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An Evaluation of Georges Bank Yellowtail Flounder Age Determination Based on Otolith Thin-Sections

Évaluation de la détermination de l'âge des limandes à queue jaune du banc Georges par analyse de lames minces d'otolites

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Abstract

An evaluation of Georges Bank yellowtail flounder age interpretations using otolith thin sections collected from DFO surveys and commercial port samples was conducted. Age interpretations made within and between DFO and NMFS fisheries research laboratories were compared using age frequency tables, percent agreement (PA=(n_{agree}/n)x100) and age bias plots to examine systematic difference (bias) and precision. Precise age determination was hampered by the presence of weak, diffuse or split opaque zones and strong checks that made interpretation of annulii subjective and difficult. The implications of using these age interpretations on the 1999-2001 DFO spring survey indices and the 2000 commercial fishery catch at age are examined and recommendations for future research are provided.

Résumé

Nous avons évalué la détermination de l'âge des limandes à queue jaune du banc Georges fondées sur l'interprétation de lames minces d'otolites obtenus lors de relevés effectués par le MPO et de l'échantillonnage à quai des prises commerciales. Nous avons comparé les déterminations des âges réalisées par les laboratoires de recherche halieutique du MPO et du National Marine Fisheries Service (NMFS) à l'aide de tableaux de fréquences des âges, du pourcentage de concordance (PC=(nconcord/n)x100) et des diagrammes des biais d'âge afin d'analyser la différence systématique (biais) et la précision. La présence de zones opaques pâles, diffuses ou fendues et de craques profondes ont compliqué la détermination précise de l'âge en rendant l'analyse des anneaux de croissance subjective. Nous étudions les conséquences de l'emploi de ces données d'âge pour les indices des relevés printaniers effectués par le MPO de 1999 à 2001 et sur les taux de capture selon l'âge de la pêche commerciale 2000 et nous proposons des voies à suivre pour de futures recherches.

Introduction

In 1993, a directed Canadian fishery for yellowtail flounder (*Limanda ferruginea*) began on Georges Bank, pursued mainly by small otter trawlers (< 20 m). The Georges Bank stock is a transboundary resource, with 5Zhjmn as the management unit and is fished by both Canada and the USA (Fig.1). For several years, the Transboundary Resource Assessment Committee (TRAC) has recommended that a yellowtail flounder aging program be developed at the Biological Station in St. Andrews, but only recently have resources been available to do so.

As part of the stock assessment, an age-structured virtual population analysis is used to determine the population abundance and exploitation rate of this stock. The validity of this approach relies upon precise age determination of fish samples. Canada and the US share information on commercial catches and research surveys to evaluate the status of this stock. However, all of the age data used to construct the catch at age and age-specific indices of abundance are based on scale age determinations from samples collected during National Marine Fisheries Service (NMFS) groundfish surveys and US commercial port sampling. Separate sex age-length keys from NMFS spring surveys have been applied to DFO spring survey length samples to develop age-specific indices of abundance. NMFS fall survey combined with US commercial port sample ages are used to construct the catch at age by sex for the Canadian portion of the management area (5Zjm). Consequently, potential differences in the age structure of the yellowtail flounder aggregations on the Canadian and US sides of the international boundary may not be apparent when only US ages are used. Also, there is concern with regard to the low occurrance of fish greater than age 5 in the catch, even though effort has been greatly reduced since 1995 and the average size in the fishery has been increasing.

Historically, scales have been the principal structure used for age determinations by NMFS for the Georges Bank, Cape Cod and southern New England stocks (Penttila 1988). Lux and Nichy (1969) conducted a detailed study on age and growth of all three stocks using scales which provided good documentation of first annulus formation and growth through age two. A partial validation of aging for fish aged 2-5 was achieved through recapture of 35 tagged fish that had been sampled for scales. Results indicated that growth was sexually dimorphic, with females growing faster after age two and reaching larger sizes than males. Few old fish (6+) were actually examined in their paper but the authors concluded that age assessment of older fish was difficult because of "narrowing of the growth zones on the scales" and frequently disagreed on ages for fish over age 5. This is of concern for the Georges Bank stock since it has been subjected to low rates of exploitation since 1994 and older fish are expected to become an important component of the overall catch. Using scales for aging may therefore result in older fish being under-aged and not well represented in age length keys.

A recent study by Whalen *et al.* (2000) showed that the standard method of reading whole otoliths for aging Grand Bank yellowtail flounder was inadequate after age 7, and that otolith thin-sections provided more promise for aging older fish from this slow growing stock. Preliminary analyses of Georges Bank yellowtail flounder ages determined from scales, whole otoliths and otolith thin sections from the same fish were conducted by the authors (Stone and Perley) for a workshop on yellowtail flounder age reading (Walsh and Burnett 2001). The results indicated that whole otoliths had a tendency to be underaged relative to scale and otolith thin sections, particularly at ages 4 and older, and that the ages determined from scales and otolith thin sections showed less bias compared to whole otoliths. Recently, Dwyer *et al.* (2001) found that scales had a tendency to underestimate the ages of older fish compared to otolith thin sections from Grand Bank yellowtail flounder. Based on these results, and the fact that sectioned otoliths are relatively easy to prepare, it was concluded that otolith thin sections would be the structure of choice when developing a Canadian aging program for Georges Bank yellowtail flounder.

Aging material (otoliths) from yellowtail flounder has been collected from DFO spring groundfish surveys and the Canadian fishery on Georges Bank since 1996. The main objective of our study was to provide an initial evaluation of the use of otolith thin sections from yellowtail flounder for age interpretations of selected DFO spring survey and commercial fishery port samples. The implications of using these age interpretations on the 1999-2001 survey indices and the 2000 catch at age are examined, bearing in mind that there has been no validation of ages determined from otolith thin sections to confirm the accuracy of age estimations.

Methods

Sample collection and preparation

Aging material is routinely collected during annual spring bottom trawl surveys conducted by DFO on Georges Bank. All yellowtail flounder captured during these surveys are measured for total length (cm) and sex is determined. For each set, saggital otoliths are removed from a stratified subsample of fish (i.e. one pair of otoliths per 1cm interval by sex) and stored dry in labeled coin envelopes. For this analysis, we examined a subsample of otoliths (3 samples per 1cm grouping by sex for Georges Bank Strata 5Z1 though 5Z4, which comprise the current management unit) for surveys conducted in 1999 (n=324), 2000 (n=468) and 2001 (n=361). Yellowtail flounder are also routinely sampled at dockside from the commercial fishery for size composition by sex. A subsample of otoliths representative of the size range for each sex are extracted and stored dry in coin envelopes. We examined otoliths from 17 port samples collected from the commercial fishery on Georges Bank representing catches from July through October, 2000 (n=471).

Otoliths from flatfish are often asymmetrical with one otolith being thicker and more irregular in shape than the other (Hunt 1992). This may result in a difference between ages estimated for left and right otoliths since one of the otoliths may have more detectable annuli present (Whalen *et al.* 2000). We examined differences in otolith mass as a first step to see if differences exist between left and right otoliths from Georges Bank yellowtail flounder. All otolith pairs from the 1999 survey were weighed (to the nearest

0.001 g) and compared by sex using paired sample *t*-tests. No significant difference between left and right otolith weights occurred in males (t=1.847, p=0.063, df=125) or females (t=-0.308, p=0.759, df=162). Therefore, it was assumed that either structure could be used for aging purposes. Otolith sections were prepared using the method of Strong *et. al* (1985) by setting left and right otoliths (sulcal groove side down) in a polyester resin and cutting a 0.8 mm strip through the core using a surface grinder adapted to accommodate a diamond edged blade. The strips containing left and right otolith sections were examined under a binocular microscope using reflected light at 25-50x magnification after covering with a layer of soapy water to enhance zonation patterns.

Age interpretation and evaluation

Ages were determined by counting periodic structures (dark hyaline bands under reflected light assumed to be annuli) along the edge of the sulcual groove (usually the region with greatest clarity) or longitudinally along the dorsal or ventral axes of the section (Fig. 2a). Both left and right otolith sections were examined but annular counts were only made on the clearest section (left or right). Any structures found to be crystallized or unreadable were excluded from the analysis, and represented 9% of total samples available (n=145 out of 1624). Information on fish length and sex was made available for reference during reading. For yellowtail flounder, the birth date for aging purposes by convention is assumed to be Jan 1st, therefore, because all DFO surveys were conducted in February, the outer edge of the otolith section was considered to be an annulus (winter growth zone).

To evaluate presumed annular marks, three age readings were made for each of the samples: one by an experienced groundfish age reader (primary ager: P. Perley) and one by a less-experienced age reader (secondary ager: H. Stone) and a final consensus age reading by both age readers. Both agers had some previous experience reading Georges Bank yellowtail flounder otolith sections and were familiar with the growth patterns of this stock. A within reader comparison was also conducted by the secondary ager to evaluate precision of age interpretations. A subsample of prepared sections from the three DFO spring surveys (n=365) was sent to the National Marine Fisheries Service Lab in Woods Hole for comparative age determinations by the primary age reader responsible for the Georges Bank stock. Although it is recognized that the NMFS ager has had more experience working with flatfish scales compared to otholith sections, it was assumed that comparisons with the more experienced NMFS age reader would help determine if the ages interpreted by the new DFO agers were consistent.

Age interpretations made within and between labs were compared using age frequency tables, percent agreement (PA=(n_{agree}/n)x100) and age bias plots to examine systematic difference (bias) and precision (Campana *et al.* 1995). An Optimas image analysis system was used to measure the width (to the nearest 0.001mm) of the 2nd and 3rd annuli on left otolith sections for separate sexes from the DFO 2000 spring survey to determine the degree of overlap between annular marks (Figs 2b-2d). This exercise was conducted to investigate the substantial overlap in the size range of these age groups evident in age length keys for both sexes.

Comparisons of survey indices and catch-at-age

Separate sex age length keys for the three DFO spring surveys based on consensus age estimations by DFO agers and stratified survey catch at size by sex data was used to calculate age-specific indices of abundance for combined and separate sexes. These values were compared with DFO age-specific indices from past stock assessments that used NMFS spring survey ages by sex for the same year. A Canadian 2000 fishery catch at age (CAA) was calculated using separate sex age length keys from DFO ages (this study) and commercial landings data. This CAA was compared with the 2000 fishery CAA used in the 2001 assessment developed from combined 2000 NMFS fall survey and second half commercial port sample ages by sex.

