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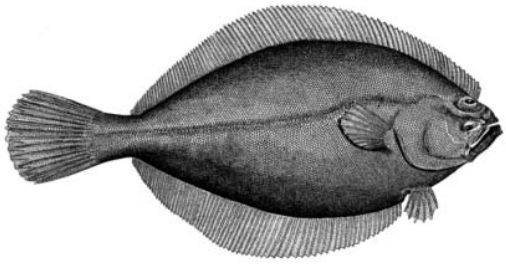
Gulf, Maritimes, and Quebec Regions
Canadian Science Advisory Secretariat
Science Advisory Report 2011/043

# RECOVERY POTENTIAL ASSESSMENT OF THE MARITIME DESIGNATABLE UNIT OF AMERICAN PLAICE (*HIPPOGLOSSOIDES PLATESSOIDES*)



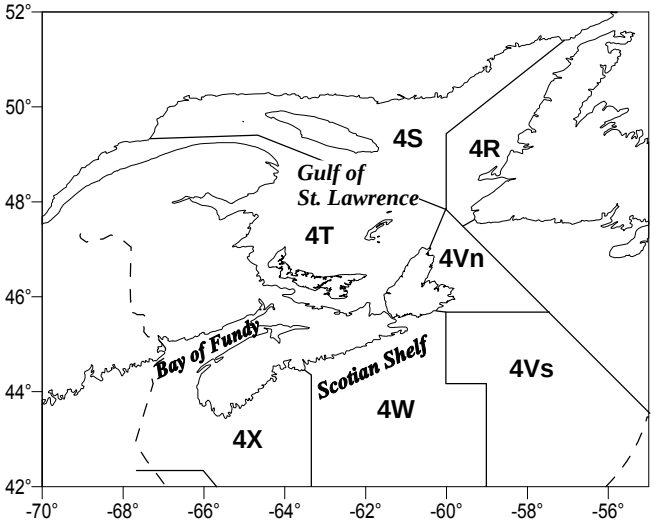



*Figure 1: American Plaice stock management areas 4RS (Northern Gulf of St. Lawrence), 4T (Southern Gulf of St. Lawrence), 4VW (Scotian Shelf) and 4X (Bay of Fundy) of the Maritime Designatable Unit.*

**Context :**

*In 2009, the Maritime Designatable Unit of American Plaice was assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The rationale for this assessment was the significant decline in abundance.*

*A recovery potential assessment (RPA) is conducted by DFO Science to provide the information and scientific advice required to meet various requirements of the Species at Risk Act (SARA), including decisions regarding the listing of Maritime American Plaice under the Act and developing a recovery strategy.*

*This science advisory report describes the status of American Plaice in DFO management areas 4RS (Northern Gulf of St. Lawrence), 4T (Southern Gulf of St. Lawrence), 4VW (Scotian Shelf) and 4X (Bay of Fundy) that constitute the Maritime Designatable Unit. Historic population trajectories and projections are presented. This scientific advice also addresses the major threats to the survival and recovery of Maritime American Plaice and the limiting factors. The measures that can help its recovery are listed.*

## SUMMARY

- The American Plaice *(Hippoglossoides platessoides*) Maritime Designatable Unit (DU) was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April 2009 due to significant declines in stock abundance.

- COSEWIC defined the Maritime DU as encompassing three stocks: the northern Gulf of St. Lawrence (NAFO 4RS), southern Gulf of St. Lawrence (4T), Scotian Shelf and Bay of Fundy (4VWX).

- COSEWIC designated this DU as threatened based on a rate of decline of equal or greater than 30% of the abundance of mature individuals over three generations. None of the plaice stocks in the Maritime DU has recovery targets defined under the precautionary approach framework. Reduction in the decline rate to less than 30% over three generations (the COSEWIC criterion for threatened status) was considered a reference level indicating a reduced risk of extinction.

- This RPA evaluates the risk of attaining the reference level for stock status by projecting the abundance of adult female for each stock and for the DU over 48 years (three generations). These long term projections, rather than predicting future stock status, describe abundance trends under current conditions of productivity and mortality. The probability that these conditions will change over the projected time period is unknown. Most projections have extremely large confidence intervals, reflecting a large degree of uncertainty.

## Northern Gulf of St. Lawrence (NAFO 4RS)

- Trawl surveys in this area since 1985 indicate widely fluctuating abundance but with an increasing trend over time for both the total and adult population.

- A Bayesian state-space model was applied to plaice grouped in three size stages. The model describes an increasing trend during the late 1980's and early 1990's for the first two stages, at lengths <35 cm, followed by relative stability in abundance. Plaice of lengths 35 cm and longer appear to follow an increasing trend since the mid-1990's.

- Natural mortality (M) on 4RS plaice of 35 cm and longer has increased over time, but is lower than other stocks in the Maritime DU (median M of 0.4 for 1999-2009 period).

- The adult female stock of American Plaice in 4RS is projected to increase over the next 48 years (median trend); however, due to uncertainty in the projection, there is an 18% probability of the stock declining to the reference level, even without any harvests.

- The northern Gulf stock of American Plaice is currently exploited at a low level with a small directed fishery in 4R and limited bycatch in other fisheries. Current harvest levels have minimal impact on the projected abundance of female plaice (19% probability of declining to the reference level).

## Southern Gulf of St. Lawrence (NAFO 4T)

- Trawl surveys of 4T, conducted annually since 1971, indicate that the stock attained peak abundance in the late 1970's, but has declined since then to its lowest level in recent years. Similar trends are observed for the total and adult populations.

- An age-based population model (VPA) was applied to this stock. The spawning stock biomass has declined over time to its lowest level in 2009 at 28 thousand tonnes. M has increased over time and is estimated at 0.45 on plaice of both sexes, age 4 years and older.

Year-class strength was particularly high in the 1970's, but has been at a low level for the past 20 years.

- A 48-year projection was done using the VPA model results. Under productivity conditions observed over the past 20 years and with no harvesting, spawning stock numbers (SSN) will decline below the reference level with a 55% probability (59% with harvesting continued at current levels). Assuming that future stock productivity (growth, recruitment and mortality) may encompass conditions observed throughout the 34-year time period of the VPA model, SSN is projected to decline below the reference level with a probability of 31% without harvests (34% with current harvest levels).

- A Bayesian state-space model was applied to plaice grouped in three size stages. All stages have declined over time and are currently at their lowest level. M on plaice of 35 cm and longer, composed mainly of females, has increased over time and is currently greater than 0.6.

- Projections were conducted with the Bayesian 4T model to estimate the female spawning stock numbers (SSN) over 48 years, 2010-2057. Without any exploitation, the median SSN was projected to increase, but with a probability of 36% of declining to below the reference level. The projected SSN was similar with current harvests continuing over the next 48 years (37% probability of declining to the reference level).

- The high rate of natural mortality in recent years appears to be the major cause of the lack of recovery of 4T plaice, as fishing mortality is currently estimated to be very low (mean F=0.03 on age-10+ plaice in 2000's, based on VPA model).

## Scotian Shelf and Bay of Fundy (NAFO 4VWX)

- Annual summer trawl surveys since 1970 in 4VWX, indicate that the stock was most abundant in the 1970's, but has declined since then. Trends in mature abundance depend on assumptions concerning size at maturity after 1985. Maturity was not measured from 1986 to 2009. Sampling in 2010 indicated a decline in the size at maturity relative to 1985, but the extent of the decline is uncertain. Assuming constant size at maturity after 1985, there has been a decline in the abundance of adult plaice. If the size at maturity is assumed to have declined after 1985, the abundance of adult plaice has remained stable.

- A Bayesian state-space model was applied to plaice grouped in stages based on sex and maturity. When size at maturity is assumed to decline after 1985, abundance remained stable for adult females but increased for adult males. When it is assumed that there has been no change in maturity after 1985, abundance declines for adult females and remains stable for adult males. Natural mortality estimates (M) were dependent on the maturity assumptions; however, M increased over time on adult females under either assumption.

- Projections of female spawning stock numbers (SSN) were made over 48 years under three levels of exploitation. Assuming a decline in size at maturity from 1985 to 2009, the probability of SSN declining below the reference level is 25% with no exploitation, 28% at recent exploitation, and 39% with a 750 t harvest. Assuming no decline in size at maturity after 1985, projections were more pessimistic (probabilities of 32%, 36% and 44%, respectively, of declining below the reference level).

## Maritime Designatable Unit

- Combining trawl survey abundance estimates, American Plaice in the Maritime DU have declined by 28% since 1985 and by 39% to 43% for adult plaice since 1987, depending on the maturity assumption in 4VWX. The decline in abundance in the areas surveyed since at least 1971 (NAFO divisions 4T and 4VWX) has been 75% (78%-81% for mature plaice).

- Plaice are widely distributed throughout the Maritime DU. In summer trawl surveys, plaice occupy between 66 and 84% of the area surveyed. The area occupied by the total plaice population appears to be stable or slightly increasing over time; however, the area occupied by the upper size range of adult plaice appears to be in decline.

- The stock projections based on Bayesian state-space models were combined to provide a view of future trends of abundance of female spawning stock numbers. The median SSN will increase over the next 48 years with a 29% probability of plaice in the DU declining to the reference level without a fishery and 36% probability with current harvests.

- For each stock in the Maritime DU, the difference in probability of declining below the reference level without fishing or with current harvests is small (1% to 4%).

# BACKGROUND

## Rationale for Assessment

In 2009, the American Plaice of the Maritime Designatable Unit (DU) was assessed as Threatened by COSEWIC, based on declines in adult abundance of 86% for the Gulf of St. Lawrence and 67% for the Scotian Shelf over the most recent 2.25 generations.

As part of the assessment, scientific information is needed to support the development of social and economic cost assessment scenarios for recovery, to better inform public consultations and to support other entities involved in the decision of adding the species to Schedule 1 of the *Species at Risk Act*. The recovery team also requires this information to develop a recovery strategy, and if necessary, one or more action plans.

