Plaice Populations in the Flemish Pass?

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Abstract

Although American plaice (*Hippoglossoides platessoides*) on the Grand Bank (Div. 3LNO) and Flemish Cap (Div. 3M) are thought to represent separate populations, in the late-1980s, early-1990s there was a change in the distribution of American plaice in the region. They were found in the deep waters of the Flemish Pass and in addition, the Div. 3LNO population as a whole was found in deeper waters. This raises the possibility of mixing between the two populations, at least in the area of the Flemish Pass. The purpose of this study was to examine the distribution, size and maturation of American plaice in the Flemish pass to determine if fish in that area are a mix of fish from the two adjacent populations or if the fish remain separated there. American plaice collected from the Div. 3L and Div. 3M sides of the Flemish Pass were clearly different in mean length at age and in their maturation. Further, American plaice were not collected in the deepest part of the Pass that was surveyed. Thus it seems that fish in the Flemish Pass area are not mixing but rather are separate groups.

Key words: American plaice, Flemish Pass, stock isolation

Introduction

American plaice (*Hippoglossoides platessoides*) is a flatfish species that is found through out the north Atlantic. In the Northwest Atlantic it is distributed from west Greenland in the north to the Gulf of Maine off the eastern United States (Scott and Scott, 1988). This distribution includes the Grand Bank (NAFO Div. 3LNO) and the Flemish Cap (NAFO Div. 3M). The population on the Grand Bank has historically been much larger than that on the Flemish Cap, supporting fisheries of 50 000 tons, compared to a fishery of only a few thousand tons on the Flemish Cap (Bowering and Brodie, 1991). Both populations have declined in abundance to very low levels and are under moratoria to directed fishing (Alpoim *et al.*, MS 2002; Morgan *et al.*, MS 2003).

The populations on the Flemish Cap and on the Grand Bank are thought to be separate with little or no connection between them (Pitt, 1963). An examination of distribution, growth, age composition and maturity by Bowering and Brodie (1994) indicated that American plaice on the Flemish Cap were distributed in warmer waters, were bigger at age and had a truncated age distribution compared to fish on the Grand Bank.

In the late-1980s, early-1990s American plaice were found in the deep waters of the Flemish Pass (Iglesias *et al.*, 1996). In addition, the Div. 3LNO population as a whole was found in deeper waters (Morgan and Colbourne, 1999; Morgan, 2001). This raises the possibility of mixing between the two populations, at least in the area of the Flemish Pass.

The purpose of this study was to examine the distribution, size-at-age and maturation of American plaice in the Flemish pass to determine if fish in that area are a mix of fish from the two adjacent populations or if the fish remain separated there.

Materials and Methods

Surveys conducted by the Canadian Department of Fisheries and Oceans in Div. 3L and 3M and in the deep water of the Flemish Pass were examined. In 1991, a deep water survey was conducted by the vessel *Cape Adair* in Div. 3KLM, during September 4-30, at depths ranging from 750-1 500 m. In 1994, a deep water survey in Div. 3KLMN was conducted by the vessel *Zandvoort* during Feb. 3- Mar. 13, in depths from 550-1 500 m. From March 16-April 21 1995, the RV *Teleost* conducted a survey of the same area from 500-1 500 m. All surveys used the same fishing gear, an Engel 145 otter trawl (see McCallum and Walsh, MS 1996 for trawl details). In 1994 and 1995 data from the regular spring survey of Div. 3L conducted by Canada were available. This survey was conducted to a depth of 731 m by the RV *Wilfred Templeman*, also using the same gear. In fall of 1996, Div. 3L and 3M were surveyed by the RV *Wilfred Templeman* and *Teleost* to a depth of 1 500 m, using a Campelen 1800 otter trawl. The Flemish Pass area was covered during November and December during this survey. The 1991 survey used a line transect design. All other surveys were stratified random and all used electronic sensors to record net dimensions and to determine bottom contact. The towing speed and tow duration were different in the 1991, 1994 and 1995 surveys from that in the 1996 fall survey. Fall 1996 survey conducted 15 min tows at 3.0 knots while the other surveys towed at 3.5 knots for 30 min.