Results and Discussion

Size composition

The size of yellowtail flounder used for age determinations from the three surveys ranged from 9-50 cm for males and 12-53 cm for females. Similar size compositions were observed in all three survey subsamples, although there were slightly more large males present in the 2000 survey collections (Fig. 3). The size composition of the port sample was narrower than the survey size composition with few smaller fish; males ranged from 26-46 cm and females from 28-50 cm. Differences between survey and commercial catch size composition reflect the use of a 1.0 cm mesh liner in the Western IIa trawl during surveys compared to 155 cm square mesh in the cod end of commercial gear.

Comparisons between age readers

A total of 1,479 otolith sections were read by each of the DFO agers, with an overall between reader agreement (precision) of 66%. For individual survey and port sample age interpretations, between reader agreement ranged from a low of 58% for the 2001 survey to a high of 73% for the 2000 port samples (Figs. 4-7). Coefficients of variation (CV's) ranged from a low of 5.2% for port samples to a high of 8.7% for the 2001 survey. In all cases, ages interpreted by the secondary reader showed some bias at older ages attributed to assigning a greater proportion of lower ages after age 5, relative to the primary age reader. (Note: Within-reader comparisons of survey sample age determinations by the secondary ager ranged from 69-81% and indicate a moderate degree of precision). Many otolith sections were difficult to interpret, exhibiting weak, diffuse or split opaque zones and strong checks. On some otoliths, the growth patterns were so weak and variable that error in age interpretation was likely and they had to be excluded from the comparisons. Overall, the low agreement reflects the generally poor clarity of marks and the resulting subjectivity in otolith section age readings (Fig. 8).

Precision between the two DFO age readers and the NMFS age reader was generally low for all survey samples (Table 1). Percent agreement between the primary DFO ager and the NMFS ager averaged 57%, and ranged from a low of 47% in the 2001 survey samples to a high of 66% for the 1999 survey samples. Agreement between the secondary DFO reader and the NMFS reader was even lower, averaging 51% for the three surveys (range: 47%-59%). The low precision was attributed mainly to the choice of the second annulus, which may have been influenced by the presence of split opaque zones and strong checks that resulted in different age interpretations between labs. Choice of the first annulus did not appear to be problematic, since it occurs just beyond the core where few checks or splits occur.

When all structures were re-aged with both DFO agers present (consensus aging to improve precision), the overall agreement with NMFS age interpretations showed some improvement from previous comparisons with individual DFO agers (i.e. 68% *vs* 57%) but was still considered to be low. For individual surveys, agreement between the DFO consensus and NMFS age interpretations improved slightly and ranged from 59% (2001 survey) to 74% (1999 survey) with corresponding CV's ranging from 12.1% to 6.2%, respectively (Figs. 9-11). In all cases, the DFO consensus age interpretations exhibited upward bias at middle ages (3-5) and downward bias at the oldest ages (6-9) relative to NMFS ages. However, we observed some inconsistency in the way in which the NMFS ages were assigned, particularly for age 2. It is possible that the age 2 interpretations were influenced by growth patterns from scales (the principle structure used by NMFS for aging yellowtail) in which the growth between the first and second annulus is large. Consequently, the NMFS ager may have applied scale pattern proportionality to otolith patterns by placing the second annulus further out on the sectioned otolith.

An examination of mean length at age based on DFO and NMFS age estimations suggests that this may have been the case (Fig. 12, Table 2). For the 2001 DFO survey, average lengths at age were generally greater in both sexes for the NMFS age estimations compared to those estimated by DFO. When the second annulus is placed further out on the otolith (i.e. assigning age 2 rather than age 3), the mean length at age tends to be greater from age 2 onwards. This pattern was apparent to a lesser extent in the 2000 survey ages but not at all in the 1999 survey ages where the assignment of ages by length and sex appeared to be similar for both labs. These differences among surveys suggest that the growth pattern applied to otolith sections by the NMFS ager may have been inconsistent among the samples. An alternative explanation is that the otolith sections show more detail in terms of splits and checks in the opaque zone compared to scales, some of which may have been incorrectly interpreted as annuli by the DFO agers (i.e. assigning age 3 rather than age 2) resulting in the apparent smaller size at age.

Annulus cross-section width

In general, the DFO consensus age estimations were considered to provide the best interpretation of yellowtail flounder ages and were used to develop age length keys

(ALK's) for the 1999-2001 survey samples (Figs. 13-15) and the 2000 port samples (Fig. 16). All three survey ALK's were characterized by a wide range in length at age 2 which overlapped considerably with age 3. This pattern was not quite so apparent in the port sample ALK due to an absence of fish below 27 cm. Frequency plots of annuli cross section widths from 2000 survey left otolith sections showed a wide size range for the 2nd annulus in both sexes, as well as overlap in the widths of the 2nd and 3rd annuli (Fig. 17, Table 3). Although mean annulus widths were greater at age 3 for both sexes, the large degree of overlap reflects the difficulty in determining the exact location of the 2nd annulus on these structures. Normally, a wider, overlapping size range at age would be expected at older ages, with less overlap at younger ages. While Georges Bank yellowtail flounder are considered to be fairly discrete spawners with peak spawning occurring in May, NMFS MARMAP survey results show that egg production extends from March through July (Berrien 1981; Silverman 1983). This slightly protracted four month spawning season may account for some of the variability observed in size at age 2. We found little published information available on the length range at age for other flatfish species occurring on Georges Bank, however, winter flounder (*Psuedopleuronectes americanus*) apparently show a similar pattern of wide length at age for younger fish (J. Burnett, NMFS, Woods Hole, MA, pers. commun., August 2001).

Survey indices and catch-at-age

DFO survey indices of abundance for 1999, 2000 and 2001 calculated using NMFS spring survey ages (the procedure used in past assessments) and actual DFO survey ages from this study show differences in the abundance at age (Fig. 18). When NMFS spring survey ages are used, estimates of abundance for age 3 fish are higher in all three surveys compared to the abundance estimated using DFO ages. In contrast, using DFO survey ages results in lower abundance at age 3, but greater abundance at older ages, particularly for the 2001 survey. Intuitively, this scenario would seem plausible, since more older fish would be expected in the population when exploitation rates are low as has been the case in the commercial fishery since 1994. DFO spring survey abundance indices for males and females calculated with DFO ages show greater abundance at ages 4 through 6 for both sexes compared to those calculated with NMFS ages (Fig. 19). Past assessments have shown that the 1997 year class is the strongest since 1980. Although the time series covers only 3 years (1999-2001), it is difficult to track the abundance of the strong 1997 year class (i.e. age 2 in 1999, age 3 in 2000) regardless of whether DFO or NMFS age length keys are used.

When the 2000 Canadian commercial fishery CAA is calculated using ALK's based on ages estimated from Canadian port samples, there is a greater proportion of older fish in the catch, compared to the case when scale-based US ALK's are used to age the Canadian catch (Fig. 20). Since scales are the main aging structure used at the Woods Hole lab for aging yellowtail, it is possible that fewer older aged fish are detected because of the difficulty of interpreting annuli on scales of older fish, similar to reports for Newfoundland populations (Dwyer *et al.* 2001).

Conclusions

1. Precise age determination of Georges Bank yellowtail flounder using otolith thin sections is hampered by the presence of weak, diffuse or split opaque zones and strong checks, which can make interpretation of annulii subjective and difficult.

2. The wide size range observed at age 2 and the overlapping size range for ages 2 and 3 reflect the difficulties associated with identifying the second annulus. The relative strengths of the year classes represented by these age groups then becomes "smeared" and disproportionate in both the indices of abundance and the CAA, making it difficult to detect and track strong or weak year classes. Despite this, it appears as though the survey indices and CAA based on DFO ages seem plausible, since more older fish would be expected in the population due to low levels of exploitation.

3. *Which lab is correct?* In the absence of an accurate age validation process that provides accurate age confirmation for otolith sections, there is currently no way of knowing exactly whether age interpretations by the DFO agers or the NMFS agers are correct. Age validation using mark and recapture techniques is recommended.

4. Sectioned yellowtail otoliths may show more detail in terms of splits and checks compared to scales, however, scales from older fish may show fewer annuli than sectioned otoliths.

5. *Where do we go from here?* At this stage, implementation of a "production aging" program at SABS is not advised until differences in age determinations between labs have been resolved. To determine if the NMFS agers are applying scale pattern proportionality incorrectly to otolith sections, it is recommended that further comparative analysis be done at both labs (St. Andrews and Woods Hole) using scale and otolith sections from the same fish. In the meantime, it is recommended that the current approach for the analytical assessment continue (i.e. using age-structured VPA and non age-structured surplus production models) until confidence in our ability to age Georges Bank yellowtail flounder improves.

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Table 1. Percent agreement (precision) in yellowtail flounder age interpretations between DFO agers and the NMFS ager for three DFO spring survey samples.

DFO Survey	Percent Agreement: Primary DFO Ager *vs* NMFS Ager	Percent Agreement: Secondary DFO Ager *vs* NMFS Ager	Sample size
1999	66	59	125
2000	57	48	126
2001	47	47	114
Overall	**57**	**51**	**365**

Table 2. Summary statistics for yellowtail flounder length at age by sex based on ages determined by DFO and NMFS agers from samples collected during the 1999, 2000 and 2001 DFO spring surveys.