## Maritime Designatable Unit

The Maritime Designatable Unit includes two major geographic areas, the Gulf of St. Lawrence and the Scotian Shelf. The former encompasses the entire Gulf of St. Lawrence including areas west of Newfoundland and the lower St. Lawrence estuary (NAFO Divisions 4RS and 4T). The latter includes the entire Scotian Shelf and Bay of Fundy (NAFO Divisions 4VW and 4X). In the absence of a break in the species distribution, stocks within these areas were grouped into a single DU.

## Life-Cycle / Species Biology and Ecology

*Hippoglossoides platessoides*, commonly known as American Plaice, is a member of the Pleuronectidae, or right-eyed flounders. The American Plaice is a benthic marine flatfish with an elongated, strongly laterally compressed body. When the young fish hatch from the egg at or

near the surface they have the 'normal' fish orientation. During development they undergo a metamorphosis resulting in lateral compression and other morphological changes so that they swim on their side and both eyes are on the upper side of the body, facing right. The eyed side of the body is typically red to grayish brown and uniform in colour, whereas the blind side of the body is white. The head is generally small but with a relatively large mouth.

The American Plaice is an arctic-boreal to temperate marine species occurring on both sides of the North Atlantic on the continental shelves of North America and northern Europe. In the western Atlantic, it is found from Baffin Bay and Davis Strait, south to Labrador and the Grand Bank and the Flemish Cap and southwards to the Gulf of Maine and Rhode Island. Throughout their range, their summer distribution is associated with intermediate depths (about 80-250 m) and cold waters (below 0°C to 1.5°C).

American Plaice are considered a cold-water species with reported catches in temperatures from -1.5 to 13$^{o}$C, but they are most numerous within a temperature range from just below zero to around 1.5$^{o}$C. Once settled, adults and juveniles frequently inhabit the same areas over depths ranging from 20 to 700 m, with a preference for depths in the range of 100 to 300 m. Although American Plaice have been found across most bottom types they seem to prefer the firmer sediments and are generally more abundant on substrates of fine sand or gravel.

American Plaice are generally a slow growing and moderately long-lived species that exhibit sexual dimorphism in that the females grow faster and are larger than the males for any given age. Sexual maturity is reached at 4-15 years of age for females and 3-7 years of age for males. American Plaice are group synchronous, batch spawners that may release eggs every few days with the possibility of spawning as many as 10 egg batches. An individual female can spawn for more than a month. Spawning and fertilization of the eggs occur near the bottom from early spring to summer. Eggs are generally 1.5-2.8 mm in diameter. The number of eggs produced by an individual female plaice depends on body size. A 30-cm female can produce as many as 400,000 eggs, while a 60-cm female can produce in excess of 1 million eggs. Once fertilized the eggs become buoyant and float near the surface. Time to hatching is water temperature dependant and has been reported to be 11 to 14 days at around 4$^{o}$C with a hatching size of 4 to 6 mm. After hatching, plaice are pelagic until they reach a minimum length of 18 mm, when metamorphosis occurs and they become benthic.

American Plaice are highly opportunistic feeders throughout their life cycle, feeding on whatever prey items are available in appropriate sizes for ingestion and varying with fish size, locality and season. Hatched larvae are nourished by yolk reserves for the first few days after hatching and then feed on zooplankton, primarily copepods. Adults and juveniles feed on polychaetes, echinoderms, molluscs, crustaceans and fish (capelin, sand lance, other flatfish, etc.). Diet varies with fish size and region. Smaller fish (0 to 9 cm) tend to feed on polychaetes and small crustaceans. By the time plaice are 30 to 50 cm in length, fish comprise upwards of 80% of the diet.

# ASSESSMENT

## Status and Trends

Trends in abundance, biomass and population parameters were assessed by three methods of analysis.

1. Research trawl surveys have been conducted annually during summer months for each component stock of the Maritime DU: since 1970 on the Scotian Shelf-Bay of Fundy (NAFO 4VWX); since 1971 in the southern Gulf (4T) and since 1985 in the northern Gulf (4RS). The catch rates of American Plaice from each survey were standardized to a common research vessel and survey trawl, so that catch rates were comparable between stocks and over time. Population estimates derived from trawl survey catches are unadjusted for the efficiency of the survey trawl (catchability, Q).
2. An age-based population model (Virtual Population Analysis, VPA) was developed for 4T plaice. Stock abundance and biomass estimated by this model were adjusted for an estimated Q. The model was also used to estimate stock parameters, including natural mortality (M).
3. Bayesian state-space models were developed for each stock component based on size or maturity stages. These models simultaneously allow for both process and observation uncertainty, estimating population size and vital rates (e.g. M and recruitment) in stocks for which data exist on the length composition of survey catches and the commercial fishery.

### Abundance

The combined survey abundance of adult plaice in the Maritime DU has averaged approximately 318 million fish over the last three years. The largest population of adult fish is found in the southern Gulf (4T), followed by the northern Gulf of St. Lawrence (4RS) and the Scotian Shelf-Bay of Fundy (4VWX) with, respectively, 162, 86 and 70 million fish (average 2008 to 2010).

In the northern Gulf of St. Lawrence, the survey abundance indices have varied from year to year, but show a slight increasing trend (Figure 2). Similar trends are seen for total and adult biomass. In the southern Gulf, American Plaice were particularly abundant in the 1970's, with peaks in 1977 and 1979, but declined sharply in the early 1980's. The survey population index for 4T plaice increased in 1990 and 1991 due to a moderate improvement in recruitment of year classes of the late 1980's; however, the stock continued to decline after 1991, reaching minimum abundance levels in 2002 and 2009.

In the Scotian Shelf and Bay of Fundy area (4VWX), total survey abundance has fluctuated widely with a declining trend. Trends in adult abundance depend on assumptions concerning size at maturity after 1985. Based on sampling from the 2010 survey, a decline in the size at maturity relative to the period prior to 1986 was noted. If a linear decline in the size at maturity after 1985 is assumed, then there has been no decline in the abundance of adult fish. If no decline in size at maturity is assumed after 1985, then the abundance of adult plaice has declined in the 1990s and 2000s (Figure 2).

The extent of the decline in abundance for the Maritime DU was estimated by regression of the log-transformed combined DU annual survey abundance indices. The total population of plaice in the DU declined by 28% since 1985 (Figure 3) and the abundance of adult plaice declined by

39% since 1987 (43% decline, assuming no change in size at maturity after 1985 in 4VWX). For the stock components of the Maritime DU with the longest time series of survey indices (4T and 4VWX), the total population declined by 75% and the adult plaice abundance declined by 78% since 1971 (81% assuming no change in size at maturity after 1985 in 4VWX).

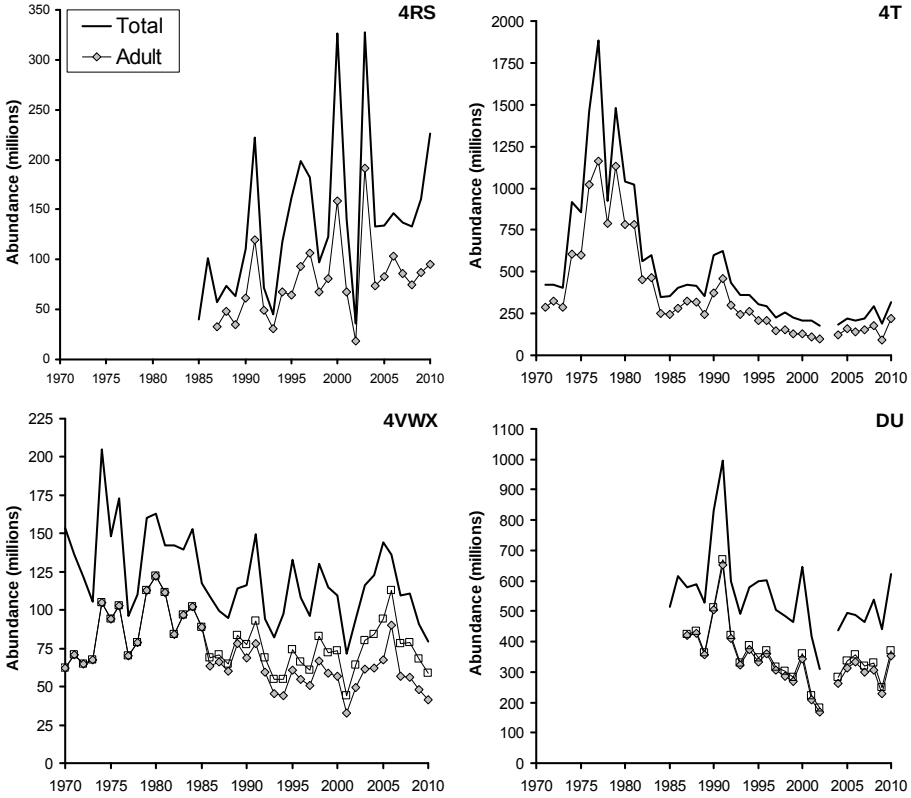



*Figure 2: Total and adult population abundance for American Plaice Maritime Designatable Unit (DU) and for the three stock components, derived from DFO research trawl surveys. Abundances of plaice, adjusted to a common vessel and trawl, are shown for each management area and combined for the DU for 1985-2010 when all areas were surveyed. For the 4VWX stock, the abundance of adult fish was calculated assuming constant length-at-maturity after 1985 (shaded symbols) or declining length-at-maturity from 1985 to 2010 (open symbols).*

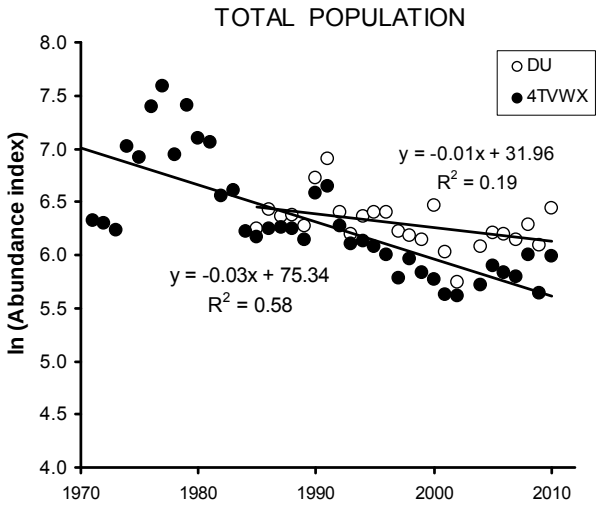



*Figure 3: Trends in log-transformed abundance of American Plaice. Trends in abundance are shown for 4TVWX areas (1971-2010) and for the Maritime DU (1985-2010).*

An age-based population model is available for the 4T plaice stock (Virtual Population Analysis, VPA). This model estimates the abundance at age, beginning at age-4, from 1976 to 2009. This model parameterized natural mortality (M) in 5-year blocks, and for the first two blocks (1976-1980, 1981-1985) M was modelled separately for ages 4-9 and ages 10-20+. This model describes a steep decline from 1976 to the mid-1980's, followed by a brief increase in the early 1990's and a subsequent gradual decline (Figure 4). The stock in 2009 is estimated to be at its lowest level in the time series (population approx. 247 million age-4+), with a spawning stock biomass (SSB) of about 28 thousand tonnes.