All surveys, except the early fall 1991 and winter 1994 deep water surveys, collected number, weight, length, sex and maturity data on every tow containing American plaice, as well as otoliths for ageing. The other two surveys recorded number and weight on every set but did not collect otoliths or record length frequencies. During the winter 1994 survey a special collection of otoliths, length, sex and maturity was made from 4 sets on either side of the Flemish Pass.

Distribution maps were produced using ACON for those surveys that spanned the Flemish Pass (early fall 1991, winter 1994 and 1995 and fall 1996). From these surveys the maximum depth surveyed as well as the maximum depth at which American plaice were found was determined.

Mean length at age for males and females was calculated accounting for the length stratified nature of the sampling. Mean length at age was then compared within the winter 1994 and 1995 surveys for fish caught on the Div. 3L and Div. 3M sides of the Pass. In addition, mean length at age for these fish was compared to that for fish caught during the spring 1994 Div. 3L and fall 1996 Div. 3M surveys. The fall survey in 1996 had a different selectivity because of the different fishing gear used but it is the only survey of all of Div. 3M conducted by Canada during this time period.

Maturity at size and age was also compared for fish caught on either side of the Flemish Pass during the 1994 and 1995 deep water surveys. These were also compared to the spring 1994 and fall 1996 surveys. Maturity data from the spring 1995 survey of Div. 3L were also examined. Observed proportion mature-at-age was calculated according to the method of Morgan and Hoenig (1997), accounting for the length stratified sampling. Proportion mature at length or age was estimated using generalized linear models with binomial error and a logit link function (McCullagh and Nelder, 1983). These same models were used to test for significant differences between areas. Because of the limited data, estimates were made across year rather than by cohort.

Results

In the Cape Adair survey in early fall 1991, no American plaice were captured in Div. 3L. The maximum depth of the survey in Div. 3M was 1 495 m and American plaice were caught to a depth of 1 000 m. In the other three surveys that covered the Flemish Pass area, American plaice were distributed on both the Div. 3L and 3M sides of the Pass (Fig. 1). However, in sets that occurred in the middle of the Pass and at the greatest depths, no American plaice were found. In the winter 1994 survey, the maximum depth surveyed was 1421 m, while American plaice were only caught to a depth of 1 241 m. In the winter 1995 survey, American plaice were found to a depth of 1 281 m while the deepest survey set was 1 425 m. The deepest survey sets in the fall 1996 survey in the area were 1 433 m, while American plaice were not found beyond 1 383 m.

There was a clear difference in mean size-at-age between fish found on the two sides of the Flemish Pass. This was true both in the special collection made in 1994 and in the full collection covering the whole area in winter 1995 (Fig. 2). Fish in Div. 3M were bigger at age than those in Div. 3L for both males and females. The fish sampled

from the Div. 3L side of the Pass in both 1994 and 1995 were very similar in size to the average size-at-age of those fish sampled throughout Div. 3L during the spring 1994 survey. Fish sampled on the Div. 3M side of the pass during the winter 1994 and 1995 deep water surveys were very similar in mean size-at-age to those sampled over the whole of Div. 3M during the fall 1996 survey, even though that survey used a different gear.

Proportion mature at length could only be estimated for females in the Flemish Pass, as there was no significant model fit to the male data. Females matured at a significantly smaller size on the Div. 3L side of the Pass, as compared to those fish sampled on the Div. 3M side of the Pass in both the 1994 and 1995 deep water surveys (Fig. 3, Table 1). Maturity at length for fish sampled in the deep water in Div. 3L in 1994 was not significantly different from those sampled in the deep water in Div. 3L in 1995. Similarly, the Div. 3M deep water samples in 1994 and 1995 were not significantly different from one another. Fish sampled in the 1994 and 1995 deep water surveys in Div. 3M did not have significantly different maturities at length than those sampled in Div. 3M during the fall 1996 survey of the Flemish Cap. However, the proportion mature at length for fish in the deepwater in Div. 3L in 1994 and 1995 was significantly different from fish sampled over the entire Div. 3L during the spring 1994 survey (Table 1).