		DFO Age Determinations					NMFS Age Determinations				
Year	Age	n	Mean	s.d.	Min	Max	n	Mean	s.d.	Min	Max
Males											
1999	2	27	25.8	3.63	19	32	22	24.7	3.05	19	31
1999	3	14	33.1	2.11	29	36	23	33.2	2.70	29	39
1999	4	9	37.2	1.72	35	40	9	37.9	2.03	35	41
1999	5	5	38.4	1.14	37	40	4	39.5	2.38	38	43
1999	6	1	35.0		35	35	-	-	-	-	-
1999	7	2	42.0	1.41	41	43	-	-	-	-	-
2000	2	19	27.4	4.93	14	33	21	28.1	5.16	14	36
2000	3	12	33.7	1.61	31	36	15	34.9	2.83	31	41
2000	4	9	38.2	2.68	34	42	12	39.4	1.78	36	42
2000	5	10	38.9	1.60	36	41	5	38.8	2.59	36	43
2000	6	3	40.7	2.52	38	43	-	-	-	-	-
2001	2	7	28.1	3.13	24	32	13	29.8	3.24	24	36
2001	3	18	32.7	2.77	27	37	20	34.4	3.27	27	42
2001	4	12	37.5	3.99	33	47	11	40.1	3.65	34	47
2001	5	12	40.8	3.27	35	45	6	41.5	3.27	37	45
2001	7	1	43.0	-	43	43	1	43.0	-	43	43
2001	8	1	40.0	-	40	40	-	-	-	-	-
Females											
1999	2	18	25.1	4.22	20	34	15	23.7	2.94	20	31
1999	3	11	35.3	3.41	29	41	19	35.3	3.26	29	41
1999	4	16	39.2	2.71	34	43	16	40.6	2.58	36	44
1999	5	13	44.0	2.68	38	49	7	45.0	1.29	43	47
1999	6	4	46.8	1.71	45	49	3	45.7	0.58	45	46
1999	7	5	49.0	2.35	47	52	6	49.0	2.10	47	52
2000	2	17	28.9	3.52	20	34	18	29.1	3.55	20	34
2000	3	18	36.1	2.88	30	42	20	36.8	2.98	30	42
2000	4	4	41.0	1.41	39	42	7	42.6	2.07	41	47
2000	5	9	43.4	3.21	40	50	12	45.9	2.84	43	51
2000	6	13	46.4	2.43	43	52	8	48.1	1.81	46	52
2000	7	10	48.4	2.50	43	51	6	47.8	2.93	43	51
2000	8	2	50.0	2.83	48	52	2	50.5	2.12	49	52
2001	1	-	-	-	-	-	1	24.0	-	24	24
2001	2	7	27.6	3.91	23	33	8	29.4	4.03	23	34
2001	3	12	34.1	3.00	30	39	18	35.9	3.06	30	40
2001	4	14	38.8	3.22	35	44	12	40.9	4.21	33	47
2001	5	10	42.0	2.31	39	46	13	43.9	2.96	40	49
2001	6	11	46.4	2.16	42	50	6	45.7	1.97	43	48
2001	7	5	43.4	4.04	38	49	-	-	-	-	
2001	8	3	49.7	0.58	49	50	1	49.0	-	49	49
2001	9	1	51.0	-	51	51	4	50.3	0.50	50	51

Table 3. Summary statistics for 2^{nd} and 3^{rd} annulus width measurements by sex based on DFO age interpretations from left otolith cross sections from yellowtail flounder collected during the 2000 DFO spring survey.

			Annulus width (mm)		
Annulus	**Sex**	**No. measured**	**Mean ± SD**	**Minimum**	**Maximum**
2^{nd}	male	95	3.32 ± 0.288	2.63	3.99
3^{rd}	male	21	3.83 ± 0.200	3.44	4.13
2^{nd}	female	84	3.47 ± 0.336	2.55	4.31
3^{rd}	female	35	4.15 ± 0.255	3.63	4.71

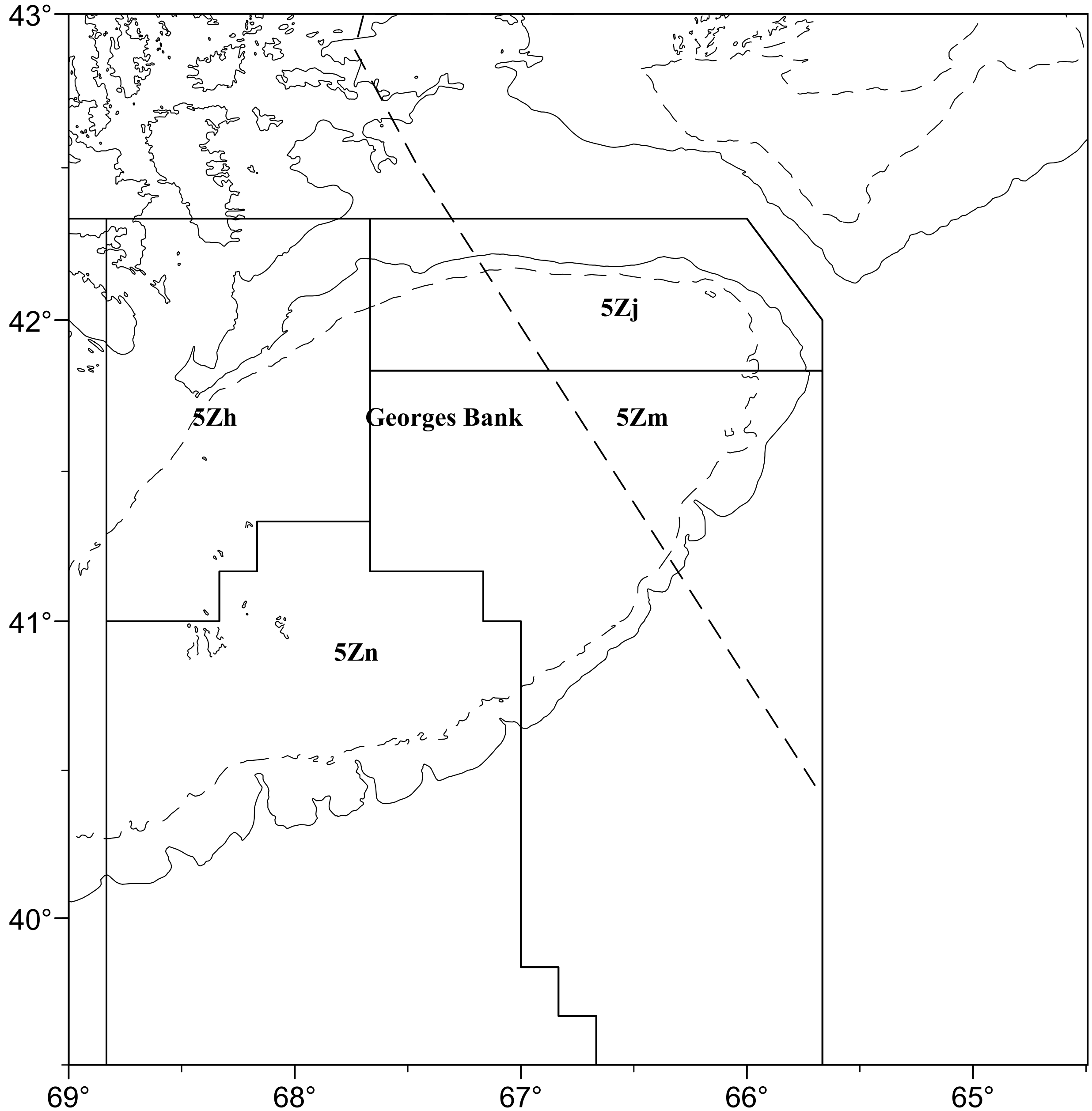

Figure 1. Georges Bank yellowtail flounder management unit, 5Zjmnh.

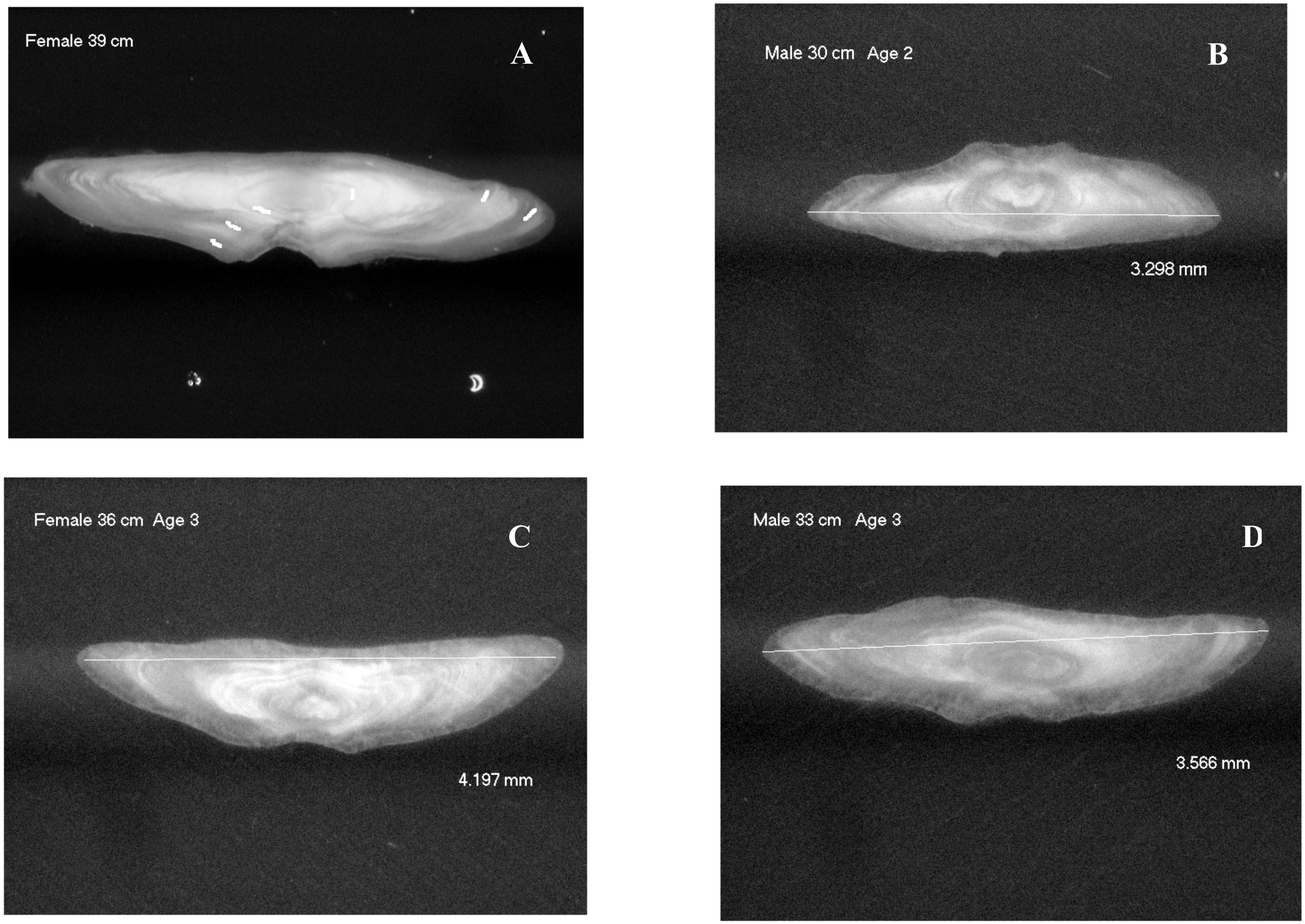

Figure 2. Images showing presumed annular marks (A) and annulus width measurments (B-D) from otolith sections for age 2 and 3 male and female yellowtail flounder from Georges Bank.