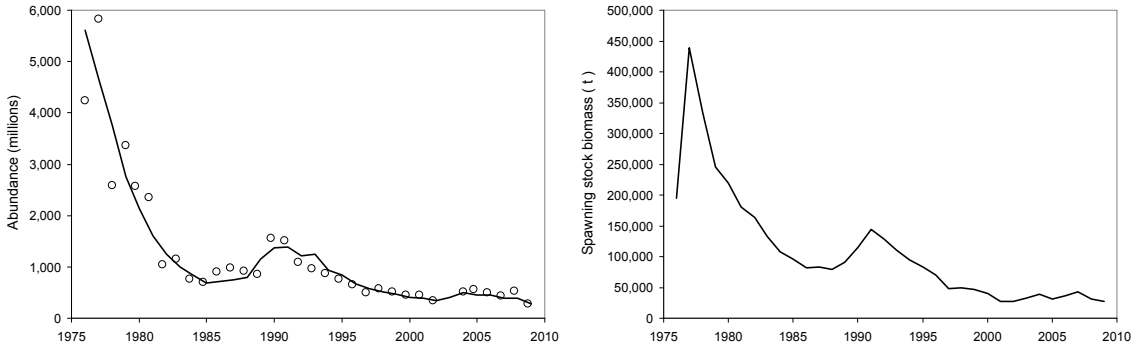



*Figure 4: Trends in abundance of 4T American Plaice (ages 4+) and spawning stock biomass, based on the population model (VPA). The solid line is the model estimate; the points represent the survey abundance values adjusted for catchability of the gear.*

Stage-based models using a Bayesian state-space framework were applied to each stock. These models were structured on the basis of life stages corresponding to length groupings or maturity stages. The Gulf stocks were modeled with three length categories: 19-27 cm equivalent to starting age of 4 years, 28-34 cm length equivalent to a starting age of 8 years, and 35 cm and over. The last stage was composed mainly of female plaice that were fully recruited to the fishery and not subject to discarding at sea. The 4VWX plaice stock was modeled using four stages corresponding to juvenile and mature plaice, by sex. Some

parameters, such as natural mortality and recruitment rate, were allowed to vary by time period, depending on the model. In all cases, the stage-based models fit observed values well.

In the northern Gulf (4RS), the observed values of plaice abundance vary widely and, as a result, the confidence limits are correspondingly wide (Figure 5). The model describes an increasing trend during the late 1980's and early 1990's for the first two stages, at lengths <35 cm, followed by relative stability in abundance. The 4RS plaice of lengths 35 cm and longer appear to follow an increasing trend since the mid-1990's. In the southern Gulf, the abundance of plaice of all stages declined rapidly during the late 1970's and early 1980's, rallied briefly in the early 1990's, then pursued a more gradual decline (Figure 5).

Stage-based models for 4VWX plaice show opposing trends for male and females, depending on their maturity stage (Figure 6). Under the assumption of a declining trend in length at maturity after 1985, the abundance of juveniles and adult females since the early 1980's was relatively stable but there was an increasing trend for mature males (Figure 6).

In recent years (2007-2009), population estimates combined over all stages, have been approximately 340 million animals in 4RS, 470 million animals in 4T, and 260 million animals in 4VWX.

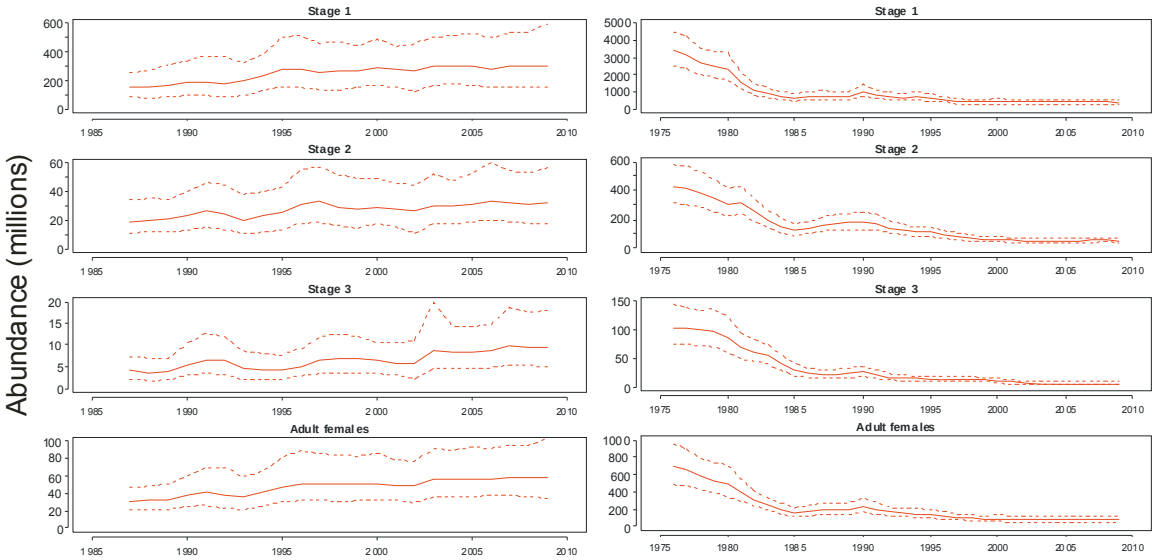



*Figure 5: Median estimates (solid lines) and 95% confidence limits (dashed lines) of plaice abundance, by length stage and for adult females, in NAFO 4RS (left panel) and 4T (right panel) from Bayesian stage-based population models. Stage 1 corresponds to lengths 19-27 cm; stage 2: 28-34 cm; stage 3: 35+ cm.*

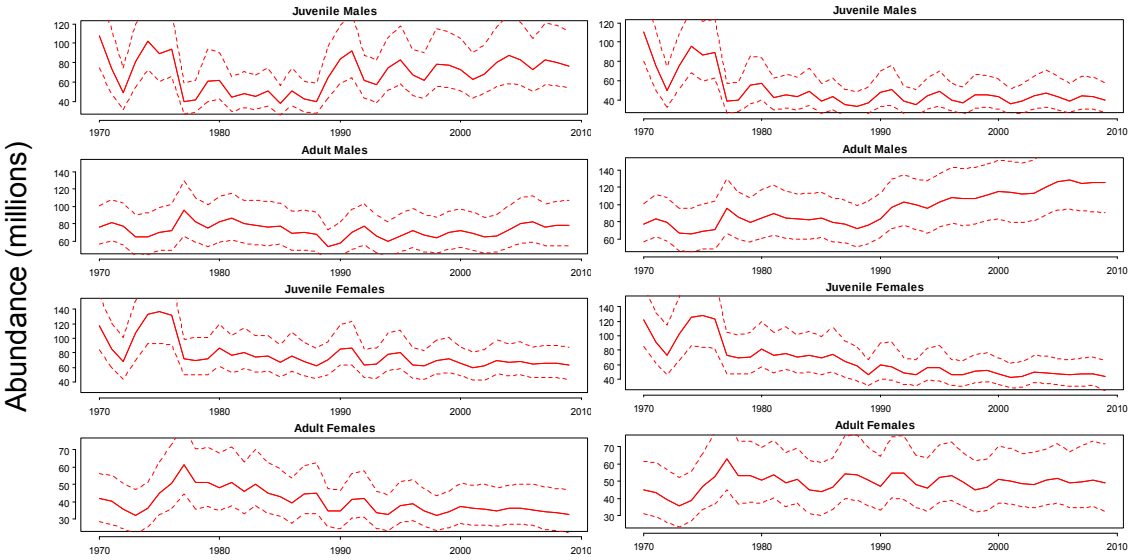



*Figure 6: Median estimates (solid lines) and 95% confidence limits (dashed lines) of plaice abundance in NAFO 4VWX based on Bayesian stage-based population models. Panel at left shows estimates assuming no change in length-at-maturity after 1985; panel at right shows estimates based on length-at-maturity assumed to decline between 1985 and 2010.*

## Distribution and range

Research trawl surveys, conducted in July to September, were used to describe the distribution of American Plaice (Figure 7). Plaice are widely distributed in the Maritime DU. In the Gulf of St. Lawrence, they are absent from the Laurentian and Esquiman channels and sparsely distributed around Anticosti Island. American Plaice are concentrated in the northern Gulf on the west coast of Newfoundland and in the southern Gulf on the Magdalen Shallows, in Chaleur Bay and off the southwestern coast of Cape Breton. Data from strata added later to the northern Gulf survey (not shown in Figure 7) indicate the presence of American Plaice in the lower Estuary, in strata along the west coast of Newfoundland and in Bay St. George. In NAFO 4VWX, plaice appear to be largely absent from the Bay of Fundy and sparsely distributed on the south-western Scotian Shelf. They are most concentrated on Banquereau Bank and Sable Island Bank.

