Table A1. Summary of decline rate estimates for each of the NAFO subdivisions. Estimates in bold represent an increase from 2003.

Stock		Age at Maturity	Generation time	Data type	Time period	Rate of change	2003 Estimate
1.	2GH	5.25	11	RV Survey	1978-2006	-85%	Na
						Na	Na
2.	2J3KL	6	11	RV Survey	1983-2007	-99%	-99.9
				VPA	1978-2007*	-97%	-97
3.	3NO	6	11	RV Survey	1959-2007	**-99%**	-95
				VPA	1984-2007	-97%	-98
4.	3Ps	6	11	RV Survey	1983-2007	**-65%**	-47
				VPA	1959-2007*	-41%	-46
5.	3Pn4RS	4	9	RV Survey	1990-2007	-58%	-64
				VPA	1974-2008	**-97%**	-93
6.	4T	4.5	9.5	RV Survey	1950-2008	**-86%**	+27
				VPA	1971-2007	**-83%**	-23
7.	4Vn	4.5	9.5	RV Survey	1970-2007	**-91%**	-4
				VPA	1981-2007*	-94%	-95
8.	4VSw	4	9	RV Survey	1970-2007	**-93%**	-92
				VPA	1970-2007	**-80%**	-75
9.	4X	2.5	7.5	RV Survey	1970-2007	**-73%**	-53
				VPA	1948-2008*	-72%	-78
10.	$5Z_{jm}$	2.5	7.5	DFO RV Survey	1986-2008	+3.7%	+6
				VPA	1978-2007	-49%	-70

*VPA data extended using linear approximation of relationship with RV survey data for overlapping time interval.

Annual estimates of exploitation rate (Brattey and Healey 2005, 2007) indicate that during 1998-2002, exploitation rates in the inshore ranged from 10-17% peaking in 1999, in area 3Ki at 37%. Exploitation rates dropped with the fishery closure (2-9%) during 2003-2005, but increased in 2006 and 2007 to 6-20% depending on region. As noted above, offshore 2J3KL cod may continue to make traditional feeding migrations to the inshore during the summer. At present levels of offshore population abundance, the levels of exploitation in the inshore represent a significant risk to stock growth offshore (Brattey *et al.* 2008b; Shelton *et al.* 2006). It is worth noting that the closure of the fishery in 2003 and lower landings in 2004-2005 coincided with a decline in mortality and improved survival in the offshore. Sentinel catch rates in the inshore also began to increase in this period.

Bycatch represents another significant threat to cod in 2J3KL. Bycatches are common in gillnet fisheries for lumpfish, turbot and winter flounder (blackback). During 2004 and 2005, substantial bycatches (>600 t) of cod were taken in the inshore, mostly in 3KL, in the winter flounder (blackback, *Pseudopleuronectes americanus*) fishery, although it is well-known that blackback has limited commercial value and that this was in fact a cod-directed fishery. Bycatch of cod also occurs in the herring gillnet fishery, the capelin trap fishery, the bait-net fishery and the shrimp fishery, though this was dramatically reduced with the introduction of the Nordmore grate in 1993 (Kulka 1998). Total discards from the large vessel shrimp fishery in 2J3K were 5 t in 1995 and 13 t in 1996 (Kulka 1998).

Predation by marine mammals remains a concern. For this stock there is no new information regarding the influence of marine mammal predation on the rebuilding. Previous assessments (DFO 2008) have concluded that predation by seals is likely a major factor contributing to high levels of mortality in both the offshore and inshore.

During the period from 2003-2007, total mortality estimated following Sinclair (2001) was 0.346 (±0.174SE) or 29% annually (Table A2). This value represents a significant decline in comparison to the previous time period. As fishing pressure has not declined over this period, the drop in total mortality seems likely the result of declines in natural mortality, though this remains speculative.

4. Southern Grand Bank (3NO)

Stock structure

Cod in 3NO are commonly distributed over the shallower parts of the Grand Bank in summer such as the southeast shoal, and on the slopes of the bank in winter.

Life History

As noted elsewhere, there have been shifts in the age of maturity during the last 40-50 years in 3NO. Age at maturity declined from around 6-6.5 to under 5 and despite some recovery, the recent cohort still seems to be maturing at <6yrs of age (Trippel *et al.* 1997; Stansbury *et al.* 2001). Thus, in an unfished state, generation time is estimated to be 11yr, yielding a three-generation time period of 33 years.

Table A2. Estimates of total mortality (Z) for cod stocks in Canadian waters. Estimates based on the descending limb of the catch curve estimated using Analysis of Co-variance (ANCOVA) following Sinclair (2001).

Stock/NAFO Division	Data Source	Age groups considered	Survey years	Z (std. error)	Percent annual mortality
2J3KL	Brattey *et al.* 2008	4-6	2003-2007	0.346 (0.174)	29%
3NO	Morgan *et al.* 2007	4-6	2006-2006	0.519 (0.214)	40%
3Ps	Brattey *et al.* 2008	5-8	2002-2007	0.899 (0.124)	59%
3Pn4RS	Alain Frechet pers. comm.	5-10	2004-2008	0.792 (0.052)	55%
4T	Swain *et al.* 2008	7-11	2004-2008	0.722 (0.114)	51%
4Vn	M. Fowler pers. comm.	5-10	2003-2007	0.791 (0.117)	55%
4VsW	R. Mohn pers. comm.	3-8	2004-2008	0.845 (0.151)	57%
4X	J. Emberley pers. comm.	4-7	2004-2008	1.420 (0.273)	76%
$5Z_{jm}$	Clarke *et al.* (2008)	4-7	2003-2007	0.437 (0.193)	35%

Abundance trends

Survey catch data from the Spring RV survey and VPA estimates of abundance are from Morgan *et al.* (2007) and provided by J. Morgan, Fisheries and Oceans Canada. As per above, the areal expansions of survey abundance were calculated using the number of trawlable units in the survey area and the average catch at age per tow. Again this was based on the autumn RV survey and all data are presented as Campelen equivalents (Figure A3a). Contemporary total abundance represents about 2% of the average abundance of the 1960's, and 25% of 2002. The abundance of mature individuals represents about 40% of the 2002 estimate (Figure A3a). Estimates of the 3-generation rate of decline indicate a 98% and 97% decline using the RV data or VPA respectively (Figure A3b, Table A1).

Area of occupancy

Between 2002 and 2007(since the last report), the area of occupancy has increased from 61,000 km^2 to 93,000 km^2 and the D95 from 29,000 km^2 to 48,000 km^2. This increase is similar to the increase from 1996 to 2001 and within the range of variation observed. Taken with the abundance data it seems that cod in 3NO are less aggregated in recent years despite lower abundances.