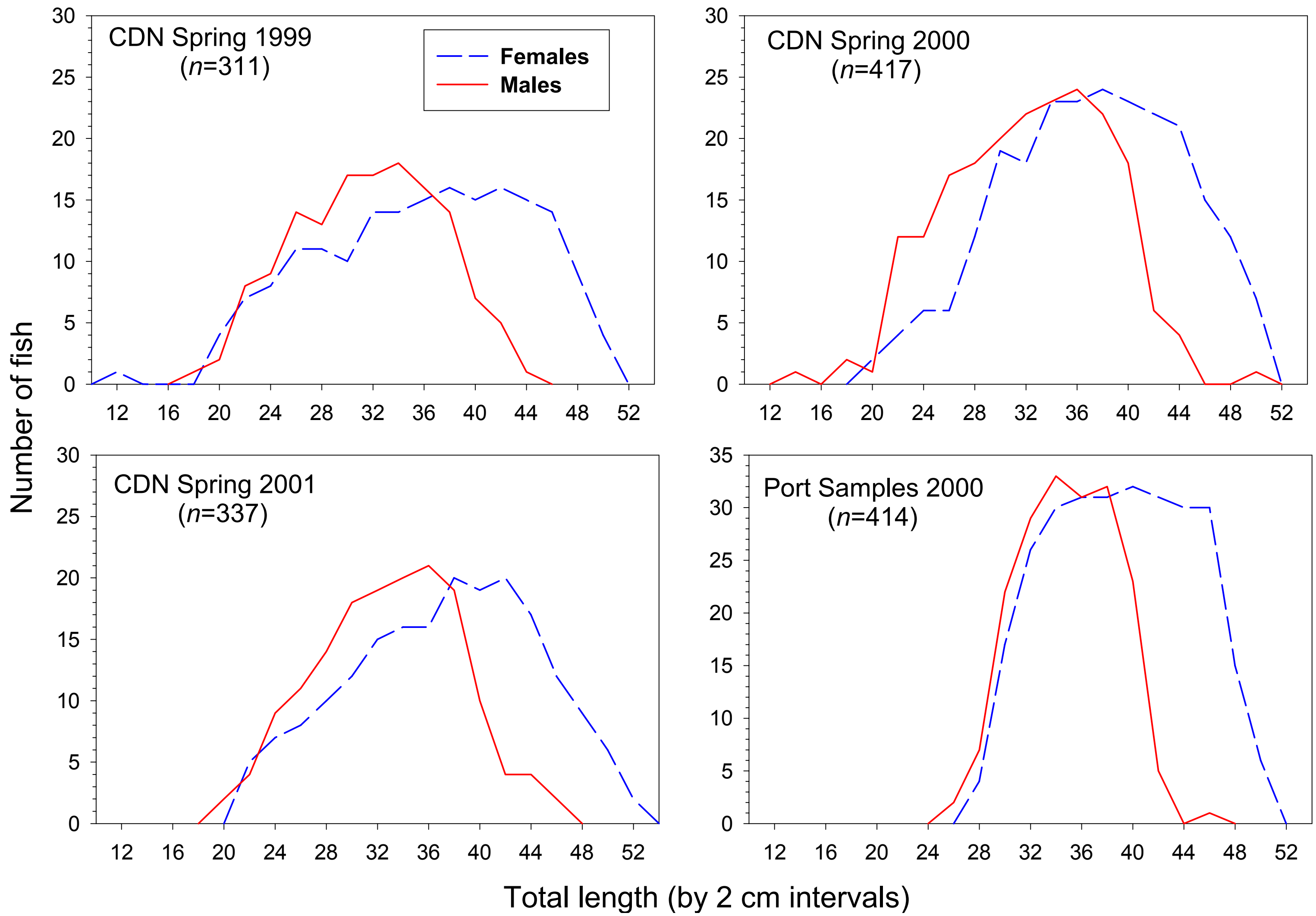

Fig. 3. Size composition of Georges Bank yellowtail flounder subsampled from DFO spring groundfish surveys (1999-2001) and commercial port samples (2000) used for age determinations based on otolith thin sections.

A

Ager	Primary							
Secondary	1	2	3	4	5	6	7	Grand Total
1	2							2
2		108	8					116
3		5	49	8		1		63
4			14	24	12	4	1	55
5				12	19	2	2	35
6					10	10	3	23
7					3	5	7	15
8					1	1		2
Grand Total	2	113	71	44	45	23	13	311

Agreement=70%

B

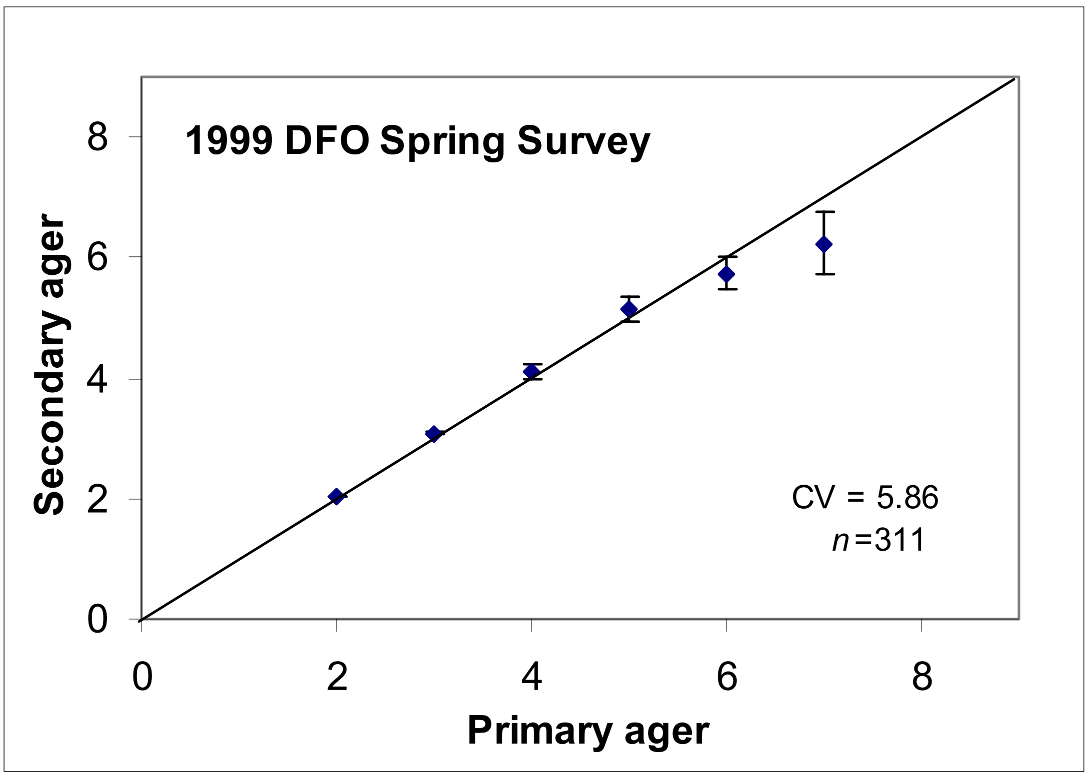

Figure 4. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the primary age reader (P. Perley) and the secondary age reader (H. Stone) for samples from the 1999 DFO spring survey. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 7, as determined by the primary age reader.

A

Ager	Primary								
Secondary	2	3	4	5	6	7	8	9	Grand Total
2	112	34	2						148
3	15	45	9	2					71
4		20	48	21	2				91
5			7	24	8	2	1		42
6			3	10	11	7			31
7				4	7	8	4	1	24
8					2	4	2		8
9						1	1		2
Grand Total	127	99	69	61	30	22	8	1	417

Agreement = 60%

B

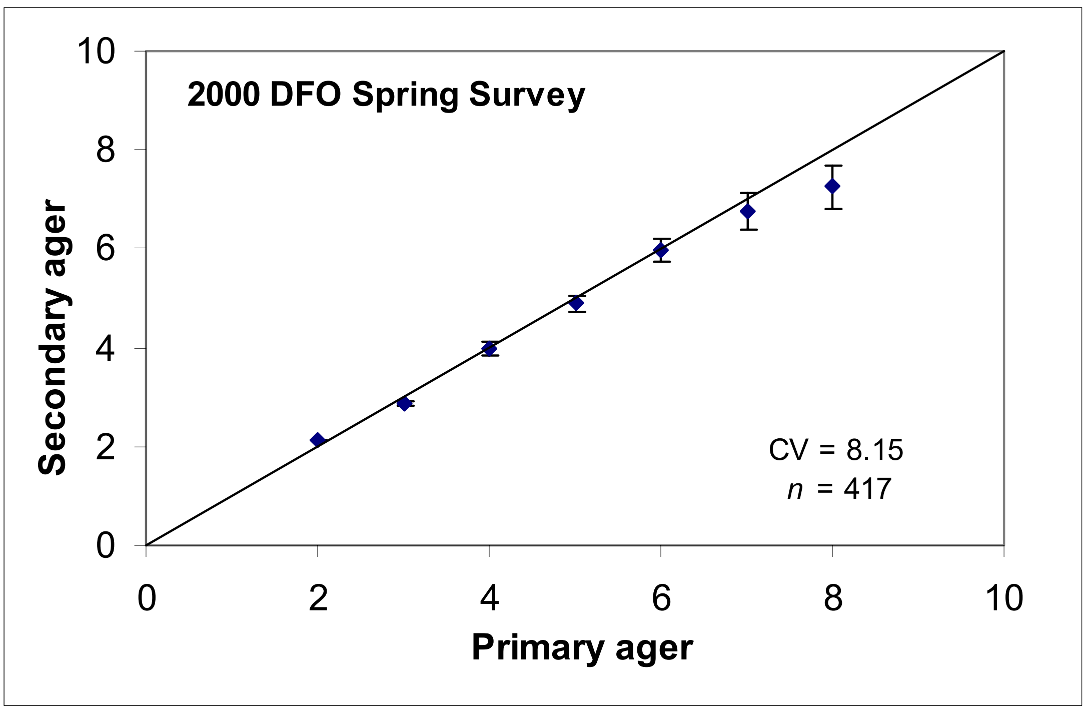

Figure 5. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the primary age reader (P. Perley) and the secondary age reader (H. Stone) for samples from the 2000 DFO spring survey. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 8, as determined by the primary age reader.