In the 1970s, American Plaice was particularly abundant in the southern Gulf, mainly on the Magdalen Shallows, in Chaleur Bay and off the south-western coast of Cape Breton. The abundance has decreased over time, particularly on the Magdalen Shallows and western parts of 4T. In the northern Gulf, the distribution of plaice has broadened over the 1985 -2010 period and has become more concentrated off the west coast of Newfoundland and in the Anticosti channel. On the Scotian Shelf, when the stock was at its highest abundance during the 1970s, it was concentrated on the northeastern shelf on Banquereau Bank and Sable Island Bank. The stock has remained concentrated in these areas despite declines in abundance over the past three decades.

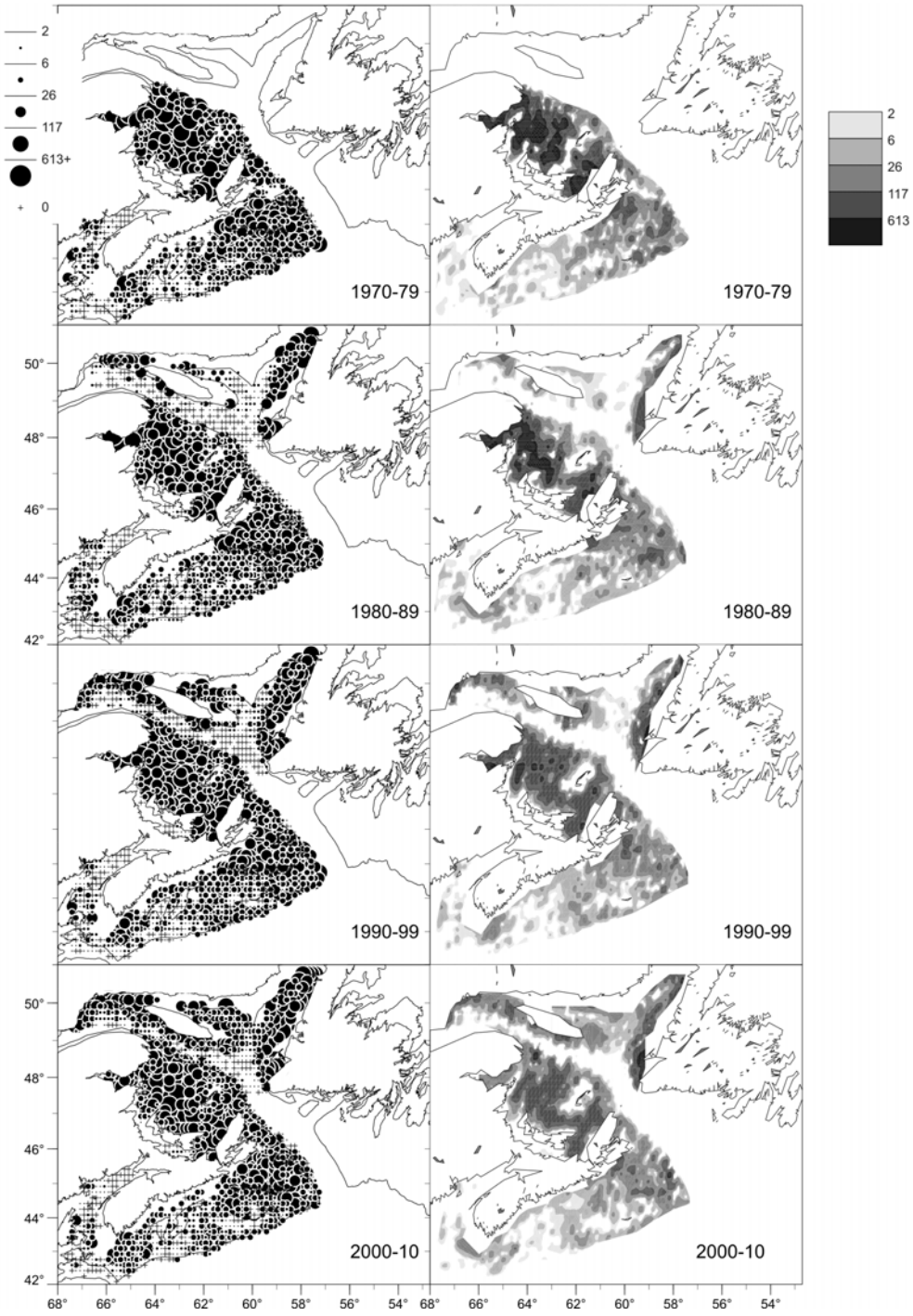



*Figure 7: Distribution of all size groups of American Plaice (standardized numbers caught) based on DFO bottom trawl surveys. Catch rates for all surveys were standardized to a common vessel and survey trawl. Catches were averaged over years within 10-minute squares (left panel) or depicted by Delaunay triangles (right panel). Scaling was determined by the 10, 25, 50, 75 and 95$^{th}$ percentiles of non-zero catches over all years. Note that the northern Gulf of St. Lawrence survey started in 1985.*

The area occupied by American Plaice was calculated from trawl survey catches using a Design-Weighted Area Occupied (DWAO) index. These analyses were based on strata that

were sampled consistently over all years in each survey. DWAO was calculated for the total population (all sizes) and for the upper range of mature individuals (the length at 50% maturity for Gulf stocks; 32 cm+ for Scotian Shelf plaice). The combined area occupied is presented for the Maritime DU, an area of 320,000 km$^2$ sampled since 1985, and for 4T and 4VWX, an area of 232,000 km$^2$ sampled since 1971. From 1971-2010, the plaice population has occupied between 72 and 86% of the area surveyed in 4TVWX, while DWAO in the Maritime DU since 1985 has varied between 66 and 84% of the area surveyed. The area occupied by the total population appears stable over time in 4TVWX, whereas there is an increasing trend for the DU (Figure 8). However, in both series, particularly in 4TVWX, the area occupied by larger, mature plaice is in decline.

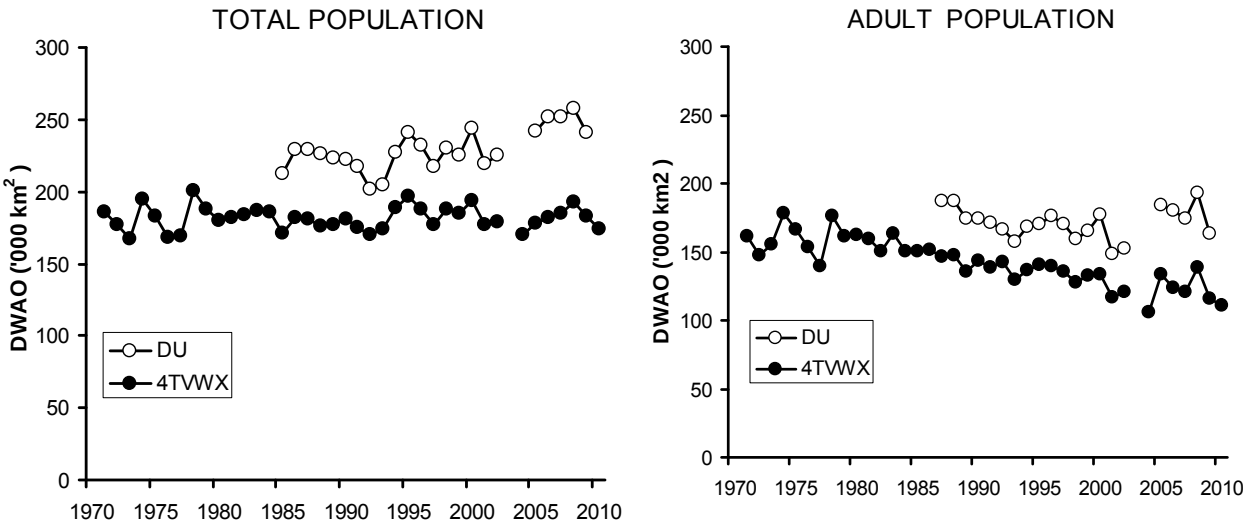



*Figure 8: Design-Weighted Area Occupied (DWAO) for total (left panel) and adult (right panel) components of American Plaice.*

## Life History Parameters

### *Maturity*

The size and age of maturity are assessed from visual examination of gonads in research trawl surveys of the southern Gulf and Scotian Shelf (4VWX). Maturity data were obtained from the southern Gulf since 1997 and from the summer Scotian Shelf surveys from 1970 to 1985 and in 2010. No observations on plaice maturity have been made from the northern Gulf surveys.

Survey data for the southern Gulf since 1997 indicate a median age and size at maturity of 6.1 years and 26 cm for females and 3.7 years and 19 cm for males. There is no clear indication from the surveys of a change in the size or age of maturity over this period. In 1960 and 1961 surveys of the southern Gulf, the length at 50% maturity (L50) of female plaice was reported as 41 cm and the age at 50% maturity (A50) was 10 years, indicating a strong decline in the age and size of maturity over the time series.

The 4VWX survey results indicate a decline in the size and age at maturity of plaice between 1970 and 1985. No maturity data are available from 1986 to 2009. Estimates of age and size at maturity from sampling in 2010 indicated further declines in age and size at maturity for females

and for size at maturity for males. These results, obtained after a 25-year gap in sampling, should be regarded with caution.

| **4VWX** | Range of sizes (cm) | | Mean age (years) | |
|---|---|---|---|---|
| | Male L50 | Female L50 | Male A50 | Female A50 |
| 1970-1976 | 23-26 | 29-33 | 4.8 | 6.9 |
| 1977-1985 | 21-24 | 26-29 | 3.8 | 5.3 |
| 2010 | 18 | 21 | 3.5 | 4.3 |

Data from 2010 indicate a decline in the size at maturity; however, the results are unclear as to the degree of change. The data from 2010 suggest a stronger decline in size at maturity for females than for males. The age at maturity for 4VWX plaice has declined similarly. Other data suggest that the stock has undergone a long term change in maturity, particularly for females. Reports indicate that female maturity from 1959-1968 occurred at lengths of 33-41 cm and ages of 10.5 to 11.5 years.