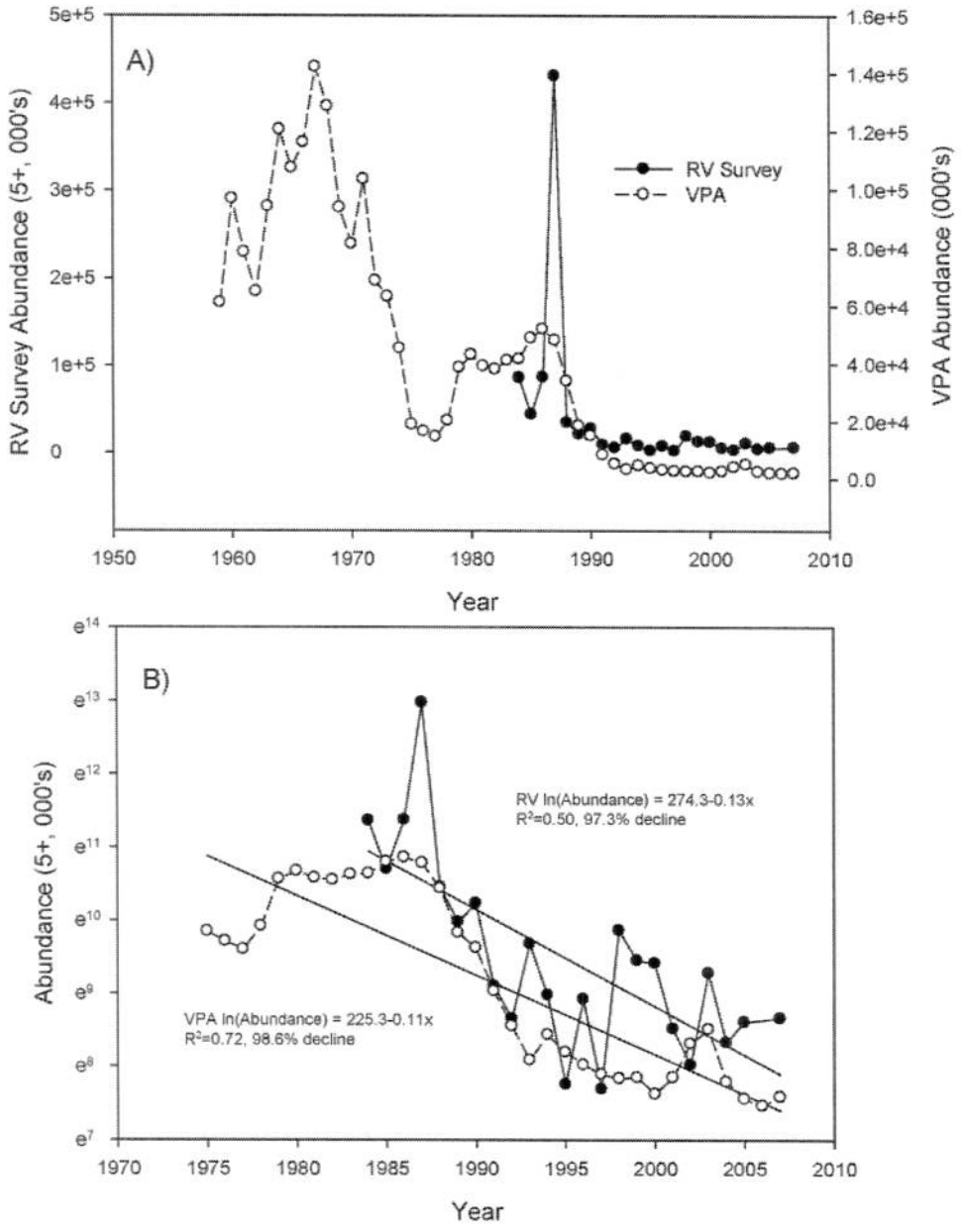

Figure A3. (A)Temporal variation in abundance of mature individuals in the southern Grand Bank cod stock (3NO). (B) Estimation of three-generation rate of decline. Data from Morgan *et al.* 2007.

Threats to recovery

DFO has identified fishing mortality as the main threat to cod in 3NO. Catches in 3NO peaked in 1967 at 227,000 t declining thereafter. Catches following the moratorium have increased from 170 t in 1995 to 4,800 t in 2003. Since 2003 catches have been below 1000 t. At the current level of fishing, spawner biomass is predicted to decline by

6% by 2012 (Shelton and Morgan 2005). During the period from 2002-2006, total mortality, estimated following Sinclair (2001), was 0.519 (±0.214SE) or 40% annually (Table A2).

5. St. Pierre Bank (3Ps)

Stock Structure

Tagging results from different regions within 3Ps (Brattey and Healey 2004, 2005, 2006) suggest that the stock comprises several offshore components and several inshore components in Placentia and Fortune Bay with limited mixing between. Regular shoreward migrations appear to occur in the offshore fish resulting in mixing with inshore fish during the summer and fall. Examinations of early life history stages within Placentia Bay suggest large amounts of eggs and larvae are exported from the Bay early in the season but local recruitment may occur later in the summer when temperatures warm (Bradbury *et al.* 2001, 2003, 2008). Egg production within the head of Placentia Bay did not correlate with local recruitment but rather stockwide recruitment suggesting either correlation or some connection (Rose *et al.* 2008). Comparison of the rate of multiyear spawning fidelity to spawning locations in Placentia Bay (~50%) and egg export from the bay (~100% Spring), suggests that mixing if it occurs may be primarily during the early life history.

Life History

Based on data from the 1960s and 1970s, age at 50% maturity is about 6-7 yrs for St. Pierre Bank cod (Brattey *et al.* 2001a, Worcester *et al.* 2009). Thus, in an unfished state, generation time is estimated to be 11yr, yielding a three-generation time period of 33 years.

Abundance Trends

The RV survey data are those reported by Worcester *et al.* (2009) and provided by B. Healey, Fisheries and Oceans Canada. Abundance data for the mature part of the population, as estimated by VPA, are also available from Brattey *et al.* (2001). The earliest year for which survey data are available is 1983. It is worth noting that the RV survey was conducted in the winter from 1972-1993, but moved to spring due to concerns of winter mixing between from 3Pn4RS (Worcester *et al.* 2009). Also since 1997, the survey has been modified to include inshore strata increasing the surveyed area by 12%. As with previous Newfoundland stocks, all data are presented in Campelen equivalents to account for the change from the Engel trawl. VPA estimates of abundance from the last accepted VPA (John Brattey, personal communication) extend from 1959 to 2000 (Figure A4a). The 3-generation rate of decline experienced by St. Pierre Bank cod was 65% and 41% for the RV survey and VPA respectively (Figure A4b, Table A1). Estimates of total abundance and abundance of mature individuals have been highly variable over time; however, since 2002 the number of mature individuals has dropped by 75%. The 2009 assessment, based on the DFO Spring RV

survey, indicates that the stock has declined by a factor of 3 since 2004. Other sources of data include DFO sentinel surveys which show clear declines during the late 1990s and have remained low and stable since (Maddock Parsons and Stead 2007). In addition, an industry survey (1997-2005, McClintock 2007, Worcester *et al.* 2009) indicates that the total abundance index is highly variable and the 2004 and 2005 values were record lows.