A

Age	Primary								
Secondary	2	3	4	5	6	7	8	9	Grand Total
2	71	12							83
3	12	52	20	4	2				90
4	1	10	34	17	1	3			66
5		2	11	23	6	4	2		48
6			1	7	13	7	3		31
7				1	2	2	3		8
8				2	2	2	1	2	9
9						1	1		2
Grand Total	84	76	66	54	26	19	10	2	337

Agreement = 58%

B

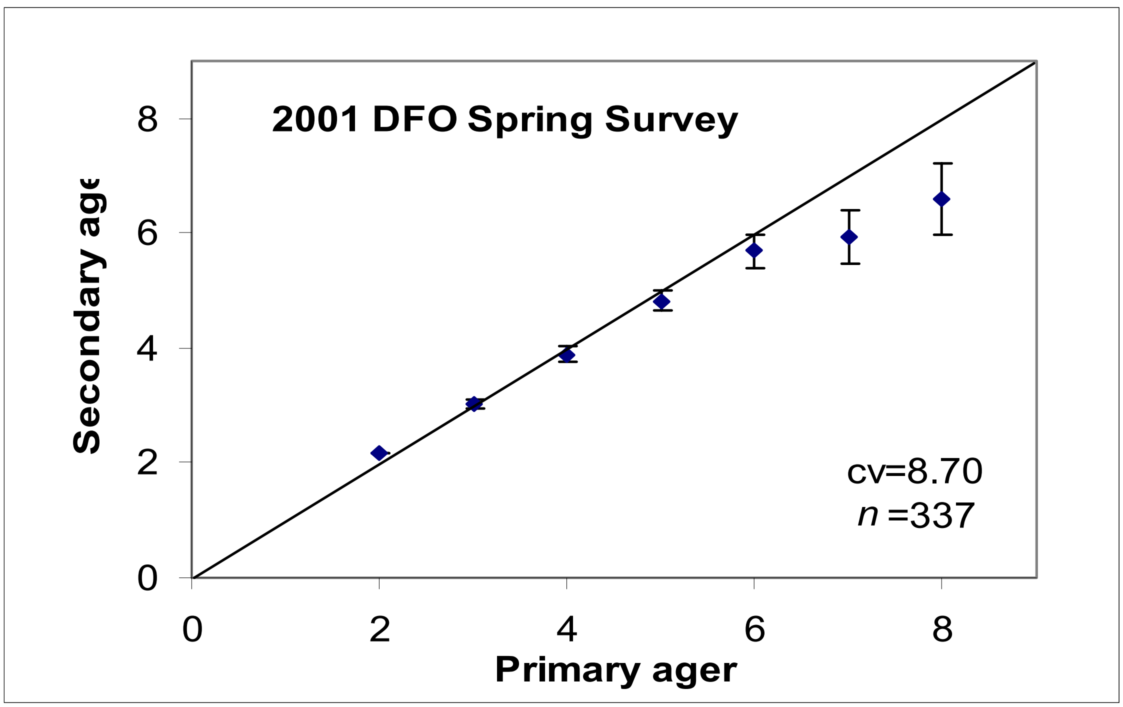

Figure 6. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the primary age reader (P. Perley) and the secondary age reader (H. Stone) for samples from the 2001 DFO spring survey. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 8, as determined by the primary age reader.

A

Age	Primary							
Secondary	2	3	4	5	6	7	8	Grand Total
2	103	17						120
3	7	75	20		1			103
4		7	55	8	5	1		76
5			8	33	9	3	1	54
6			2	11	27	4	1	45
7				1	3	9	1	14
8						1	1	2
Grand Total	110	99	85	53	45	18	4	414

Agreement=73%

B

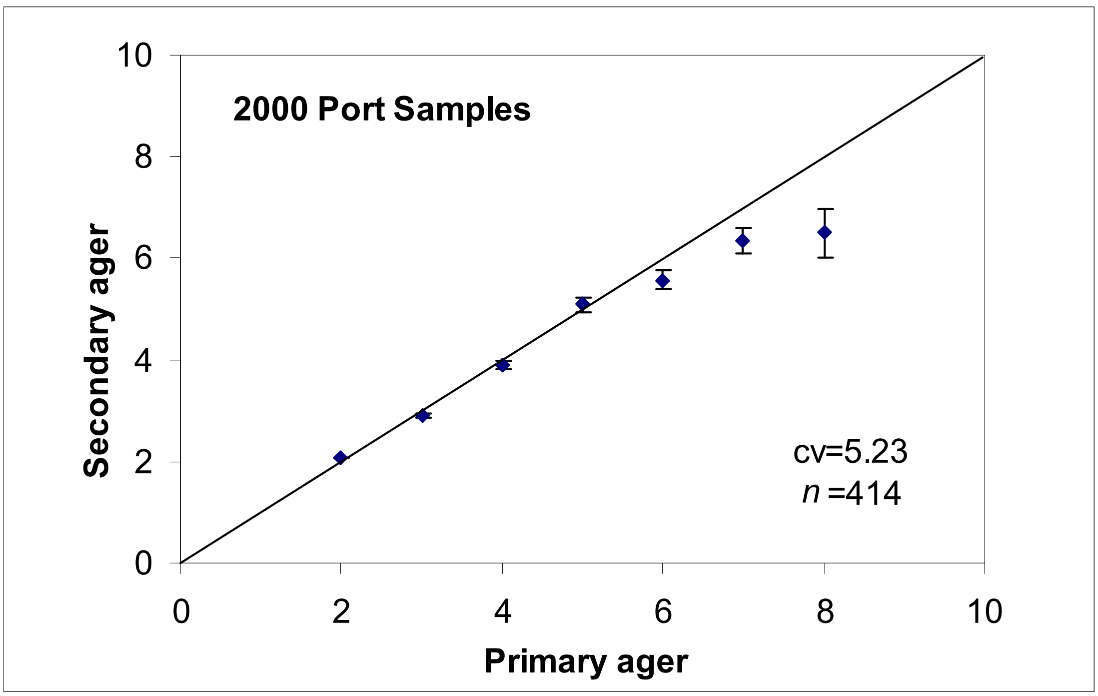

Figure 7. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the primary age reader (P. Perley) and the secondary age reader (H. Stone) for samples from the 2000 commercial fishery. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 8, as determined by the primary age reader.

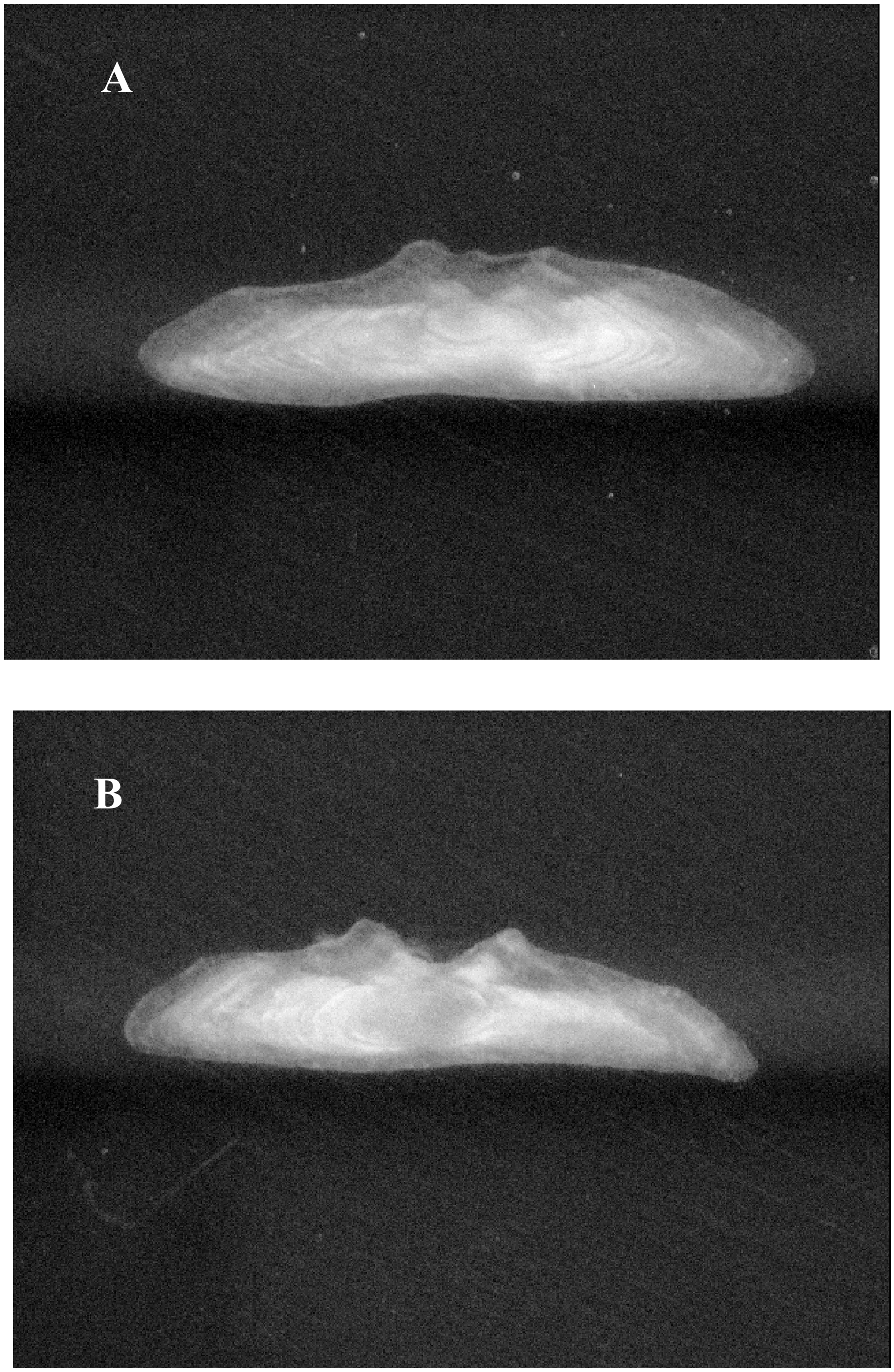

Figure 8 Otolith sections from a 33 cm male (A) and 36 cm female (B) illustrating poor clarity of marks and lack of distinct hyaline/opaque zonation.