There was only a significant fit of the model to proportion mature-at-age data for females. There was no significant model fit for the deep water survey in 1994 or for fish collected in Div. 3M during the fall 1996 survey. The fish sampled in Div. 3L during the deepwater survey in 1995 matured at a significantly older age than those collected in Div. 3M during that survey (Fig. 4, Table 1). Again there was a significant difference in proportion mature-at-age for fish in the Div. 3L portion of the 1995 deep water survey vs. those in the entire Div. 3L area during the 1995 spring survey.

Discussion

American plaice collected from the Div. 3L and Div. 3M sides of the Flemish Pass were clearly different in mean length-at-age and in their maturation. Further, American plaice were not collected in the deepest part of the Pass that was surveyed. Thus it seems that fish in the Flemish Pass area are not mixing but rather are separate groups.

The origin of the fish on either side of the Pass appears to be the adjacent populations. That is, the fish on the Div. 3L side of the pass appear to be from Div. 3L while those on the Div. 3M side of the Pass appear to be from the Div. 3M population. The mean lengths-at-age were very similar between the fish in the Pass and those from the adjacent populations. The proportion mature-at-length was also the same for fish from the Div. 3M side of the pass and fish from the whole of Div. 3M. There were however, significant differences between the proportion mature at size and age for fish in Div. 3L compared to those found on the Div. 3L side of the Flemish Pass. It is not known why mean length-at-age would be so similar between fish from the entire Div. 3L area and those on the Div. 3L side of the Pass while maturation was different. The fish collected during the spring survey came from a very wide geographic area, experiencing a variety of environmental conditions. It is possible that maturation is more sensitive to varying conditions than growth.

The occurrence of American plaice in the deep water of the Flemish Pass appears to be a seasonal phenomenon, with fish being found in higher abundance in the area in the winter and spring (Iglesias *et al.*, 1996, reports from the Canadian fishing industry). Seasonal changes in distribution in this species, including changes in depth, are not uncommon (Morgan and Brodie, 1991; Powles, 1965; Swain *et al.*, 1998). The reasons for the changes in distribution are not known but could be related to temperature selection/avoidance and/or seasonal patterns in foraging.

It is not clear whether American plaice have always been found in this area during the winter spring period. The study by Iglesias *et al.* (1996) found some interannual variability in the timing and abundance of American plaice in deep water. There has also been a change in the depth distribution of American plaice captured in the spring survey of Div. 3L with plaice being found deeper starting in the early-1990s (Morgan, 2001). The earliest survey examined here (1991) did not detect any American plaice in the deep waters of Div. 3L and only few in Div. 3M. However, this survey was in September and may have occurred before any seasonal movement into deeper water. Although data may not exist to determine the beginning of this phenomenon, continued monitoring of commercial catches in the area would provide information on whether or not it continues.

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Table 1. Results of generalized linear models comparing proportion mature at size or age for female American plaice found in Div. 3L and 3M. All tests have 1 d.f.

Comparison	χ^2	p
Maturity at length		
Deep water 1994 3M vs. 3L	8.8	<0.005
Deep water 1995 3M vs. 3L	4.6	<0.05
Deep water 3L 1994 vs. 1995	3.0	NS
Deep water 3M 1994 vs. 1995	0.1	NS
Deep water 3M 1994 vs. fall 1996	0.5	NS
Deep water 3M 1995 vs. fall 1996	0.3	NS
Deep water 3L 1994 vs. spring 1994	106	<0.0001
Deep water 3L 1995 vs. spring 1994	46	<0.0001
Deep water 3L 1995 vs. spring 1995	15.3	<0.0001
Maturity at age		
Deep water 1995 3M vs. 3L	23.2	<0.0001
Deep water 3L 1995 vs. spring 1995	17.7	<0.0001