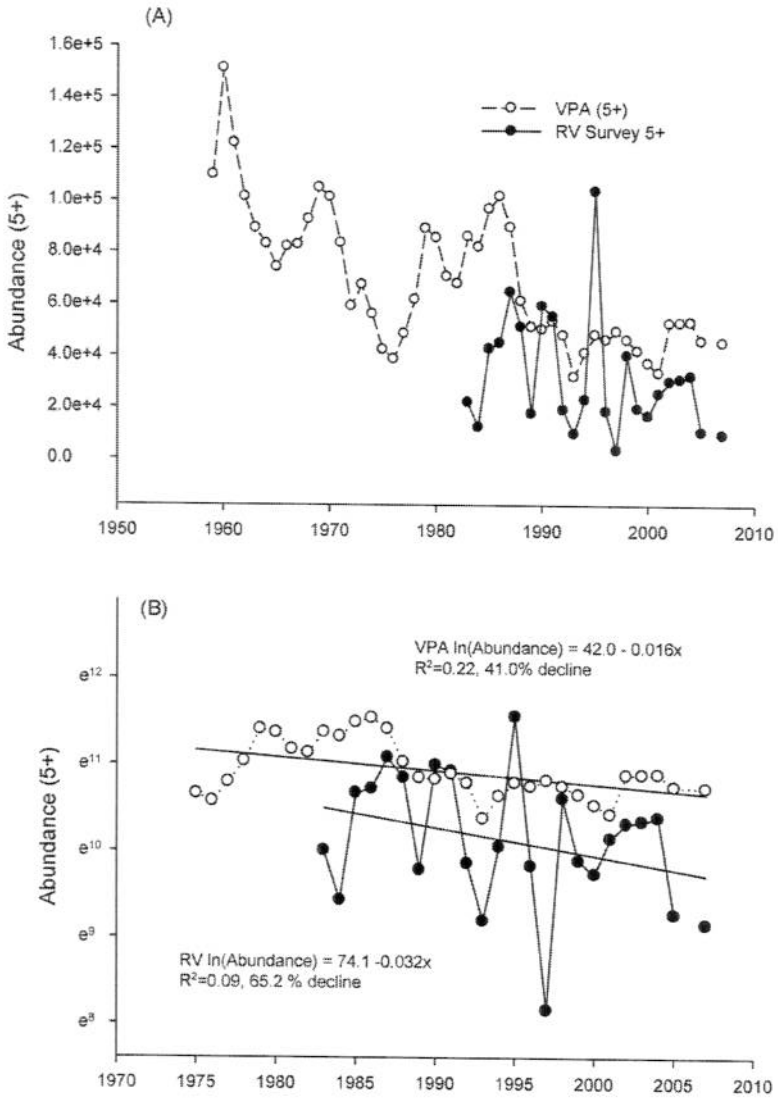

Figure A4. (A)Temporal variation in abundance of mature individuals in the St. Pierre Bank cod stock (3Ps). (B) Estimation of three-generation rate of decline. VPA estimates have not been available since 2000 (Worcester *et al.* 2000). Following COSEWIC (2003), presented data for 2001-2007 are an extrapolation based the relationship between VPA abundance and RV survey abundance for the time period 1983 to 2000. This extrapolation is done for the purposes of rate of decline calculation only.

Area of occupancy

Between 1983 and 2007 (the range of the reported data), area of occupancy, has been variable ranging from 30,000 km^2 to approximately 50,000 km^2 and the D95 index ranged between 10,000 km^2 to 25,000 km^2.

Threats to recovery

Worcester *et al.* (2009) estimated total mortality and concluded that the annual mortality rate was on average 30% during 1997-2007 and concluded that fishing mortality during this period has not been excessive. In the period 2001-2005, exploitation rates estimated based on tagging studies suggests exploitation was highest in Placentia Bay reaching 22-31%, and declined to the offshore. These high rates may pose a strong risk to the persistence of resident groups which do not migrate offshore (Mello and Rose 2005). During the period from 2002-2007, total mortality, estimated following Sinclair (2001), was 0.899 (±0.124SE) or 59% annually (Table A2).

6. Northern Gulf of St. Lawrence (3Pn4RS)

Stock Structure

Cod in 3Pn4RS are characterized by extensive migrations throughout Newfoundland's southern coast and Quebec's middle and lower north shore (Worcester *et al.* 2009). Tagging data suggests mixing occurring in the northwest Gulf of St. Lawrence, the Strait of Belle Isle, and the Burgeo Bank area. Tagging data predicts up to 75% of cod in the Burgeo Bank area of 3Ps in winter may be 3Pn4RS cod (Worcester *et al.* 2009). Within this region Templeman (1962) identified stocks associated with Burgeo Bank, western Newfoundland, and possibly the North Shore of the Gulf of St. Lawrence but noted significant spatial overlap particularly during winter months. Several studies (Templeman 1962, Campana *et al.* 1999) also identified the Laurentian Channel as a significant barrier (<5% straying across) though the nature of this barrier is unclear.

Life History

Life history characteristics of cod in 3Pn4RS have been variable over the last few decades. Growth, condition, size and age at maturity all declined in the 1980s but have rebounded since the mid-1990s and since 2000 have returned to 1980s levels. Based on maturity-at-age data for the 1970s and 1980s, age at 50% maturity is about 4yr for northern Gulf cod. Thus, in an unfished state, generation time is estimated to be 9yr, yielding a three-generation time period of 27 years.

Abundance Trends

Both the DFO RV survey data and the VPA-based abundance data for the mature part of the population were provided by A. Fréchet, Fisheries and Oceans Canada (Figure A5a). The earliest year for which survey data are available is 1990. VPA estimates of abundance extend back to 1974, and although there were two accepted VPA formulations in 2008, the rates of decline are similar so only one is shown (Fixed M). Only the VPA estimates encompassed the 3-generation time frame, and these data suggest a decline rate of 97% (Figure A5b, Table A1). In addition to the RV and VPA estimates, fixed gear sentinel fisheries provide two abundance indices. The abundance index of gillnet sentinel fisheries more than doubled from 2001 to 2003 peaking in 2006. The abundance index from the longline sentinel fisheries also increased from 2004 to 2006. Both the sentinel indices dropped from 2006 to 2007 (Worcester *et al.* 2009).