A

Ager	NMFS							
DFO	2	3	4	5	6	7	8	Grand Total
2	36	9						45
3	1	24						25
4		8	17					25
5			7	9	1	1		18
6		1		1	2		1	5
7			1	1		5		7
Grand Total	37	42	25	11	3	6	1	125

Agreement=74%

B

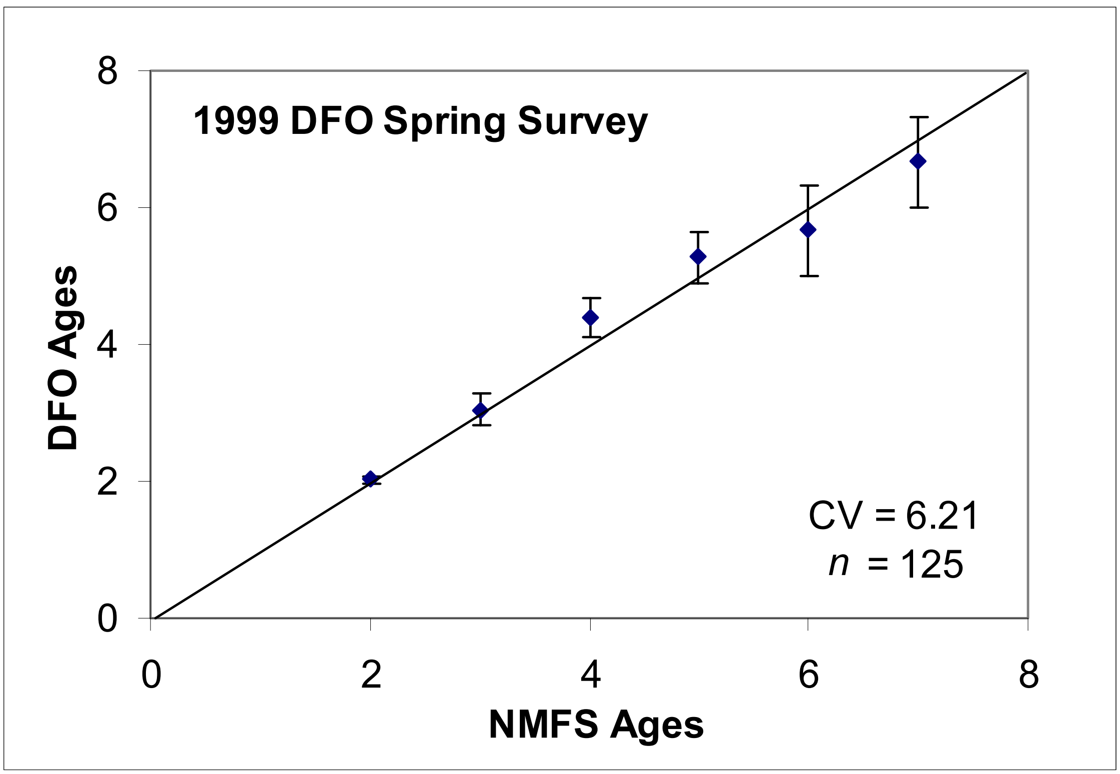

Figure 9. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the NMFS and DFO for samples from the 1999 DFO spring survey. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 7, as determined by the NMFS age reader.

A

Ager	NMFS							
DFO	2	3	4	5	6	7	8	Grand Total
2	35	1						36
3	4	26						30
4		3	10					13
5		5	7	7				19
6			1	8	6	1		16
7			1	2	2	4	1	10
8						1	1	2
Grand Total	39	35	19	17	8	6	2	126

Agreement=71%

B

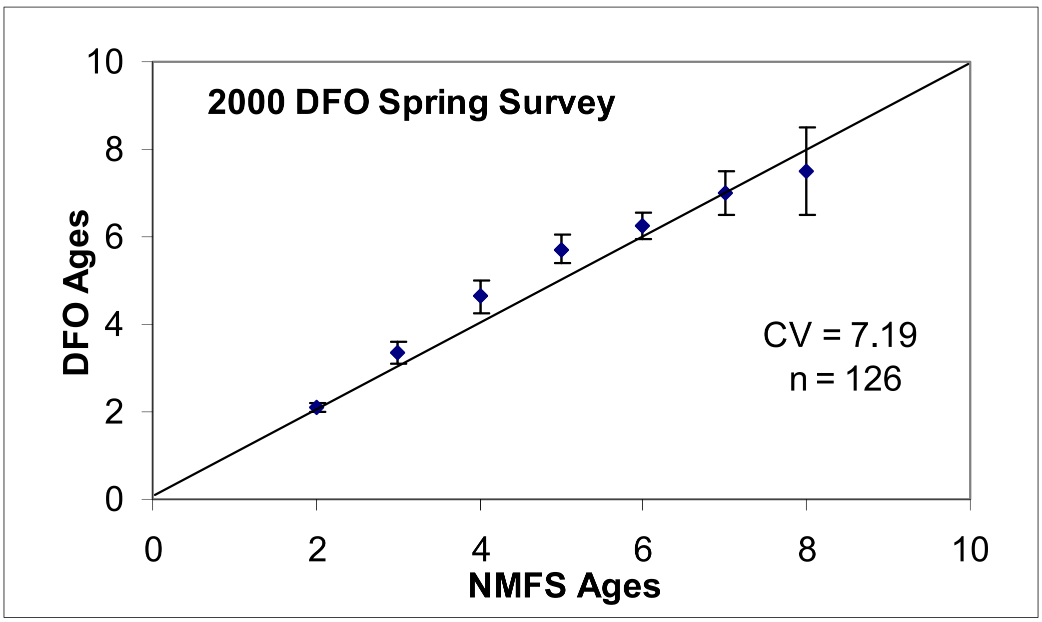

Figure 10. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the NMFS and DFO for samples from the 2000 DFO spring survey. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 8, as determined by the NMFS age reader.

A

Ager	NMFS									
DFO	1	2	3	4	5	6	7	8	9	Grand Total
2	1	13								14
3		8	21	1						30
4			12	13	1					26
5			4	5	13					22
6				2	4	4			1	11
7			1	1	1	2	1			6
8				1				1	2	4
9									1	1
Grand Total	1	21	38	23	19	6	1	1	4	114

Agreement=59%

B

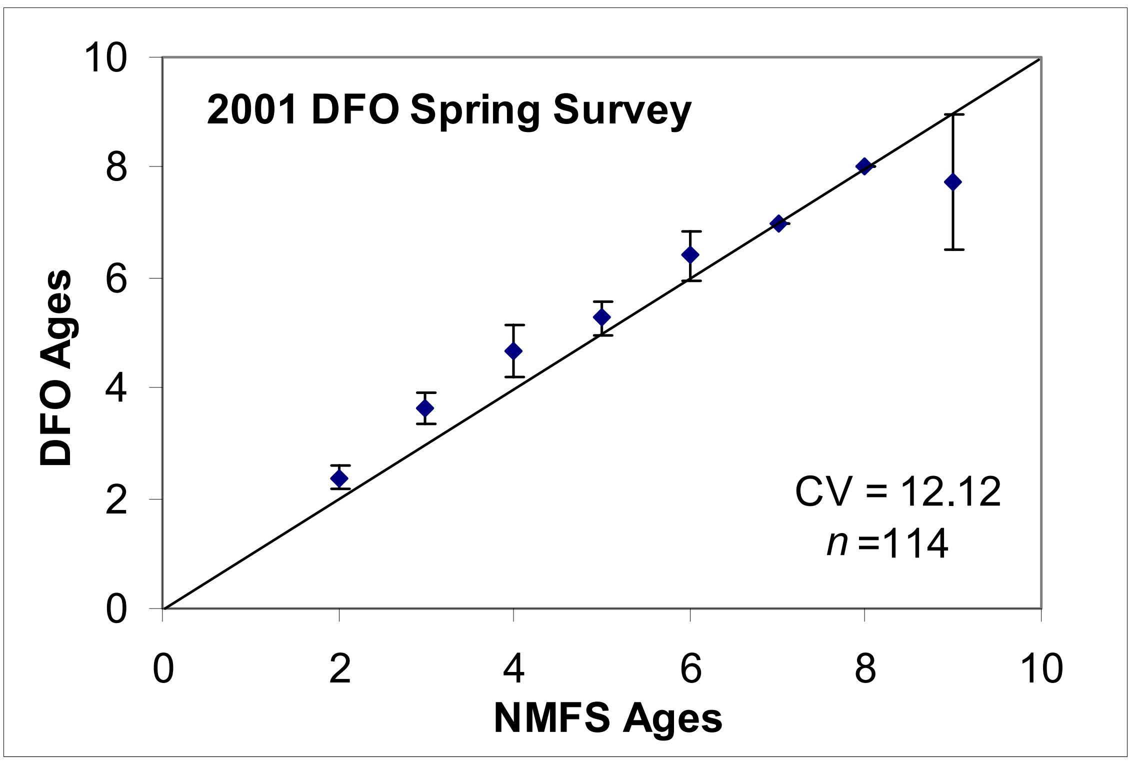

Figure 11. Age frequency (A) and age bias (B) plots comparing yellowtail flounder age interpretations by the NMFS and DFO for samples from the 2001 DFO spring survey. The mean age (with the 95% confidence interval) obtained by the secondary age reader is shown relative to all ages 2 to 9, as determined by the NMFS age reader.

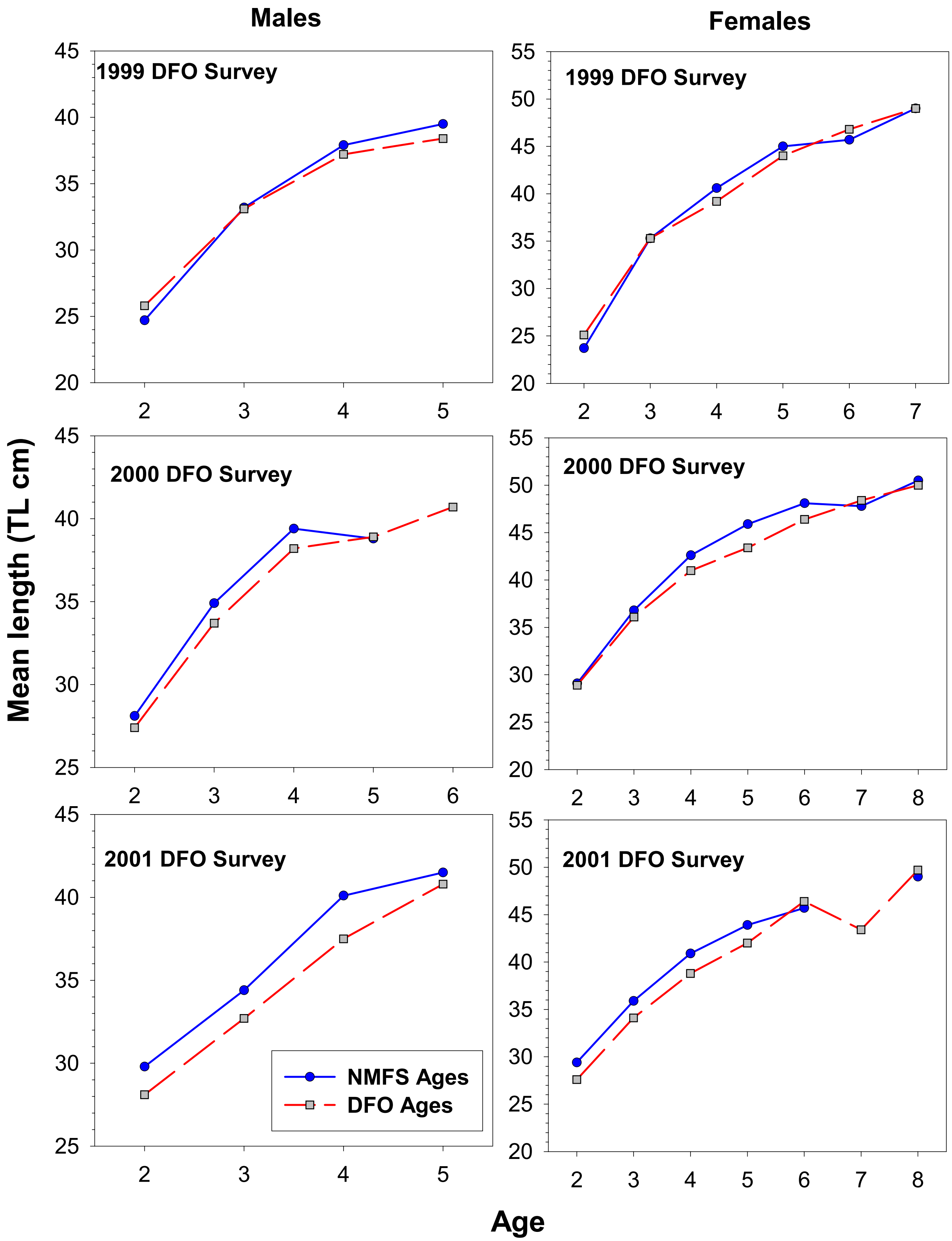

Figure 12. Mean length at age for Georges Bank yellowtail flounder by sex sampled from the 1999, 2000 and 2001 DFO surveys based on age interpretations by DFO and NMFS age readers.