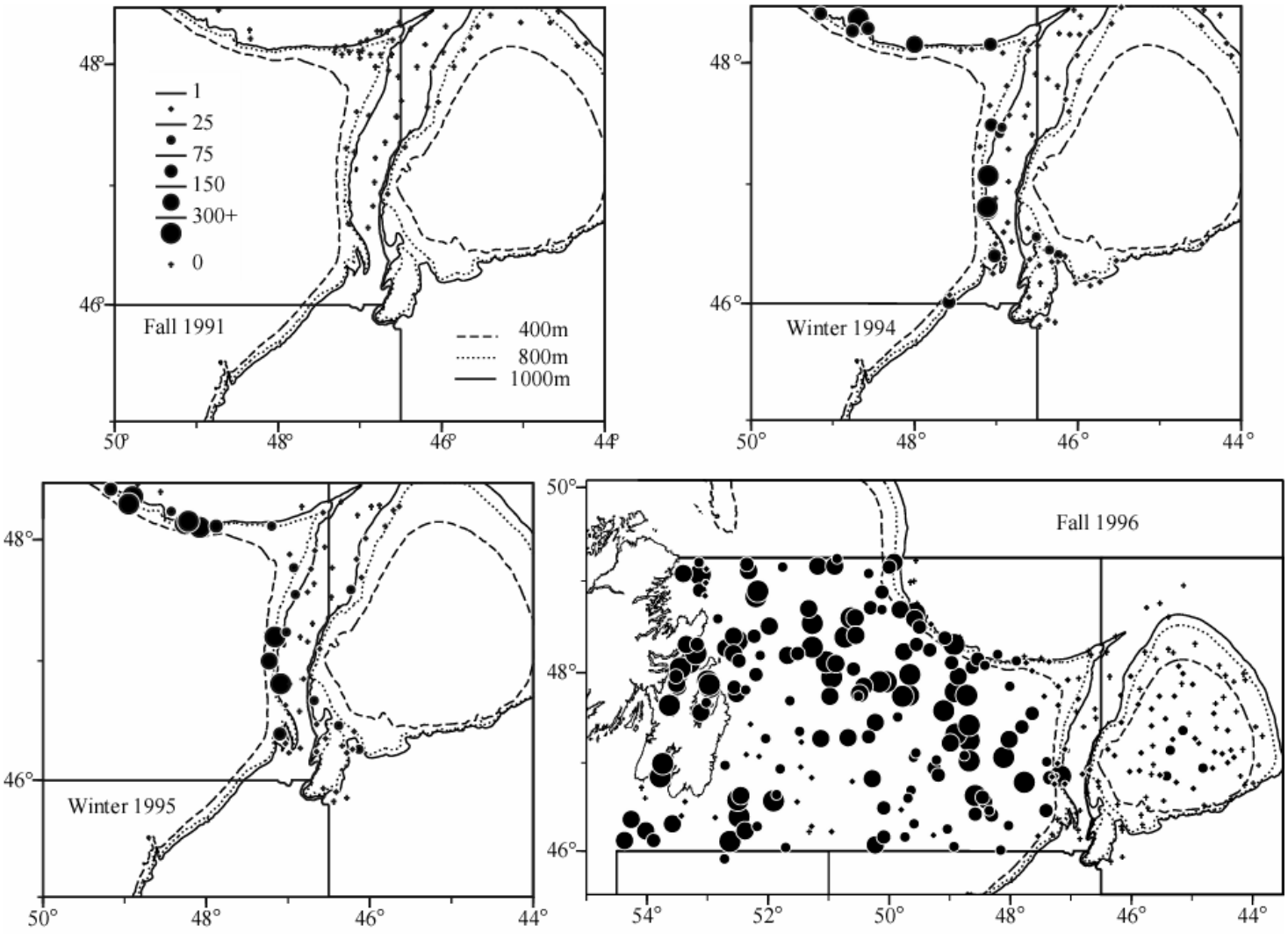

Fig. 1 Distribution of number of American plaice caught in surveys covering the area of the Flemish Pass.