*Recruitment*

Age-based recruitment estimates in the Maritime DU are currently only available for the southern Gulf for which trawl surveys have compiled the population age structure since 1971. The 4T survey data indicate that year classes originating from the early 1970s were particularly strong. An age-structured population model (VPA) estimated the abundance of year classes as 4-year-old recruits (Figure 9). The earliest year class estimated in this model (1972) was the most abundant, followed by a modest increase in the abundance of plaice born in the late 1980's. Year-class strength has been at its lowest level over the past two decades.

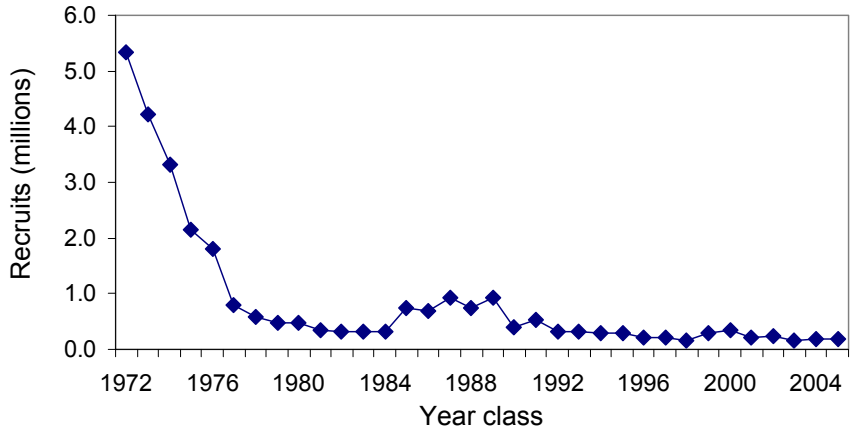



*Figure 9: Year-class abundance as age-4 recruits, estimated from a population model (VPA) for 4T plaice.*

*Fecundity*

The fecundity of American Plaice has not been studied in the Maritime DU. The number of eggs produced by female plaice typically increases with body size, a 30-cm female producing as many as 400,000 eggs and a 60-cm female may spawn in excess of 1 million eggs. In Newfoundland waters, the fecundity of plaice has declined for three stocks over the past four decades.

*Mortality*

Instantaneous total mortality (Z) was estimated from research survey catch-at-age data for 4T American Plaice. Using a regression model that takes into account variation in year-class strength, Z was estimated by 5-year blocks over ages 8-20 (Figure 10). In the early 1970's when the plaice stock was growing, Z was estimated at approximately 0.2. It increased to a peak in the late 1970's, declined and peaked again in the early to mid-1990's. The most recent period in this analysis (2005-2009) corresponds with a period of low plaice catches in 4T. Current Z is estimated at approximately 0.54, slightly above the long-term average since 1971 of 0.51.

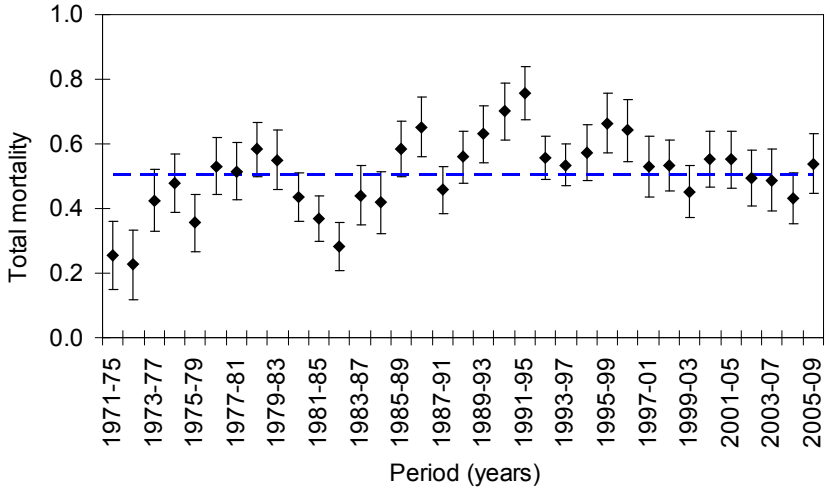



*Figure 10: Total mortality (Z) (with 95% confidence limits) of 4T American Plaice between 8 and 20 years-of-age, based on multiplicative models of survey catch data in 5-year blocks. The horizontal dashed line is the 1971-2009 average Z.*

The age-based VPA population model for 4T plaice estimated natural mortality (M) in seven 5-year blocks, beginning with 1976-1980 and ending with 2006-2009. For age 4-9 plaice, M was estimated to be very high in the first 10 years of the time series (at 0.6-0.9). Discarding and misreporting of catches of small plaice in mobile gear fisheries may have contributed to these estimates of high M. From 1976-1985, M was estimated at 0.2-0.3 for age-10 and older plaice. M on all ages peaked in the early 1990's at approximately 0.6 and was estimated for the 2006-2009 to be at 0.45. The instantaneous fishing mortality (F) is estimated to have been low throughout most of the 2000's (mean F on plaice of 10 years of age and older was 0.03). Most of the mortality on the 4T plaice stock during the 2000's was due to natural mortality.

Stage-based models on the stock components of the Maritime DU provided estimates of the rate of exploitation. With recent declines of harvests on each stock, exploitation rates through most of the 2000's have been less than 10% on 35 cm and larger plaice in the Gulf and Scotian-Shelf stocks, a harvest level that corresponds to F of approximately 0.1 or less. In 2008 and 2009, the exploitation rate on targeted plaice (35 cm and large or adults) has been less than 6% for all stocks in the Maritime DU.

Stage-based models also estimated natural mortality (M) on each stock component of the Maritime DU. In these models, M may be confounded with the estimation of other model parameters, particularly the parameter defining the probability that plaice transfer from one stage to the next. As such, M estimated by these models provides an indication of the trend in M over time and of the magnitude of M relative to fishing mortality. For each stock, M on the

largest group of plaice in the Gulf stocks and adult female plaice in 4VWX showed an increasing trend over time (Figure 11). For Gulf stocks, M on 35 cm and larger plaice was lower in 4RS (median M at 0.42 in the 1999-2009 period) than in 4T (median M at 0.63-0.68 in the 2001-2009 period). In 4VWX, estimated juvenile M increased in the 1977-1988 period. For adults in 4VWX, no trend in M is evident for males, but females show an increasing trend over the entire time period.

## Recovery Targets

According to DFO guidelines, the precautionary approach (PA) framework would be a starting point to elaborate recovery targets for species or stocks considered under the Species at Risk Act (DFO 2005). However, the PA has not been applied yet to any of the American Plaice stocks in the Maritime DU. In the absence of a PA framework the guidelines state that direct estimates of total population size and total range occupied may be used to specify recovery targets and to focus recovery efforts.

Given the broad distribution and the lack of change in the distribution of American Plaice in the Maritime DU, a measure of the area occupied would not be a good target to evaluate recovery. Thus, the abundance of adult female plaice was chosen as the indicator of the state of the population.

The Terms of Reference for the Recovery Potential Assessment require an evaluation of the probability of reaching a level where individual stocks and the DU no longer meet COSEWIC's listing criteria for threatened status. From a COSEWIC perspective, a species is considered threatened when the rate of decline in the total number of mature individuals is equal or greater than 30% over three generations, assuming that the causes of the decline have not ceased or are unknown. A generation time (G) is defined relative to the population's pre-fished state on the basis of the age at 50% maturity (A50) and natural mortality (M) ($G = A50 + M^{-1}$). Assuming a pre-exploited A50 of 11 years and M of 0.2, a generation time for American Plaice is 16 years. As a result, projections were made on three generations, or 48 years. Reduction in the decline rate to less than 30% over three generations might be considered an indication of a reduced risk of extinction.