1999 DFO Spring Survey Ages														
Total	Males							Females						
length (cm)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
9	1													
12								1						
19		1												
20									3					
21		2							1					
22		4							4					
23		4							3					
24		4							3					
25		5							5					
26		7							5					
27		7							6					
28		5							6					
29		6	1						4	1				
30		6	1						4					
31		7	3						5	1				
32		2	5						4	2				
33			10						3	3	1			
34			5	3					1	5	1			
35			5	3		1				6				
36			6	2						6	2			
37			1	5						3	4			
38			1	3	4					1	5	2		
39			1	1	2	1				4	3		1	
40				2	1	1					4	2		
41					2		1			1	4	3		
42				2							1	5	1	
43							2				4	5		
44												5	2	
45												7	1	
46												4	1	2
47												1	3	3
48													1	3
49											1	2	1	1
50														1
51													1	1
52														1
Total	1	60	39	21	9	3	3	1	57	33	30	36	12	12

Figure 13. Age length key developed from consensus age estimations for Georges Bank yellowtail flounder from the 1999 DFO spring groundfish survey.

2000 DFO Spring Survey Ages														
Total	Males							Females						
length (cm)	1	2	3	4	5	6	7	2	3	4	5	6	7	8
14	1													
19		2												
20		1						1						
21								1						
22		5												
23		7						4						
24		7						3						
25		5						3						
26		8						3						
27		9						3						
28		8						5						
29		10						7						
30		7	3					7	1					
31		8	2					10	1					
32		5	5					6	3					
33		3	9					3	6					
34		2	5	3	1			3	8					
35			5	5	1				12					
36			1	9	1				9	2	1			
37				3	8				9	2				
38				4	4	2			6	4	2			
39				1	6	2			4	4	1	1		
40				2	4	1			1	5	4			
41				3	4	2				3	4	2	1	
42				1	1	1	1		1	5	5			
43						1	1			1	5	4	1	
44							1				3	4	2	
45						2				1	6	3	1	
46											1	3	3	1
47											1	2	4	
48												2	3	1
49												4	1	2
50							1				1		2	
51													2	
52												1		1
Total	1	87	30	31	30	11	4	59	61	27	34	26	20	5

Figure 14. Age length key developed from consensus age estimations for Georges Bank yellowtail flounder from the 2000 DFO spring groundfish survey.

2001 DFO Spring Survey															
Total	Males							Females							
length (cm)	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9
20	1														
21	1														
22								1							
23	4							4							
24	3							3							
25	6							4							
26	6							3							
27	3	2						5							
28	2	4						4	2						
29	6	2						4							
30	3	6						3	3	1					
31	4	5						1	4						
32	3	7						3	6						
33	2	5	2					2	4						
34	1	3	4						8						
35		3	5	2					5	3					
36		5	4	2					4	4					
37		3	3	3	1				4	3					
38			7	3					2	5	1		1		
39			5	2	2				4	5	2				
40		1	1	4			1			2	6	1	1		
41				2						2	5	1			
42			1	2						3	4	2	1		
43						1				2	3	3	2		
44				2						1	3	2		1	
45				2							2	3	3	1	
46											2	3			
47			1		1							3		3	
48												3	2		
49											1	1	1	1	
50												1	1	2	
51													1		1
52														1	
53													1		
Total	45	46	33	24	4	1	1	37	46	31	29	23	14	9	1

Figure 15. Age length key developed from consensus age estimations for Georges Bank yellowtail flounder from the 2001 DFO spring groundfish survey.

2000 Port Samples													
Total	Males						Females						
length (cm)	2	3	4	5	6	7	2	3	4	5	6	7	8
27	2												
28	3						2						
29	4						2						
30	9						7						
31	10	1					9						
32	8	4					12						
33	8	7					10	2					
34	4	10	1				10	4					
35	2	11	3				5	5	3				
36		4	6	2	1		3	10	1				
37		7	5	2				11	4				
38		2	11	1				5	7		1		
39		1	4	3	3	1		10	6				
40			4	9	1			4	9		1		
41			1	3	1				10	3	1		
42				2	3			1	5	6	1		
43									3	5	3	2	
44									1	7	5		1
45									1	3	7	1	
46										2	8	2	2
47										3	3	5	
48										2	2	4	
49											2	1	
50											2	2	1
Total	50	47	35	22	9	1	60	52	50	31	36	17	4

Figure 16. Age length key developed from consensus age estimations for Georges Bank yellowtail flounder from 2000 Canadian fishery port samples.

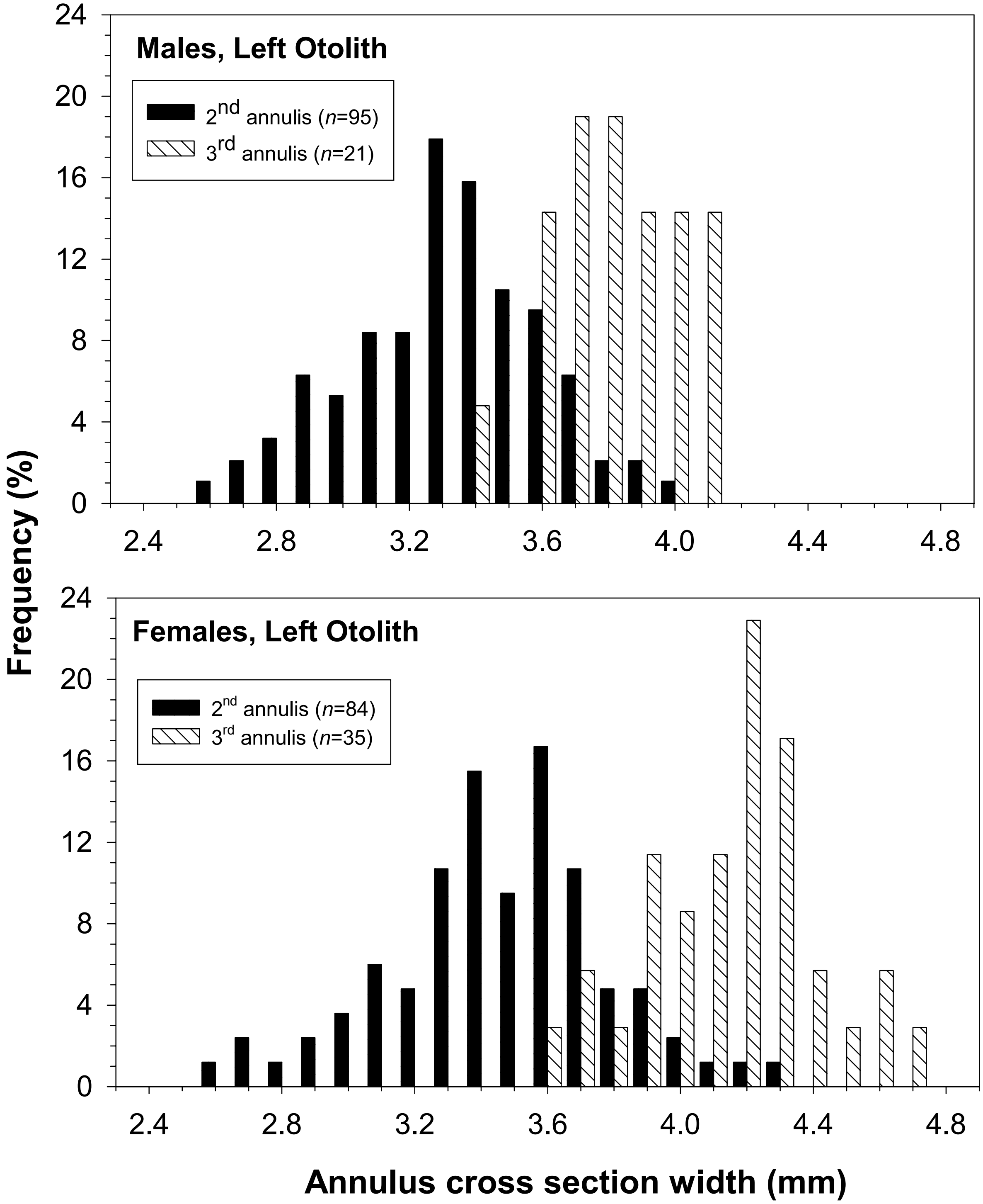

Figure 17. Frequency distribution of annulis cross-section widths by sex from age 2 and 3 yellowtail flounder from the 2000 DFO spring survey.