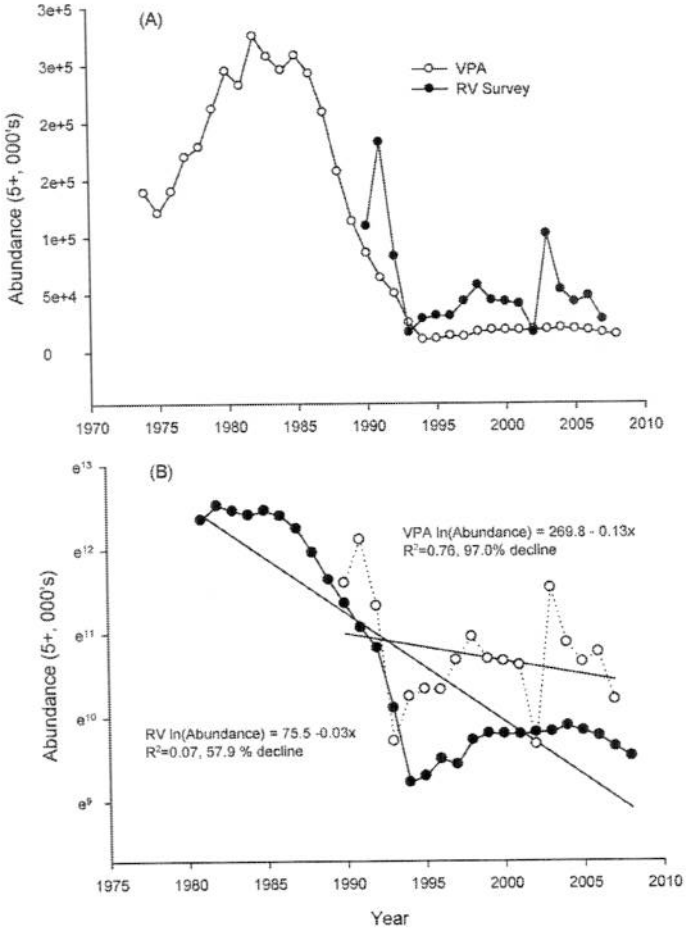

Figure A5. (A)Temporal variation in abundance of mature individuals in the Northern Gulf of St. Lawrence cod stock (3Pn4RS). (B) Estimation of three generation rate of decline. Data from Worcester *et al.* (2009) and Fréchet *et al.* (2007).

Area of occupancy

There was a decline in area of occupancy and geographic range from 1990 to 2002 (24%, Smedbol *et al.* 2002). Since that time the area of occupancy has risen from 40,000 km^2 to 60,000 km^2 and the D95 has risen from 25,000 km^2 to 40,000 km^2 for the period 2002 to 2008. Most of this increase appears due to spreading into 4S (Worcester *et al.* 2009).

Threats to recovery

Prior to 2002, exploitation rates had been steadily increasing to an estimated 30% in 2001 (Smedbol *et al.* 2002). Since 2002, fishing mortality continues to be the main threat to the stock. Spawning stock biomass is estimated to be well below the conservation limit (Worcester *et al.* 2009). Landings exceeding 5,500 tons recorded between 1999 and 2002 and in 2007 resulted in a 16% drop of mature biomass with exploitation rates reaching 29%. Such exploitation levels are inconsistent with a rebuilding strategy (Worcester *et al.* 2009). In addition to fishing, marine mammal predation appears to pose a threat to recovery for northern Gulf cod, as revealed by McLaren *et al.*'s (2001) statement: "The conclusion that seals are important predators on cod in this area appears to be inescapable". During the period from 2004-2008, total mortality, estimated following Sinclair (2001), was 0.792 (±0.0.52SE) or 55% annually (Table A2).

7. Southern Gulf of St. Lawrence (4TVn)

Stock Structure

Cod in the southern Gulf of St. Lawrence generally occupy summer spawning and feeding grounds throughout the Magdalen Shallows before overwintering outside the Gulf along the southern slope of the Laurentian Channel (4Vn) at depths near 200m (Campana *et al.* 1999; Ruzzante *et al.* 2000). As such the stock is usually identified as 4TVn(Nov.-Apr.). Within the Gulf, Templeman (1962) identified five distinct stocks in this region based on vertebral numbers, tag returns, and summer distributions but noted significant mixing likely occurs during winter. Between the Southern Gulf and neighbouring stocks, Campana *et al.* (1999) suggests that despite the apparent mixing during the winter months in the Cabot Strait, the various overwintering stocks maintain small-scale discrete spatial structure on scales <20km and as such actual mixing may be minimal.

Life History

Age at maturity in this stock declined in the 1960s and early 1970s but has remained roughly constant since then (Beacham 1983; D.P. Swain, unpublished analyses). The continued slow growth rate of 4T cod has been attributed to strong selection against fast growth which occurred in the late 1980s resulting in evolutionary changes within the stock (Swain *et al.* 2007). Data from the RV surveys (1990 to 1995)

indicated that 12% of southern Gulf cod were mature at age 3, 37% at age 4, 72% at age 5, 91% at age 6, 97% at age 7 and 100% at older ages and age at 50% maturity is about 4.5yr (Trippel *et al.* 1997; Doug Swain, DFO, Moncton, personal communication). Thus, generation time is estimated to be 9.5yr, yielding a three-generation time period of 28.5 years.

Abundance Trends

The RV survey and VPA data are reported by Chouinard *et al.* (2008) and provided by D. Swain, Fisheries and Oceans Canada. A bottom-trawl survey of the southern Gulf has been conducted each September since 1971 (Figure A6a). The survey follows a stratified-random design based on the 24 strata. It is worth noting that a change from 12-hr to 24-hr sampling occurred in 1985, the gear changed from the Yankee-36 to the Western IIA trawl in 1985; and the survey has utilized four vessels over its time course. Comparative fishing experiments were conducted to estimate the effect of each of these changes on fishing efficiency and estimate conversion factors (Nielsen 1989, 1994; Swain *et al.* 1995; Benoît 2006). VPA-based estimates of abundance extend back to 1950 (Figure A6a). Estimated rates of decline for Southern Gulf cod ranged from 86% to 85% over the past three generations for the RV survey and VPA data respectively (Figure A6b, Table A1). Chouinard *et al.* (2008) estimated the 2008 SSB at 36,000 t which is the lowest value in the 59-yr record and well below the limit reference point for this stock (80,000 t). The 2009 assessment estimated SSB at the beginning of 2009 to be only 28,000 t (DFO 2009d) and the population no longer appears to be viable even in the absence of fishing (Swain and Chouinard 2008).

Area of Occupancy

The geographic distribution of cod in 4T during the summer months appears density-dependent, expanding into offshore colder water at high abundance and contracting to shallower inshore waters at low abundance (Swain and Sinclair 1994, Swain 1999) and as such largely tracks total abundance. Both area of occupancy and D95 increased from intermediate values in the early 1970s to peak values in the mid-1980s and then steadily declined throughout the 1990s to the lowest levels observed in the 38-yr time series. In the 2000s, average area of occupancy ranged from 51000 km^2 for ages 5+ to 57000 km^2.