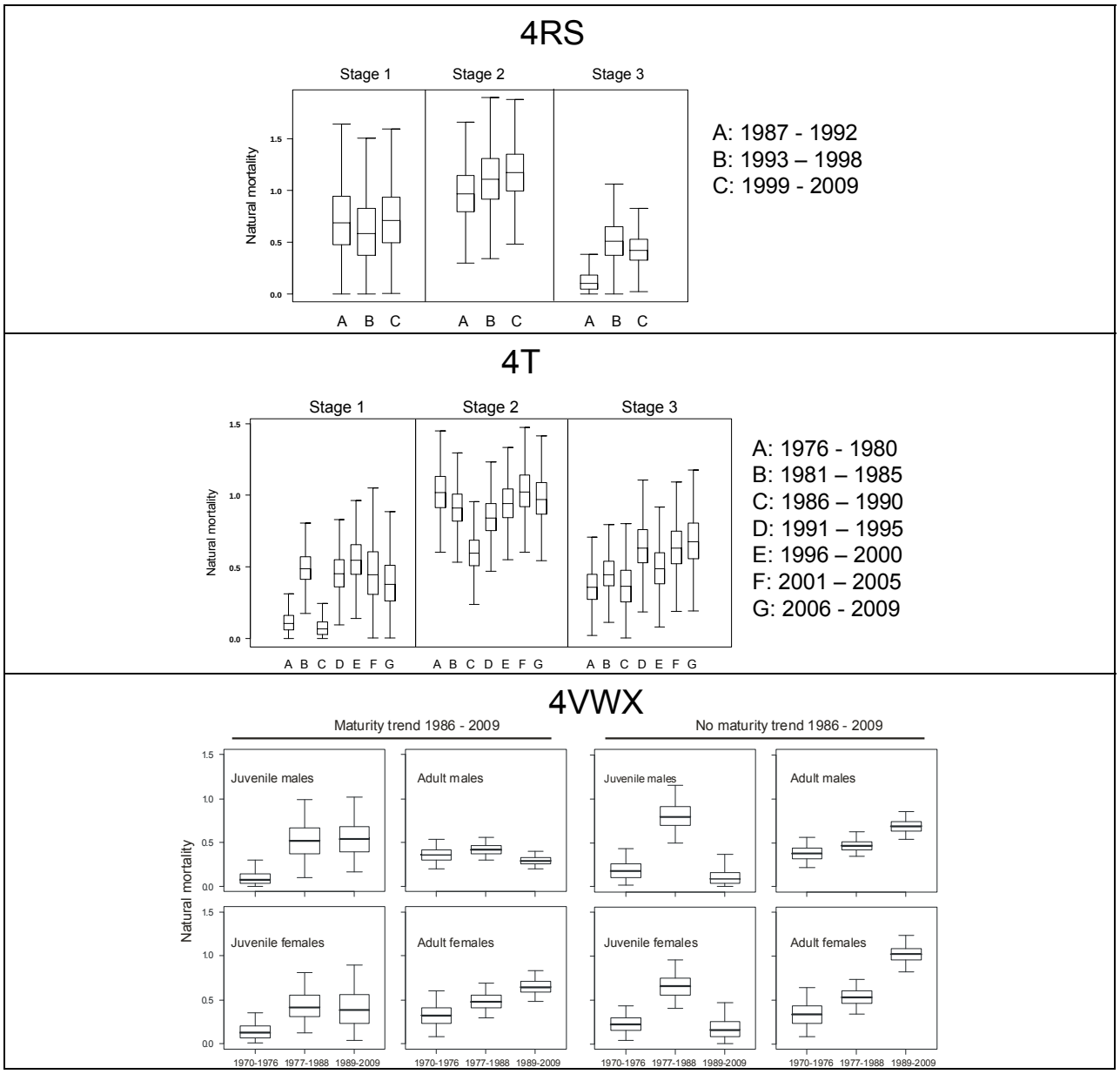



*Figure 11: Natural mortality (M) estimates from Bayesian stage-based models. Each estimate resulted from 5,000 iterations of the model, with boxes representing the inter-quartile range, the horizontal line in each box representing the median estimate and vertical lines extending to the 95% confidence limits. For 4RS and 4T stocks, stages 1-3 represent plaice length groups 19-27 cm, 28-34 cm, 35 cm and longer. M was estimated in time periods, denoted by letters for 4RST stocks. For the 4VWX stock, M was estimated by sex and maturity stage assuming a declining trend in size at maturity after 1985 or constant size at maturity (no maturity trend).*

## Projected Trajectory Given Current Parameters

Two procedures were used to conduct projections. Spawning stock biomass and numbers were projected for 4T plaice on the basis of stock parameters estimated from the age-based VPA model. Alternatively, projections were conducted on each stock using the Bayesian stage-based models. The projected female spawning population for the Maritime DU was generated by combining results from stage-based models of each stock component.

Two projection scenarios were considered: all human exploitation was removed ($F_0$); exploitation from 2010 to 2057 was held at its most recent level, the average of annual harvests since 2007 ($F_{current}$).

*4RS*

Based on the Bayesian stage-based model, with M estimated in three time periods, female spawning stock numbers (SSN) were projected to grow slightly and then stabilize for both $F_0$ and $F_{current}$ scenarios. The median SSN was projected to grow from 60 milliion plaice in 2009 to 68 million plaice by 2057 (Figure 12). Maintaining current harvest levels had little effect on the growth of the SSN. The probability of a decline of 30% or more relative to 2009 over three generations was 18% under F0 and 19% assuming current levels of harvest. This result is consistent with the low level of exploitation that was estimated for recent years (less than 5% for most of the 2000's).

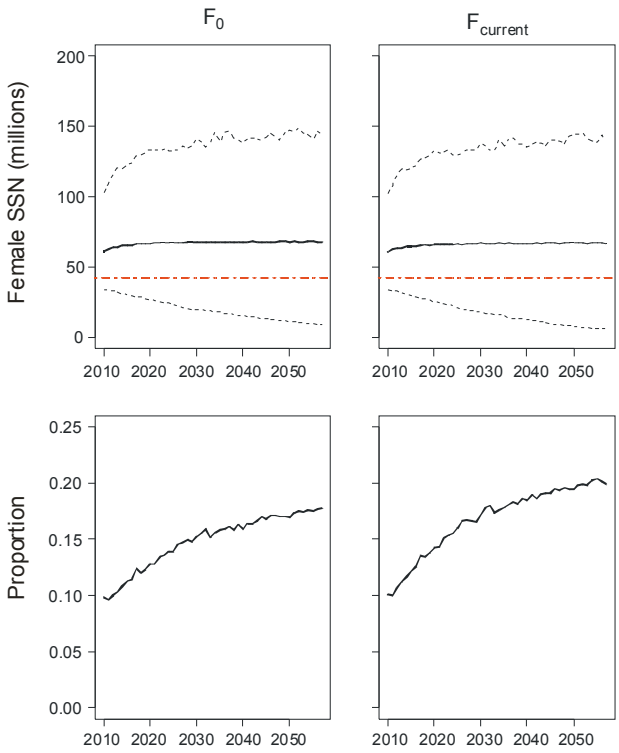



*Figure 12: Projected NAFO 4RS female plaice spawning stock numbers (SSN) over 48 years (2010-2057) without commercial fishing ($F_0$) and at recent harvests ($F_{current}$). In the upper graphs, the solid line represents the median female SSN and dotted lines represent the 95% confidence limits. The horizontal dashed line indicates the reference level of 70% of the 2009 SSN. The lower graphs indicate the proportion of annual estimates of female SSN that fall below the reference level.*

*4T*

Using the results of the age-based VPA model for 4T plaice, projections were made that took into account uncertainty in the estimated abundance at age, estimated M, weights-at-age and variability in the stock-recruit relationship. The projections were made assuming two levels of future productivity: levels equivalent to those observed over the past 20 years (current productivity assumption); future productivity levels returning to similar conditions observed at an equivalent time period in the past (expanding window assumption). The 1990-2009 period formed the basis for the current productivity assumption; the alternative drew on conditions observed since 1976.

Without any fishing and under current levels of productivity, the spawning stock biomass (SSB) and spawning stock numbers (SSN) are projected to decline steadily with a probability of 58% for SSB and 55% for SSN of a decline into 2057 of 30% or more (Figure 13 showing SSN). The expanding window assumption resulted in a projected spawning stock that was relatively stable for the first 10 years of the projection, but declined as productivity conditions return to higher M values observed in the 1990's (Figure 13). The stock gradually improves as conditions return to lower M, higher weights at age and improved recruitment levels observed in the 1970's and 1980's (Figure 13).

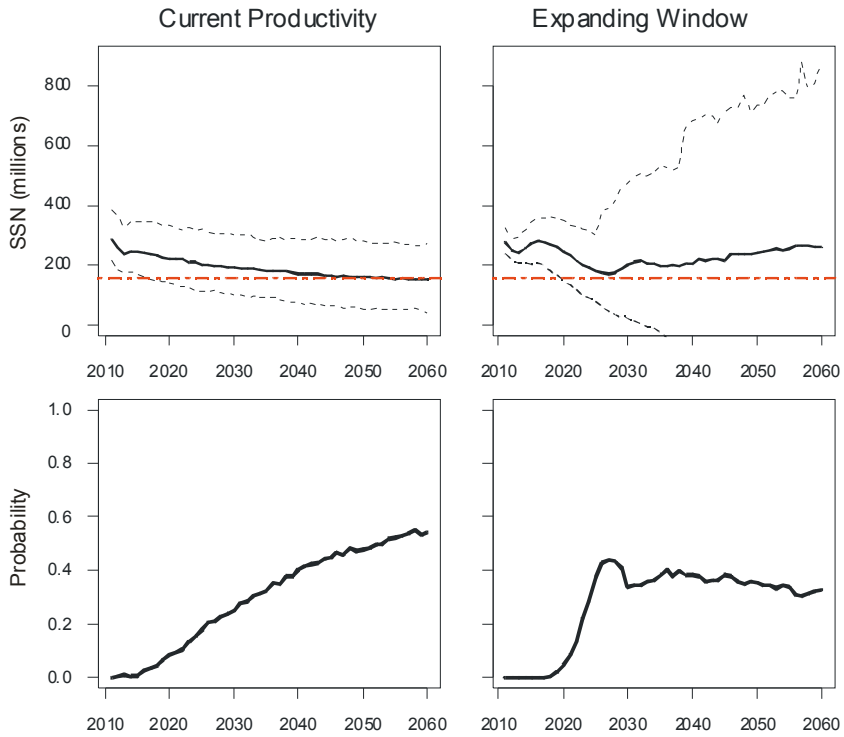



*Figure 13: Projected spawner abundance (SSN) of 4T American Plaice and the probability that SSN will be below 70% of SSN in 2009. In the upper graphs, the solid line is the median projection and the dotted lines are the 95% confidence limits. The horizontal dashed line shows 70% of the 2009 SSN.*

Similar projections were made with current fishing levels (F=0.067 on ages 16+, fully recruited, averaged over 2005-2009). Current fishing levels had little effect on the projected changes in SSB and SSN relative to the $F_0$ scenario. The probability of SSN declining by 30% or more was 59% under current productivity and 34% with an expanding window of productivity.

Projections were also made for the female SSN of 4T using the Bayesian stage-based model. Without any fishing and under current levels of productivity, the median female SSN of about 84 million fish in 2009, would increase over the following 48 years (by 2057) to 110 million animals (Figure 14). Still, there would be a 36% probability of the stock declining by 30% or more into 2057. With current harvests maintained over the next 48 years ($F_{current}$), there would be little effect on female SSN. The median estimate of female SSN is projected to be 103 million plaice and the probability of dropping below the reference level would be 37% by 2057.