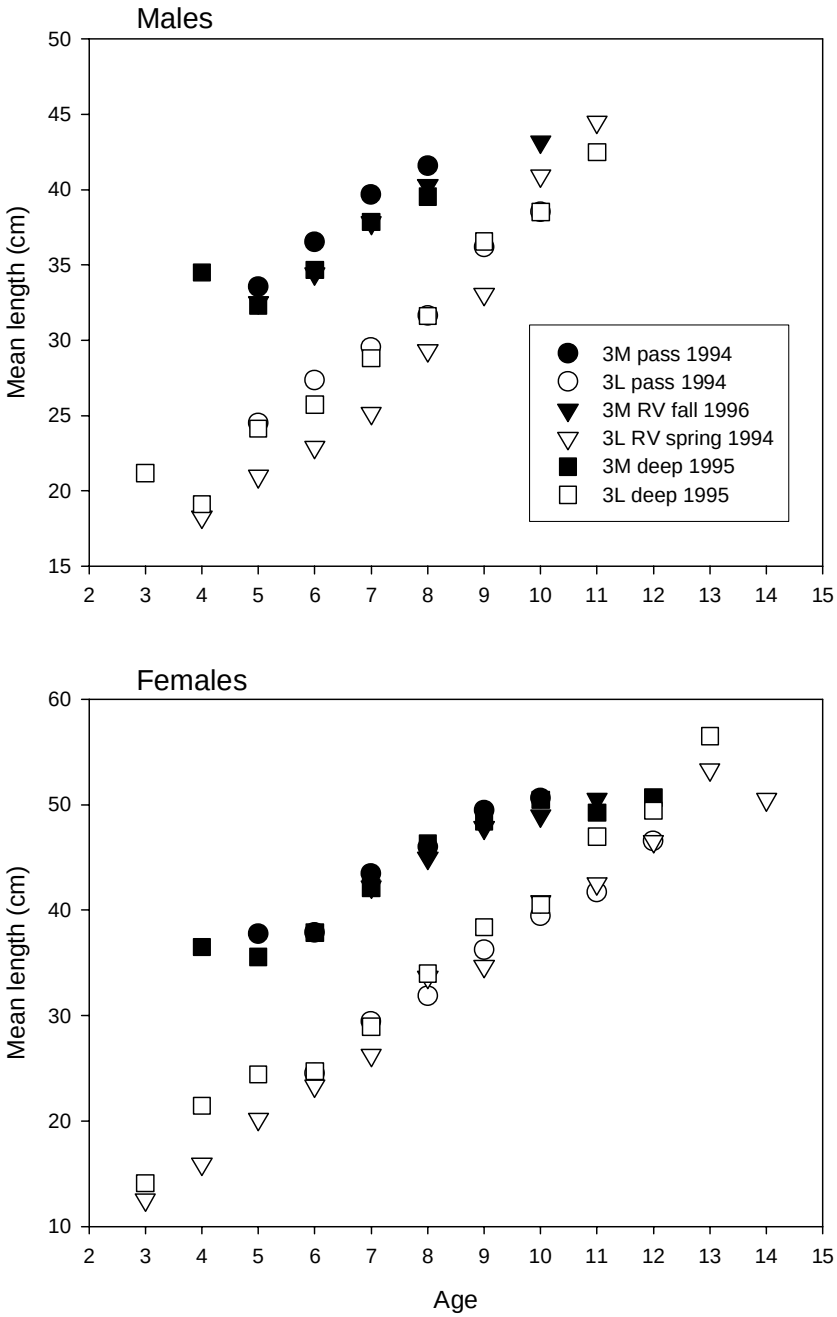

Fig. 2. Mean length-at-age (cm) for male and female American plaice. Div. 3M and 3L pass 1994 refer to fish caught on the Div. 3M and Div. 3L sides of the pass during the 1994 winter survey. Div. 3M and 3L deep 1995 refer to fish caught on the Div. 3M and Div. 3L sides of the pass during the 1995 winter survey. 3M RV fall 1996 refers to fish caught during the fall 1996 survey of Div. 3M. Div. 3L RV spring 1994 refers to fish caught in Div. 3L during the spring 1994 survey.