Threats to Recovery

Since 1999, exploitation rates have been <10% (Worcester *et al.* 2009). Despite low exploitation rates, the most important factor contributing to the current low productivity of the southern Gulf cod stock remains elevated M (Swain and Chouinard 2008). Estimates of M from the recent VPA (Chouinard *et al.* 2008) suggest that M began increasing in the 1980s reaching a current value near 0.6. Causes of this high M are unknown, though grey seal predation remains a likely candidate (DFO 2009e). It is unlikely that unreported catch could account for the high estimates of M in the period after 1993, when there has been minimal fishing effort (Chouinard *et al.* 2005). Proposed hypotheses for elevated M of cod in this or other Northwest Atlantic Cod stocks include poor fish condition due poor environmental conditions (Dutil and Lambert 2000), increased survival costs to reproduction due to fishery-induced declines in age and size at maturity (Hutchings 2005), and increased predation by the expanding grey seal herd (Chouinard *et al.* 2005, DFO 2009e). Population projections indicate that even without harvest in 2008, SSB is will decline by at least 10%, with a 53% probability of a 15% decline or greater (Chouinard *et al.* 2008). Long-term stochastic projections (Swain and Chouinard 2008) at the current productivity suggest the spawning stock biomass is certain to be less than 1000 t within 40 years in the absence of fishing, and within 20 years with fishery removals at the level of the TAC in 2007 and 2008 (2000 t) (Figure A6c). Swain and Chouinard (2008) warn that as M appears to be increasing, these projections may be overly optimistic. During the period from 2004-2008, total mortality, estimated following Sinclair (2001), was 0.722 (±0.0.114SE) or 51% annually (Table A2).

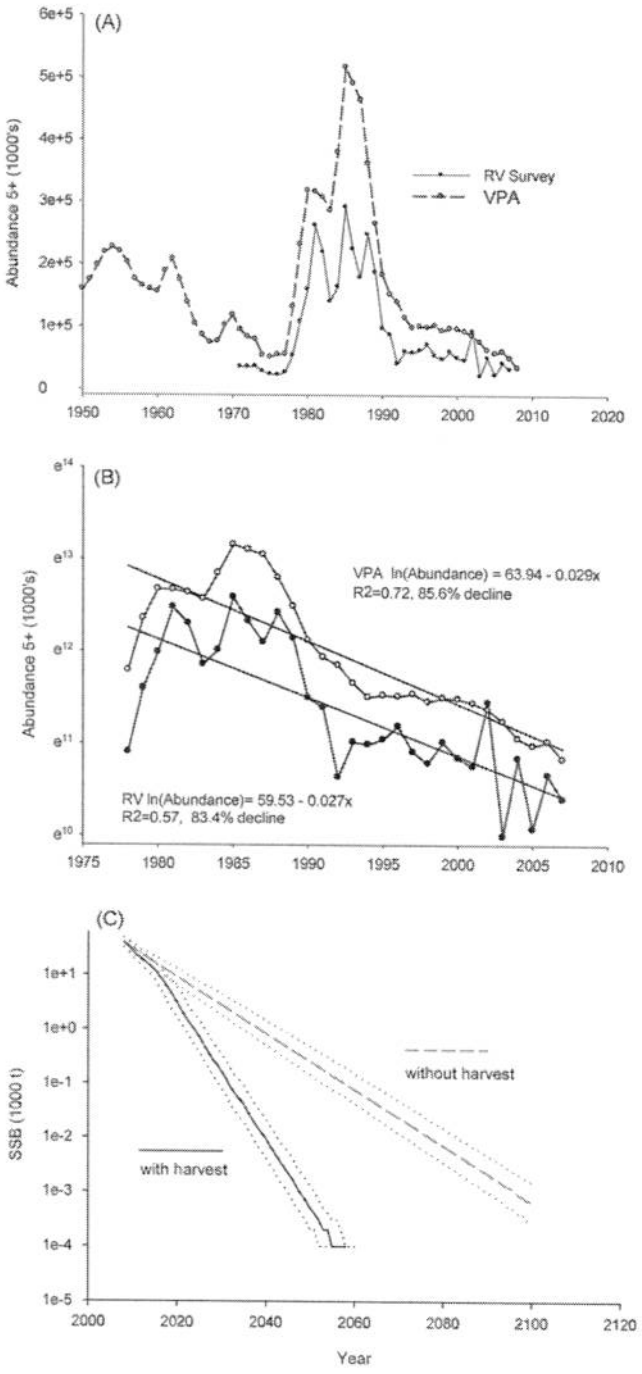

Figure A6. (A)Temporal variation in abundance of mature individuals in the Southern Gulf of St. Lawrence cod stock (4TVn). (B) Estimation of three-generation rate of decline. (C) Projections of population trends. See Chouinard *et al.* 2008 and Worcester *et al.* 2009 for details regarding data.

8. Cabot Strait (NAFO 4Vn)

Stock Structure

Cod in 4Vn are resident fish found in Sydney Bight, Cape Breton from St. Paul Island to Fourchu. As Gulf cod migrate into the area to overwinter, the stock is assessed and defined using the May-October period (i.e. 4Vn (May to Oct)).

Life History

Based on data from the 1970s and 1980s for 4T cod, age at 50% maturity is about 4.5yr for southern Cabot Strait cod (Trippel *et al.* 1997). Thus, in an unfished state, generation time is estimated to be 9.5yr, yielding a three-generation time period of 28.5 years.

Abundance Trends

Available data include the RV survey data which are available from 1970 to 2007 (Worcester *et al.* 2009, provided by M. Fowler, Fisheries and Oceans Canada) and VPA-based estimates of abundance are those reported by Mohn *et al.* (2001) which extend from 1981 to 2001. The survey data indicate the presence of a strong decline since the 1980s, with 2004 being the lowest year on record (Worcester *et al.* 2009) (Figure A7a). VPA-based abundances since 2001 were estimated to allow decline rate calculation following COSEWIC (2003) using the relationship between RV data and VPA data for the period 1981-2001 (R=0.73). The rate of decline experienced by Cabot Strait cod over the last 3 generations was estimated as 91% or 94% for the RV survey and VPA respectively (Figure A7b, Table A1).

Area of Occupancy

During the period 1990-2003 the area of occupancy displayed a gradual decline from 10,113 km^2 to 5073 km^2. Since 2003 the values have risen again slightly with 2007 at 7026 km^2.

Treats to Recovery

Since 1994, exploitation rates have remained very low at approximately 2% (Smedbol *et al.* 2002). Nonetheless, total mortality continues to be very high suggesting that natural mortality is the single most important factor threatening this stock (Worcester *et al.* 2009). At present the cause of this high natural mortality remains unknown (D. Swain, pers. comm.). DFO (2009e) recently concluded that this high mortality rate was likely associated with grey seal predation; however, the magnitude of the effect remains uncertain. During the period from 2003-2007, total mortality, estimated following Sinclair (2001), was 0.791 (±0.117SE) or 55% annually (Table A2).