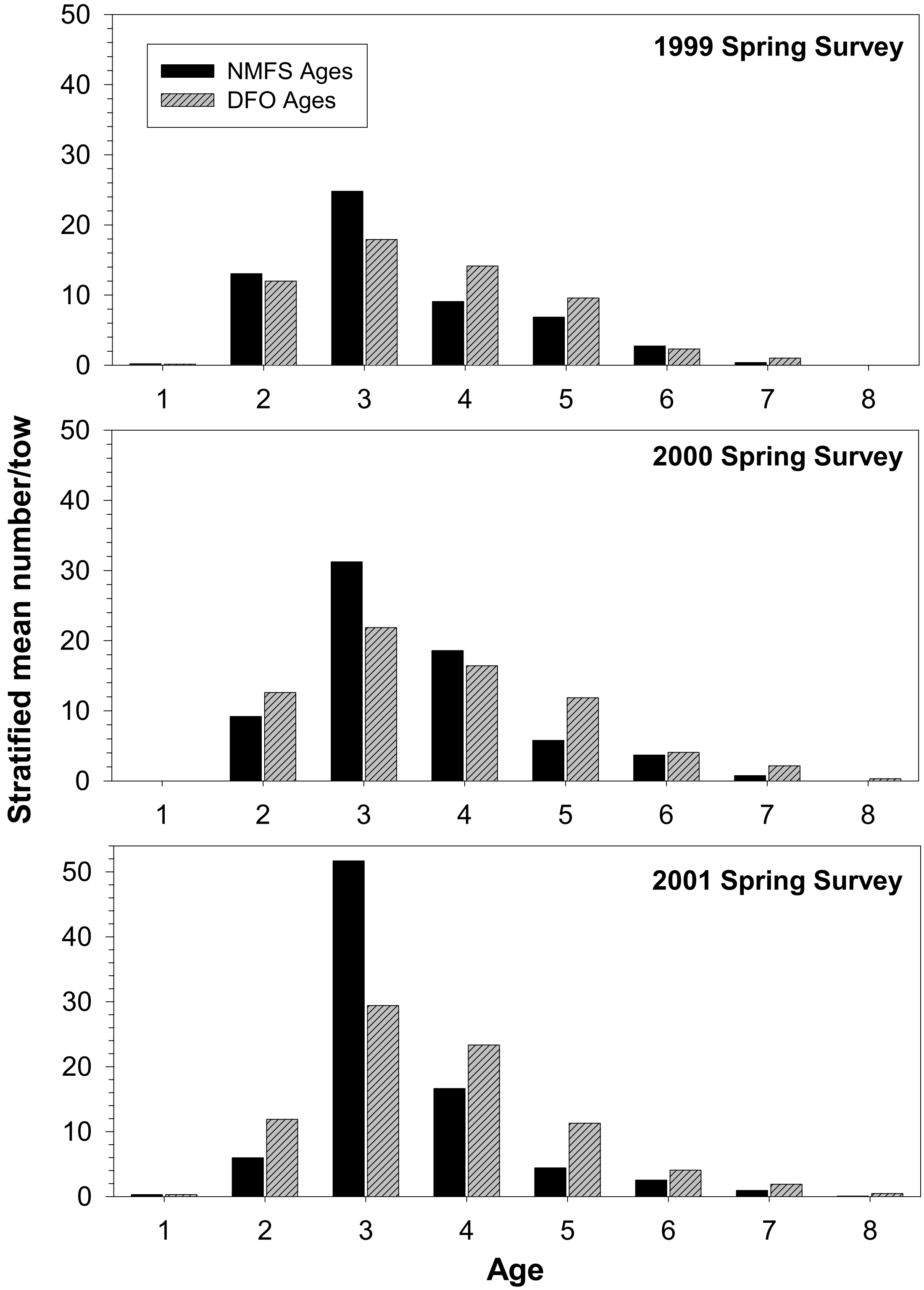

Figure 18. DFO spring survey indices of abundance for 1999, 2000 and 2001 calculated from age length keys used in previous stock assessments (NMFS ages) and from survey specific age material evaluated by DFO agers (DFO ages).

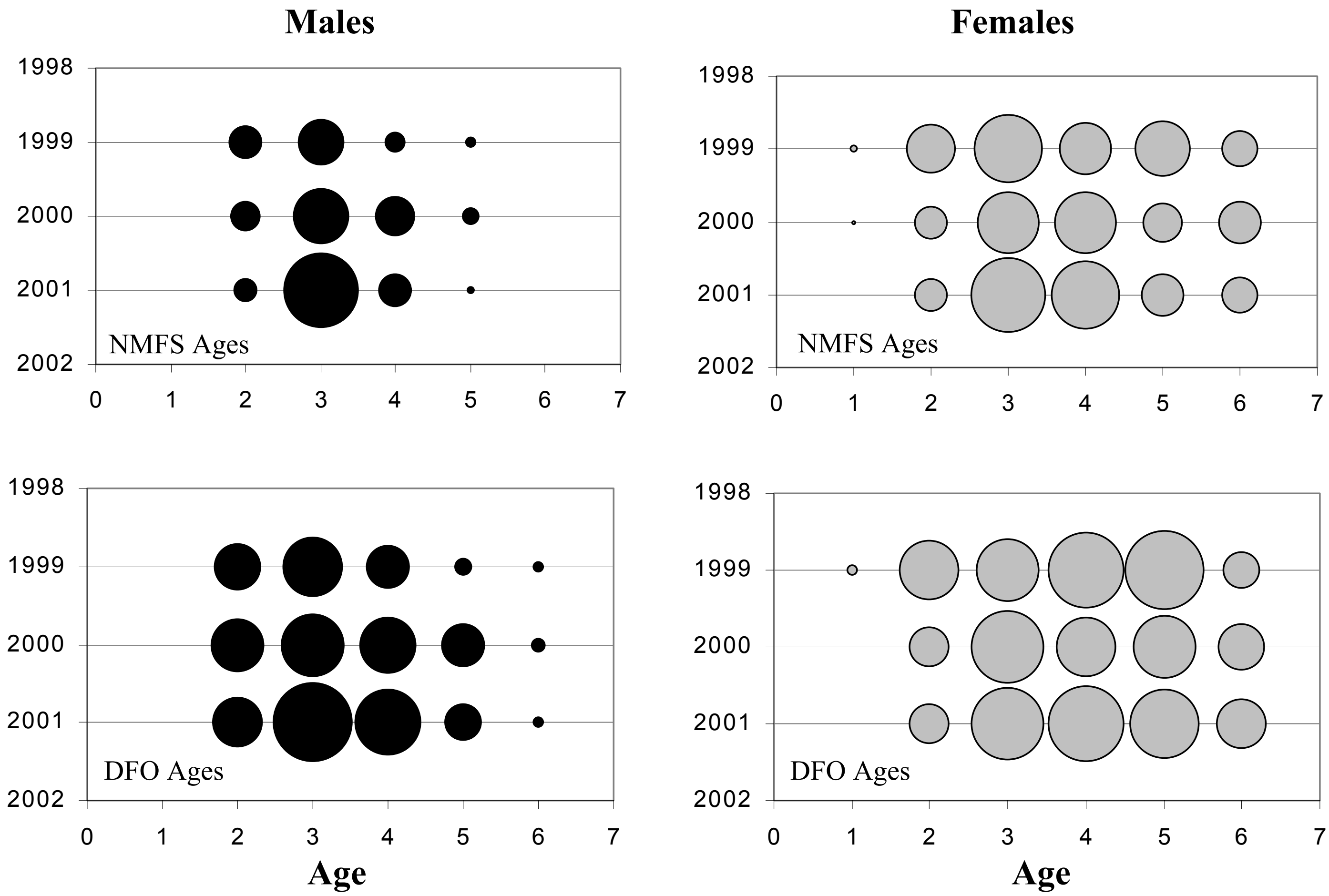

Figure 19. Bubble plots of DFO spring survey indices of abundance by sex for 1999, 2000 and 2001 calculated from age length keys used in previous stock assessments (NMFS ages) and from survey specific age material evaluated by DFO agers (DFO ages). (The area of the bubble is proportional to the magnitude of the index value).

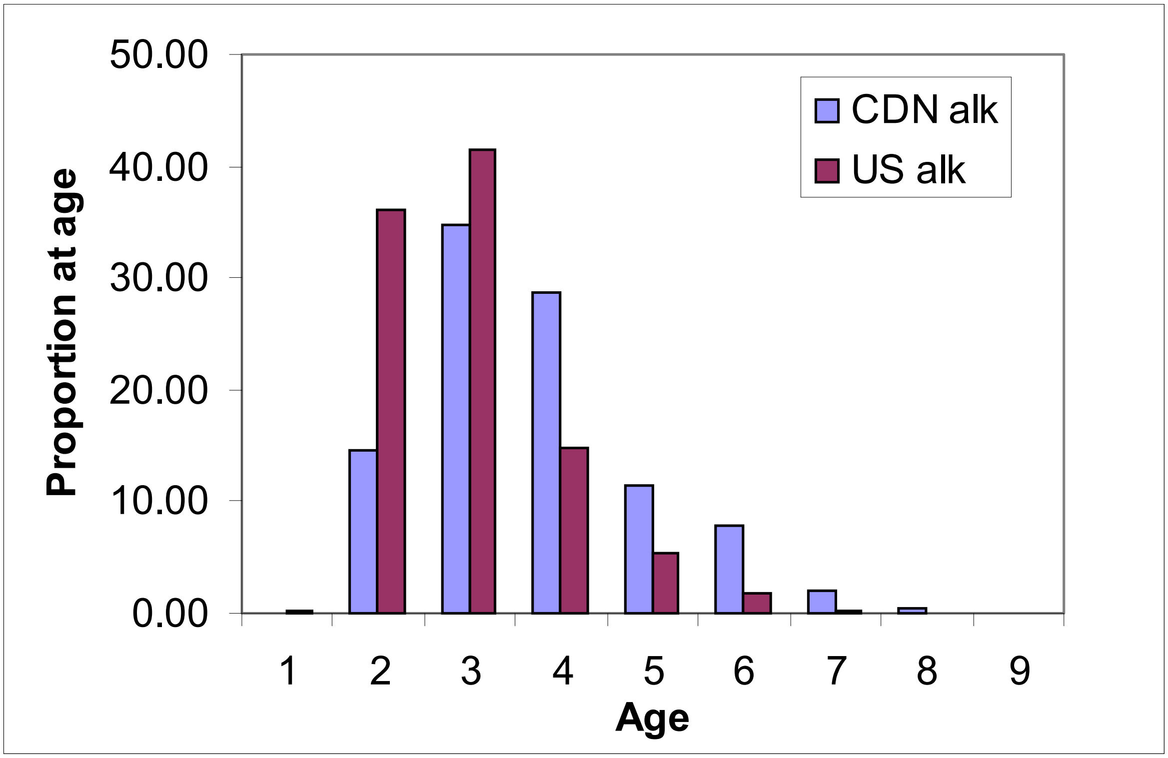

Figure 20. 2000 Canadian commercial fishery catch-at-age for Georges Bank yellowtail flounder calculated from separate sex US age length keys based on 2000 NMFS fall survey + US commercial fishery ages (US alk), and separate sex Canadian age length keys (CDN alk) based port samples from the Canadian 2000 fishery.