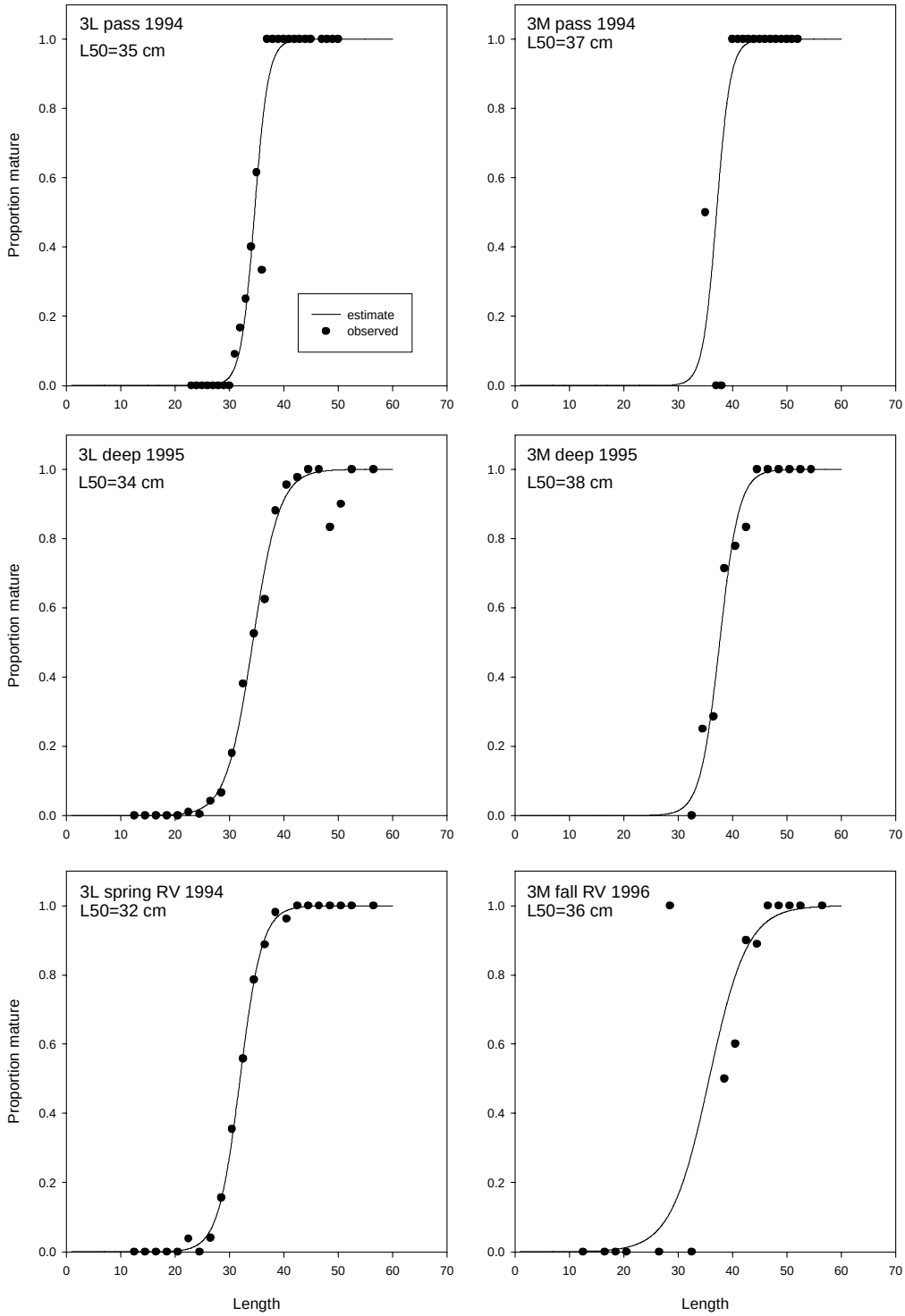

Fig. 3. Proportion mature-at-length for female American plaice sampled during various surveys. The line gives estimated proportion and the dots are the observed values. The length at 50% maturity is given on each panel. The designations for the surveys are as given in Fig. 2.