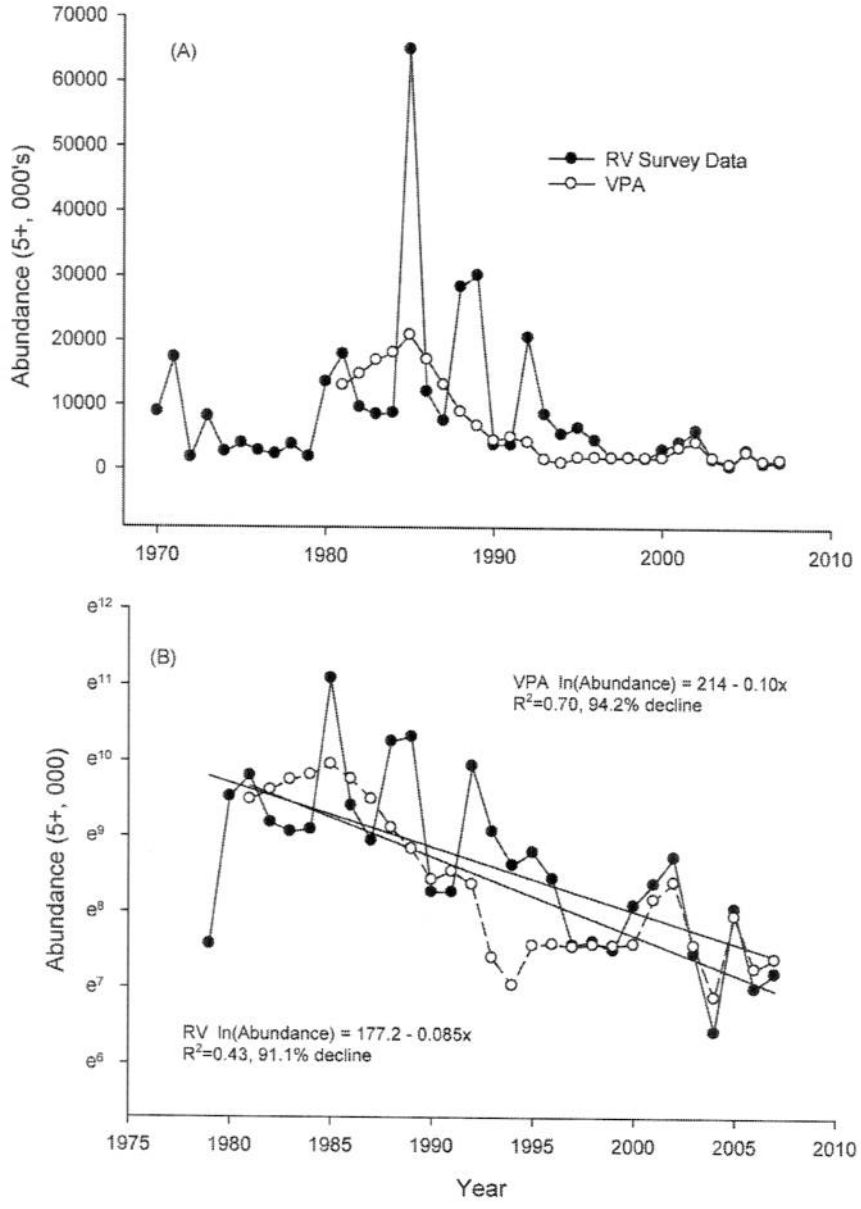

Figure A7. (A)Temporal variation in abundance of mature individuals in the Cabot Strait cod stock (4Vn). (B) Estimation of three-generation rate of decline. VPA estimates have not been available since 2001 (Mohn *et al.* 2001). Following COSEWIC (2003), presented data for 2001-2007 are an extrapolation based the relationship between VPA abundance and RV survey abundance for the time period 1981 to 2000. This extrapolation is done for the purposes of rate of decline calculation only. See Worcester *et al.* (2009) for data.

9. Eastern Scotian Shelf (NAFO 4VsW)

Stock Structure

Cod in 4VsW comprise a network of several offshore spawning locations as well as multiple inshore spawning sites (Frank *et al.* 1994). Templeman (1962) identified Western/Sable, Banquereau, and Canso Banks as possessing local stocks though there was evidence for overwintering fish from coastal Nova Scotia and the southern Gulf.

Life History

Based on data from the 1980s and 1990s, age at 50% maturity is about 4yr for eastern Scotian Shelf cod (Trippel *et al.* 1997). Thus, in an unfished state, generation time is estimated to be 9yr, yielding a three-generation time period of 27 years.

Abundance Trends

The survey data and VPA data were provided by R. Mohn, Fisheries and Oceans Canada. Abundance data for the mature part of the population, as estimated by VPA, and the RV survey extends from 1970 to 2007 (Figure A8a). The 3-generation rate of decline experienced by Eastern Scotian Shelf cod ranges between 93% and 80% for the survey data and VPA respectively (Figure A8b, Table A1).

Area of Occupancy

Between 1970 and 2007 (the range of the reported data), area of occupancy declined from approximately 78,000 km^2 to approximately 50,000 km^2.

Threats to Recovery

Since 1994, exploitation rates have remained very low at less than 2% (Smedbol *et al.* 2002). During the period from 2004-2008, total mortality, estimated following Sinclair (2001), was 0.845 (±0.151SE) or 57% annually (Table A2). DFO (2009e) recently concluded that this high mortality rate was likely associated with grey seal predation to some degree; however the magnitude of the effect remains uncertain.

10. Western Scotian Shelf/Bay of Fundy (4X/5Y)

Stock Structure

Cod in 4X are widely distributed geographically displaying both fall and spring spawning behaviour and Templeman (1962) listed 7 discrete populations within 4X. Fall spawning has been observed in the areas of Halifax Harbour, Sambro Head to St. Margarets Bay (McKenzie 1940, Templeman 1962) with spring spawning occurring on mainly on Browns Bank. In addition, tagging studies (Halliday 1971, Hunt *et al.* 1999) and phenotypic (Clarke and Perley 2006) differences support a division between cod

from the Bay of Fundy and those inhabiting the western Scotian Shelf. There does appear to be some mixing of cod through the Gulf of Maine, Georges Bank and Scotian Shelf areas.

Life History

Based on data from the 1970s and 1980s for 4X cod, age at 50% maturity is about 2.5yr (Trippel *et al.* 1997). Thus, in an unfished state, generation time is estimated to be 7.5yr, yielding a three-generation time period of 22.5 years.