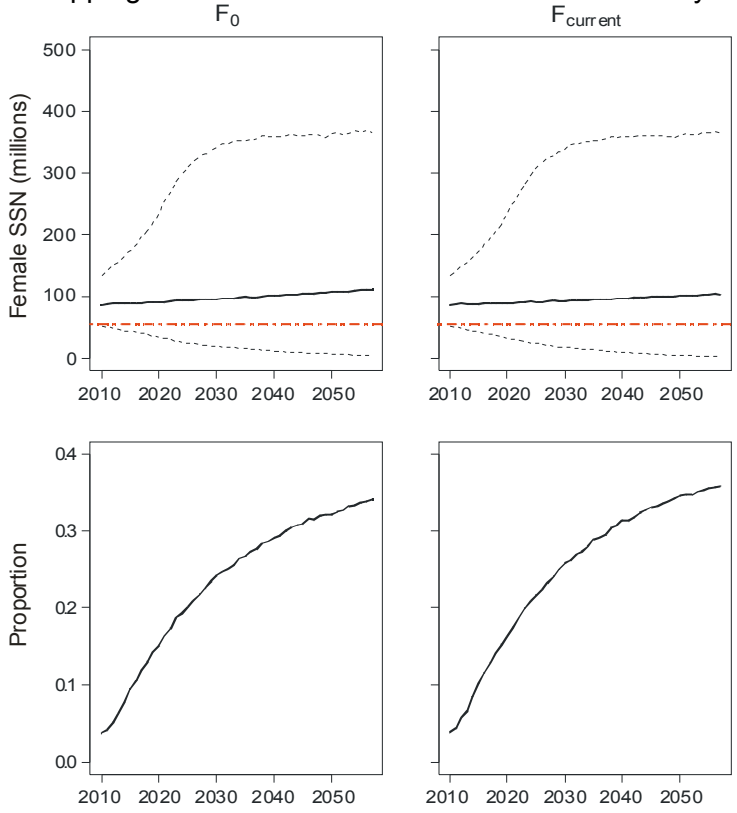



*Figure 14: Projected NAFO 4T female plaice spawning stock numbers (SSN) over 48 years (2010-2057) without commercial fishing ($F_0$) and at recent harvests ($F_{current}$). In the two upper graphs, the solid line represents the median female SSN and dotted lines represent the 95% confidence limits. The horizontal dashed line indicates 70% of the 2009 SSN. The lower graphs indicate the proportion of annual estimates of female SSN that fall below 70% of the 2009 SSN.*

*4VWX*

The Bayesian stage-based model formed the basis for projecting the abundance of female SSN in 4VWX. Without any commercial exploitation and assuming that the size at maturity declined after 1985, the median female SSN increased from approximately 48 million in 2009 to 53 million in 2057 and there was a 25% probability of the SSN declining by 30% or more (Figure 15). Maintaining recent harvests over the next 48 years (still assuming a change in maturity) resulted in the female SSN attaining 52 million by 2057 and a 28% probability of a 30% decrease in SSN relative to 2009. Assuming no change in maturity had an effect on the projected growth of female SSN. Without any harvests, female SSN declined to 32 million fish by 2057 and there was a 32% probability of the SSN declining by 30% or more. Maintaining recent harvests until 2057, the median female SSN would decline to 30 million, with a 36% probability of a decline in SSN of 30% or more.

An additional scenario was explored wherein plaice were exploited at one quarter the existing 4VWX flatfish TAC, i.e. an annual harvest of 750 tonnes. Projected over 48 years and assuming a decline in the size at maturity after 1985, the median female SSN would decline to 44 million plaice by 2057 with a 39% probability of declining by 30% or more from the 2009 SSN. If the size at maturity is assumed to remain constant after 1985, the median female SSN would decline to 26 million by 2057, with a 44% probability of the stock declining to below 70% of the 2009 SSN.

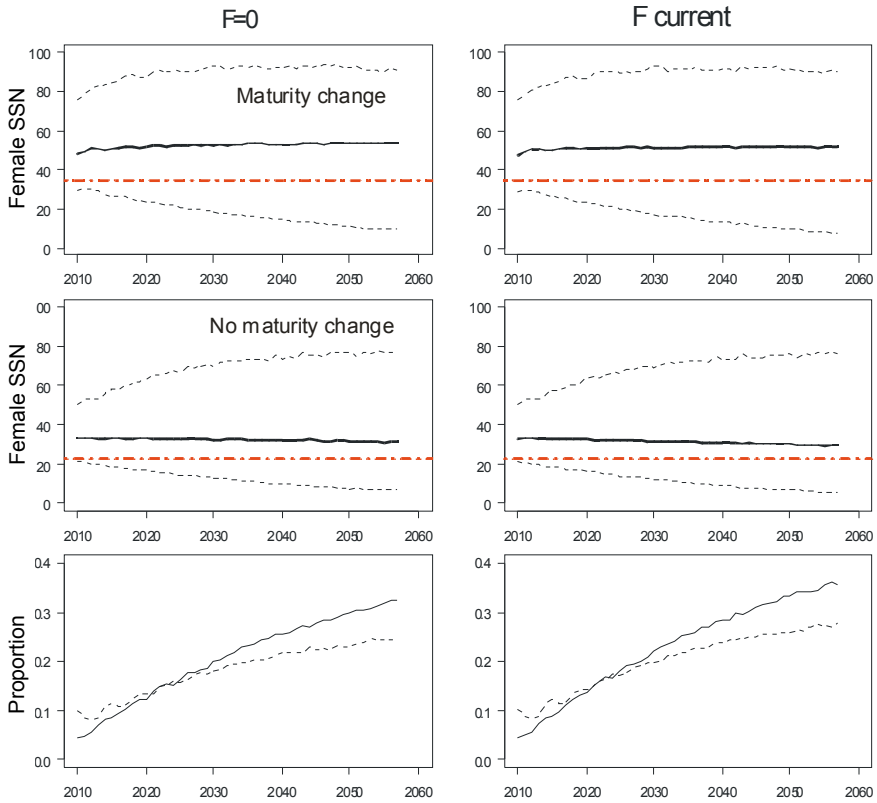



*Figure 15: Projected NAFO 4VWX female plaice spawning stock numbers (SSN, millions) over 48 years (2010-2057) without commercial fishing ($F_0$) and at recent harvests ($F_{current}$). In graphs depicting female SSN, the solid lines represent the median female SSN, the dotted lines represent the 95% confidence limits and the horizontal dashed lines indicates 70% of SSN in 2009. The upper two graphs project SSN assuming that the size at maturity of plaice declined after 1985; the middle graphs show projections assuming no change in the size at maturity after 1985. The two bottom graphs indicate the proportion of annual estimates of female SSN that fall below 70% of the 2009 SSN, assuming declining size at maturity (dashed lines) and no change in size at maturity (solid lines).*

### *Maritime DU*

The projected population estimates of female spawners (SSN) were combined to obtain a view of the trend within the Maritime DU over the next 48 years, 2010-2057. Assuming no harvests over this time period, the median projected SSN in the Maritime DU will increase from approximately 170 million plaice in 2009 to about 276 million in 2057 (Figure 16). As with the component stocks, the confidence limits on the projected SSN are large and increase over time. By 2057, the probability that plaice SSN will decline to less than 70% of the 2009 abundance is about 29%. At current levels of harvesting, the SSN will reach about 260 million fish by 2057, with a probability of declining by 30% or more of approximately 36% (Figure 16).

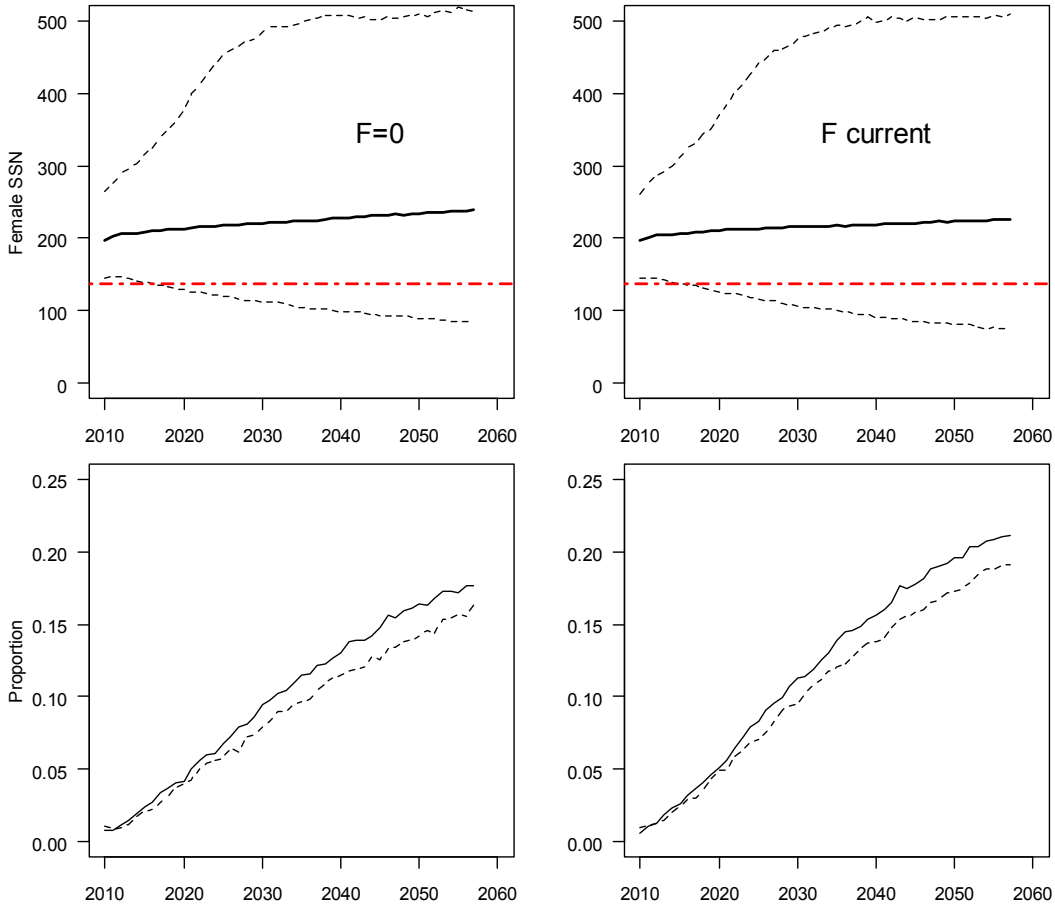



*Figure 16: Projected female plaice spawning stock numbers (SSN, millions) in the Maritime DU over 48 years (2010-2057) without commercial fishing ($F_0$) and at recent harvests ($F_{current}$). In the two upper graphs, the solid lines represent the median female SSN and dotted lines represent the 95% confidence limits, assuming that the size at maturity in the 4VWX stock declined after 1985. The horizontal dashed line indicates the value of 70% of SSN in 2009. The lower graphs indicate the proportion of annual estimates of female SSN that fall below 70% of 2009 SSN assuming a decline in size at maturity for 4VWX plaice after 1985 (dashed line) and no change in maturity after 1985 in 4VWX (solid line).*

# Habitat

## Habitat requirements

In general, knowledge on habitat requirements for American Plaice remains limited. It is not known how the biological function(s) that specific habitat(s) provide to the species varies with the state or amount of the habitat. However, the availability of physical habitat does not appear to be a limiting factor for American Plaice abundance in the Gulf of St. Lawrence, Scotian Shelf and Bay of Fundy.