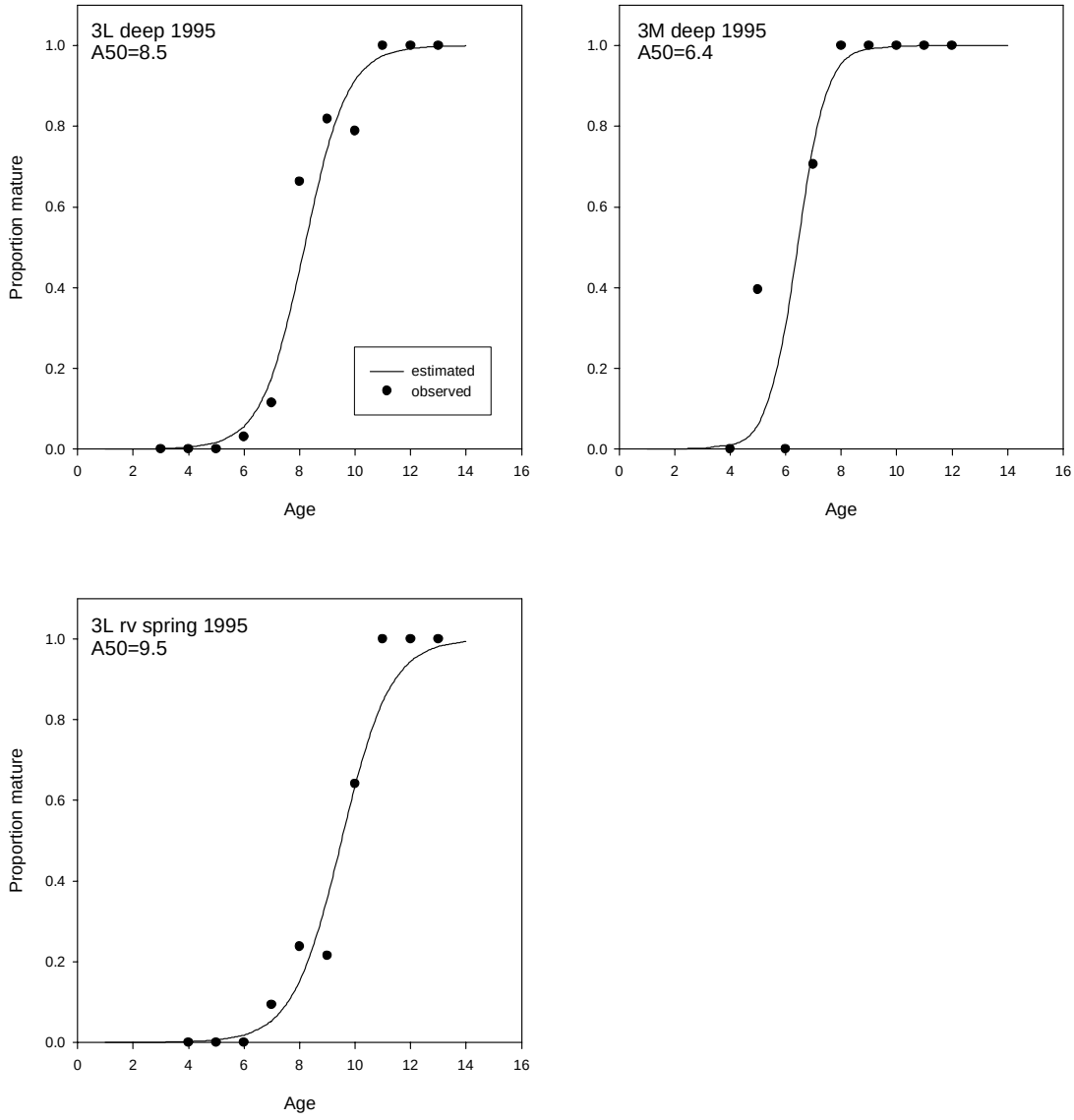

Fig. 4. Proportion mature-at-age for female American plaice sampled during various surveys. The line gives estimated proportion and the dots are the observed values. Age at 50% maturity is given on each panel. The surveys are designated as in Fig. 2 except for the bottom panel which represents the spring survey of Div. 3L in 1995.