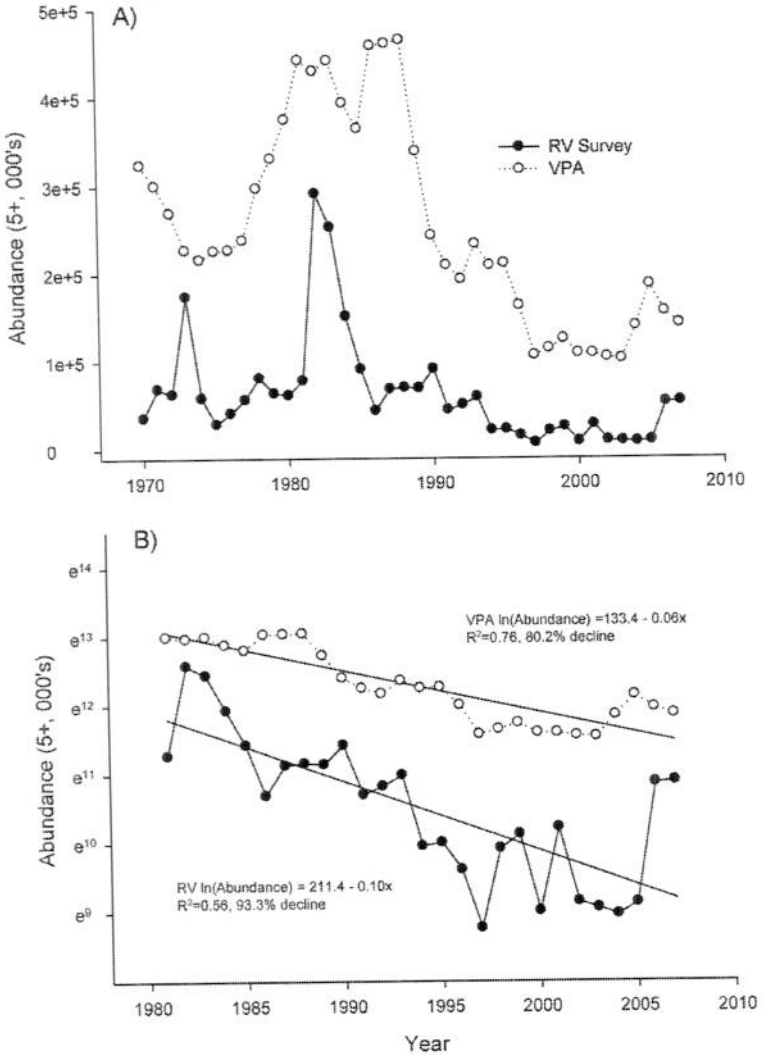

Figure A8. (A)Temporal variation in abundance of mature individuals in the Eastern Scotian Shelf cod stock (4Vsw). (B) Estimation of three-generation rate of decline. Data from R. Mohn (pers comm), and Worcester *et al.* (2009).

Abundance Trends

The survey data and VPA-based (Clarke *et al.* 2002) estimates of abundance were provided by D. Clark and J. Emberley, Fisheries and Oceans Canada. The earliest year for which survey data are available is 1970. VPA estimates of abundance at the time of the calculations for this status report extended from 1948 to 2002 and have been projected forward using the relationship for the overlapping period with the RV Survey ($R=0.7$, $p<0.001$). Abundance estimates from the RV surveys have been variable but show a decline in recent years to the lowest level on record in 2008 (Figure A9a, Clark and Emberley 2008). The 3-generation rate of decline experienced by cod on the Western Scotian Shelf and Bay of Fundy is estimated at 72% irrespective of data used (Figure A9b, Table A1). The 2009 assessment of this stock extends the VPA and provides estimates of SSB at the beginning of 2008 of 9,000 t, the lowest level in the time series for this stock (DFO 2009f).

Area of Occupancy

Between 1970 and 2002 the area of occupancy, declined slightly from approximately 45,000 km^2 to approximately 31,000 km^2 and since then has stabilized and slightly increased to 36,000 km^2.

Threats to Recovery

The primary threat to cod in 4X continues to be fishing. Although there is no directed cod fishery, cod is caught as part of multispecies groundfish fishery. Fishing mortality remains well above the 0.20 target and the TAC decline from 6000 t in 2000 to 5000 t in 2005 (Worcester *et al.* 2009). In recent years the TAC has not been caught and in 2007, DFO estimates 3790 t were taken in 4X. Possible sources of unknown mortality include the influence of a growing grey seal population and other sources of bycatch such as associated with the commercial Lobster fishery. Estimates of natural mortality have been unusually high since the mid- 1990s. During the period from 2004-2008, total mortality, estimated following Sinclair (2001), was 1.42 (±0.273SE) or 76% annually and was the highest in Canadian waters (Table A2). Mortality due to sources other than reported landings has also been high (DFO 2009f), estimated at 0.70 (46%).

11. Georges Bank ($5Z_{jm}$)

Stock Structure

There is no evidence of substructure within this region (Smedbol *et al.* 2002). However, there is evidence from tagging data of mixing between $5Z_{jm}$ and 4X. Hunt *et al.* (1999) and Wise (1963) documented mixing rates of up to 15% between Georges Bank and Browns Bank and the Bay of Fundy (4X). Recent tagging experiments suggest these rates are currently between 5-6%.

Life History

Based on data from the 1970s and 1980s, age at 50% maturity is about 2.5yr for Georges Bank cod (Hunt and Hatt 2002). Thus, in an unfished state, generation time is estimated to be 7.5yr, yielding a three-generation time period of 22.5 years.

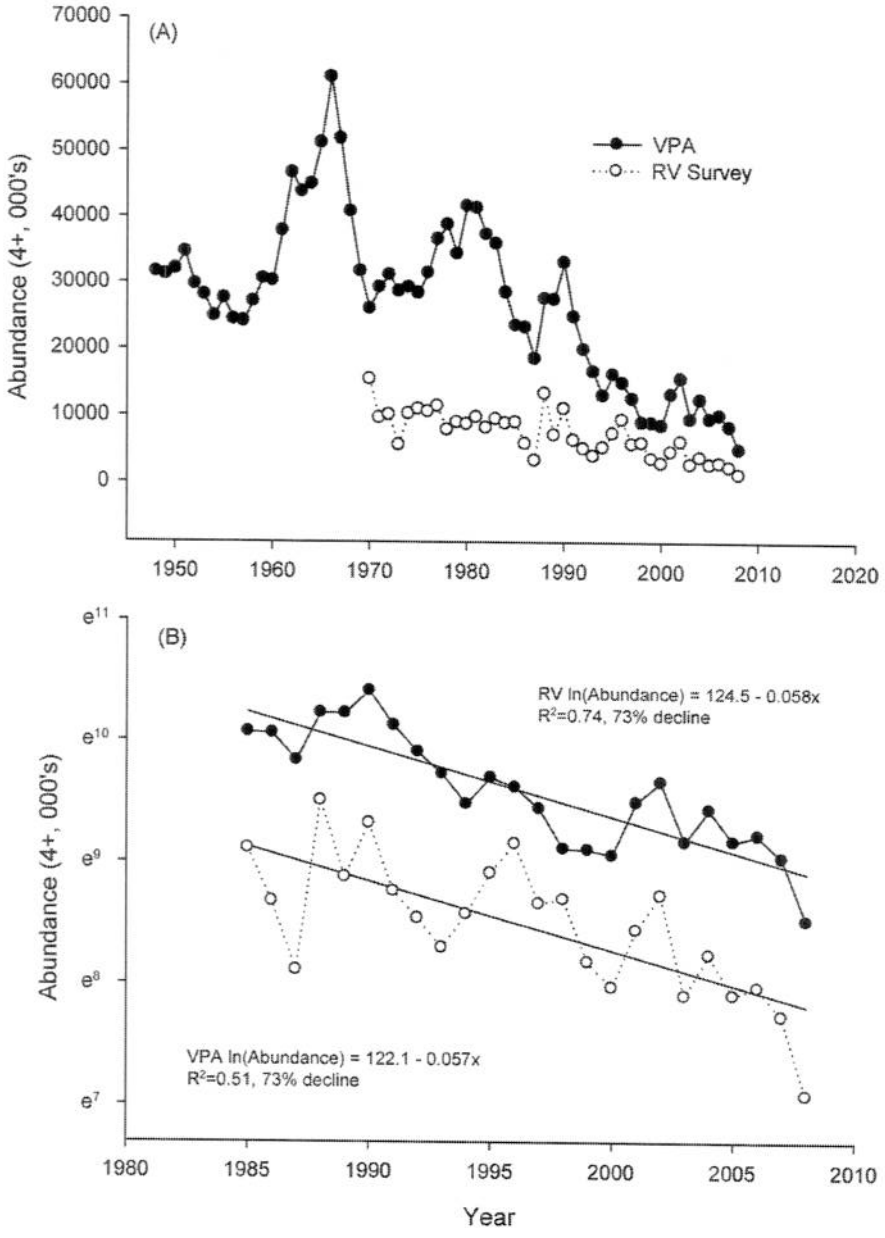

Figure A9. (A)Temporal variation in abundance of mature individuals in the Western Scotian Shelf/Bay of Fundy cod stock (4X). (B) Estimation of three-generation rate of decline. VPA estimates have not been available since 2002 (Clarke *et al.* 2002). Following COSEWIC (2003), presented data for 2002-2008 are an extrapolation based the relationship between VPA abundance and RV survey abundance for the time period 1985 to 2002. This extrapolation is done for the purposes of rate of decline calculation only.

Abundance Trends

The survey and VPA abundance data are those reported by Clark *et al.* (2008), and provided by K.J. Clark, Fisheries and Oceans Canada. Three research vessel surveys are used as indices in the eastern Georges Bank cod assessment: the NMFS spring and fall surveys and the DFO winter survey. The NMFS spring survey is partitioned into two indices to account for a change in the survey trawl in 1982. The earliest year for which survey data are available is 1978 for the U.S. NMFS (National Marine fisheries Service) fall survey and 1986 for DFO's spring survey (Figure A10a). VPA estimates of abundance extend back to 1978 (Figure A10a). Although only the eastern portion of Georges Bank lies within Canadian waters, the abundance trends represent both Canadian and US portions of Georges Bank. The estimated rate of decline for Georges Bank cod differed considerably among the sources of abundance data. Estimated rates of change over three generations ranged between 49% for the VPA data to 4% increase for the survey data (Figure A10b, Table A1). In general, the VPA abundance data reveal a steady decline since the late 1970s, and the survey catch rate data available since the mid-1980s are highly variable (Figure A10a).

Area of Occupancy

Between 1987 and 2007 (the range of the reported data), area of occupancy, remained unchanged at approximately 14,000 km^2 (Worcester *et al.* 2009).

Treats to Recovery

Between 1995 and 2004 fishing mortality varied for this stock from 0.19-0.50 and since 2005 fishing mortality has been below 0.18 with 2007 at 0.13. The source of this mortality is bycatch associated with the haddock fishery. It remains unclear to what degree marine mammal predation is influencing this stock. During the period from 2003-2007, total mortality, estimated following Sinclair (2001), was 0.437 (±0.193SE) or 35% annually (Table A2).

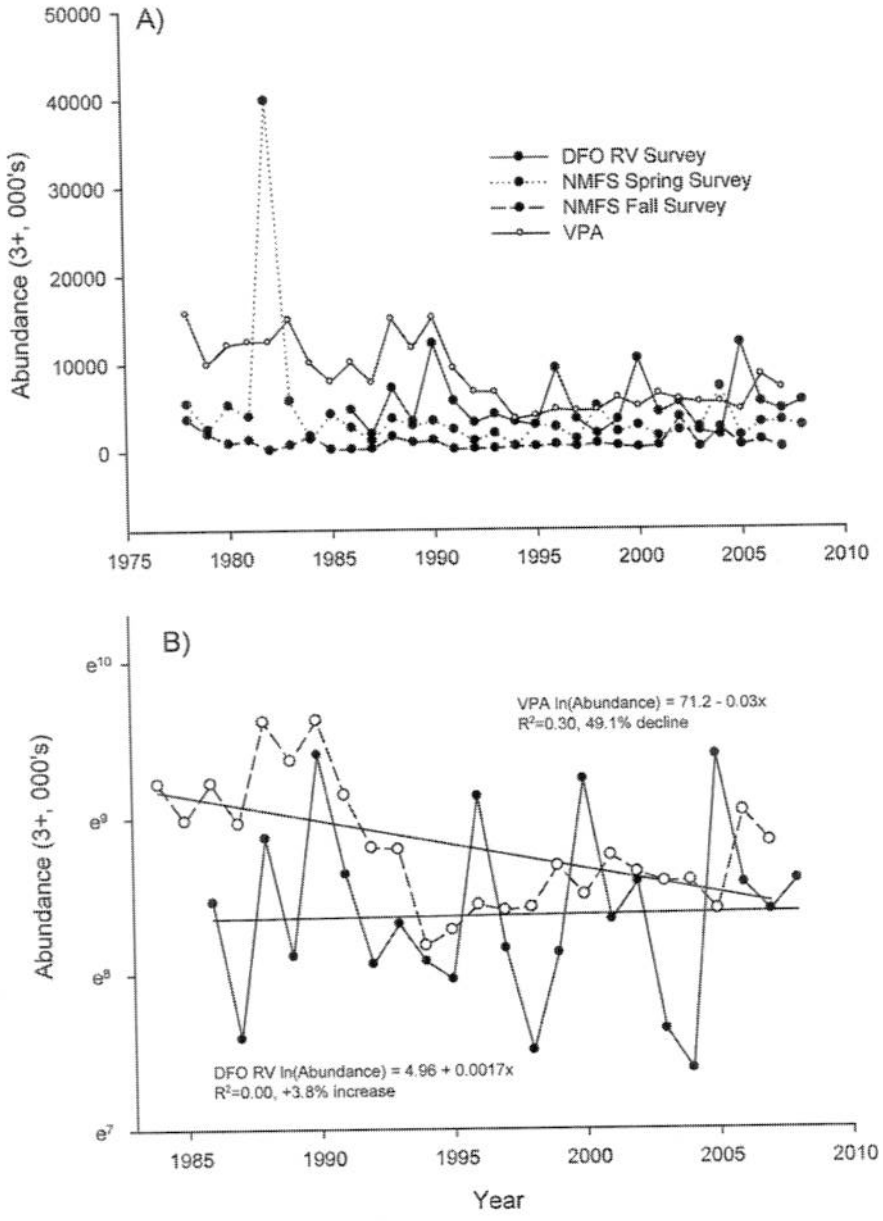

Figure A10. (A)Temporal variation in abundance of mature individuals in the Eastern Georges Bank cod stock ($5Z_{jm}$). (B) Estimation of three-generation rate of decline. Data from Clarke *et al.* 2008 and Worcester *et al.* 2009.