### *Residence*

The *Species at Risk Act* 2(1) defines a residences as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals

during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating".

Maritime American Plaice do not have any known dwelling-place similar to a den or nest during any part of their life-cycle. Therefore, the concept of residence does not apply.

*Spawning grounds*

Spawning of American Plaice generally occurs throughout its range, but certain areas are associated with much greater spawning activity, perhaps simply because of a greater abundance of fish rather than selection of spawning grounds. In the southern Gulf of St. Lawrence, the major spawning grounds appear to be east and west of the Magdalen Shallows and extending into Chaleur Bay. Specific spawning areas in the northern Gulf have not been identified. However, American Plaice eggs and larvae have been found on the west coast of Newfoundland, around Anticosti Island, in the north-western Gulf and in the lower estuary, suggesting that spawning may occur in these areas. On the Scotian Shelf, the major spawning component is on Banquereau Bank but spawning activity appears continuous over Western Bank and also occurs to a smaller extent over Browns Bank. Southern Gulf plaice migrate in autumn to deeper channel water where they occupy warmer water than in summer, returning to spawn in April and May. Elsewhere adults do not appear to undergo large spawning migrations but may move into slightly deeper, warmer waters in winter. Due to steep shelf banks, this requires little lateral movement in most areas.

*Eggs and larvae*

The eggs and larvae are pelagic, so habitat requirements are probably primarily related to temperature and prey availability. Increased temperature results in increased larval development rate, which could lead to less time spent at the highly vulnerable larval stage. However, excessive temperature (≥14°C) results in mortality during the egg stage. The primary prey items during the larval stage are diatoms, copepods and other zooplankton.

*Juvenile and adult*

Juvenile and adult American Plaice are benthic and cryptically coloured. They regularly burrow in the sediment as a means of predator avoidance, and possibly concealment from prey as ambush predators. Thus sediment type is likely an important habitat consideration and might be particularly important for juvenile flatfish. Small juvenile fish are likely only capable of burying in finer sediments. Juveniles on the Grand Bank have been found in highest numbers on sand/shell hash sediments and less abundant on (or in some cases almost absent from) mud, muddy sand, rock/sand and boulder/rock.

The wide range of environmental conditions from which adult American Plaice have been caught suggests the species is a generalist without tightly constrained habitat requirements. Adults, like juveniles, commonly bury themselves in sediment, presumably to avoid predators. Under laboratory conditions plaice have demonstrated a clear preference for gravely sand particles over coarser gravel substrate, continuing to choose the preferred substrate even in temperatures outside of their preference. Larger flatfish can bury themselves in larger sediment particles than smaller individuals. Sediment preference, however, might vary spatially. For example, in the deeper western side of the Gulf of St. Lawrence, plaice have been caught in high numbers from soft mud. It is also possible that the sediment type that individuals are

collected from might better reflect the preferred habitat of prey animals rather than the fish being studied.

In the southern Gulf of St. Lawrence, American Plaice densities in September surveys peaked at intermediate depths of 70-90 m with little variation due to age or year. On the Scotian Shelf, preferred depths of 55-128 m were reported. Seasonal changes in depth preference are thought to be linked to temperature selection, with fish moving into deeper and warmer waters in winter.

In the southern Gulf, it was found that American Plaice in September trawl surveys tend to select cold temperatures relative to those available. Temperature selection did not vary much with age, but female plaice tended to occupy warmer water than male plaice. Similar results were found for northern Gulf and Newfoundland populations, with average occupied temperatures up to the early 1990s of -0.11°C on the Grand Bank, 0.12°C on St. Pierre Bank and 1.34°C in the southern Gulf. Preferred temperature is reported to be -0.5°C to 2.5°C in the Newfoundland and Labrador area and 1 to 4°C on the Scotian Shelf, with fish to the south having a higher temperature preference. It was reported that plaice in captivity had a wide temperature tolerance (-1.4 to 15°C) but that they did not feed and lost weight at very cold temperatures. Plaice on the Grand Bank have been found to move out of areas of colder water (≤ -1.2°C) under some circumstances, resulting in what seems to be a seasonal distribution pattern related to water temperature.

Adult American Plaice do not appear to have stringent salinity requirements. They have been collected at a range of salinities from 31-34 ppt, with a single report of plaice collected from Hamilton Inlet off Labrador at 20-22 ppt.

American Plaice are highly opportunistic feeders and are therefore not likely to be dependent on the availability of any single prey item. Common groups of prey items include polychaetes, echinoderms, molluscs, crustaceans and small fish, with spatial differences often existing.

Given the extent of the distribution of American Plaice in the Maritime DU, it is likely that, while habitat preference appears to exist for this species, the range of habitats that can be occupied covers most of the area.

### Threats to habitat suitability

There are no known spatial configuration constraints. American Plaice are widely distributed and they occupy more than 70% of the surveyed area in most years. It would seem that sufficient habitat exists and habitat availability is not foreseen as a limiting factor in recovery. Critical habitat for American Plaice in the Maritime DU has not been defined. It is unknown to what extent various threats may alter the quality and/or quantity of habitat that is available.

*Damage to habitat by fishing gear*

It is possible that long-term effects of fishing gear have had an impact on American Plaice due to habitat disturbance. Mobile bottom-contact fishing gears do have impacts on benthic populations, communities and habitats. The effects are not uniform, however, but depend on at least: (a) the specific features of the seafloor habitats, including the natural disturbance regime; (b) the species present; (c) the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and (d) the history of human activities, especially past fishing, in the area of concern. Throughout the Maritime DU, fishing effort by mobile gears (mainly trawls and seines) decreased markedly with the first moratorium on cod fishing in the early 1990's and has decreased again over the past 5-10 years.

*Oil and gas exploration and exploitation*

American Plaice habitat overlaps regions covered by oil and gas development. Possible threats related to oil drilling include the discharge of oil-based sludge or drill cuttings, drilling fluids, waste from the platform and production waste. Accidental oil spills into the environment, whether from an accident involving an oil tanker or a leak from an oil well, are possible threats.

*Temperature*

The cold ocean conditions, from the mid-1980s to early 1990s, could have caused changes in the biological characteristics of American Plaice and may have resulted in increased natural mortality if these conditions were unfavourable to certain life stages. Bottom water temperatures in the Gulf and 4VW have since warmed to normal or above-normal conditions.

*Climate change*

The impact of global warming is yet unknown on the biology of American Plaice. It was predicted that temperature and salinity changes in the North Atlantic induced by climate change would see a northward shift in the distribution of many cold water marine fishes, including plaice. In the same way, warmer water species would shift northwards, filling the current niches of the cold water species. For fishes, climate change may strongly influence distribution and abundance through changes in growth, survival, reproduction, or responses to changes at other trophic levels. Species-specific responses are likely to vary according to rates of population turnover and species with slower life histories, which are already more vulnerable to overexploitation, may also be less able to compensate for warming through rapid demographic responses.

*Coastal eutrophication and hypoxia*

The oxygen requirements of plaice have not been studied but would be of particular interest in the Gulf of St. Lawrence population. Oxygen levels are low in deep waters of the Laurentian Channel, particularly in the St. Lawrence Estuary.

It is not known which biological functions of plaice relate to specific habitats and how these relationships vary with the state or amount of the habitat. However, American Plaice are widely distributed and habitat availability is not likely to be a limiting factor in their recovery.

# Scope for Management to Facilitate Recovery

## Major sources of mortality - magnitude

Some stocks in the Maritime DU have experienced significant fishing effort over the known history of their exploitation. The northern Gulf fishery is the exception, plaice being fished mainly as bycatch in other fisheries and landings rarely exceeding 3,000 tonnes. Fishing effort throughout the Maritime DU was reduced in the early 1990's when a moratorium was imposed on Atlantic cod. Further reductions in fishing effort have occurred in the 2000's. Most of the declines throughout the past 20 years and the failure of the stocks to recover significantly may be attributed to high natural mortality. There may be several factors contributing to high natural mortality, including predation and adverse environmental conditions. For example, the early 1990s was a period of decline in plaice abundance and poor recruitment, but it was also a period of unusually cold ocean temperatures, possibly contributing to increased natural mortality. Bottom water temperatures in the Gulf and 4VW have since warmed to normal or above-normal conditions.

### *Fishing – directed fishery, by-catch, discarding and misreporting*

#### 4T

Before the introduction of otter trawling to the southern Gulf of St. Lawrence (NAFO Division 4T) in the 1940s, American Plaice was exploited mainly by longlines. By the 1960s most landings were made by seines and otter trawls. Plaice are now caught by mobile gear, with the dominant sector being seines operated by vessels less than 45 feet. With the growth of mobile gear sectors during the 1960s, a large component of plaice catches in 4T (30- 40% by weight) was commercially-undersized and discarded at sea. From the mid-1960s and throughout the 1970s, reported landings fluctuated around 9,000 t, reaching their highest level in 1976 at over 11,000 t. Southern Gulf American Plaice has been under quota management since 1977. A TAC of 10,000 t was maintained until 1992 despite concern that the stock was undergoing a decline in abundance through the 1980s. It was felt at the time that more restrictive quotas would only incite increases in discarding at sea. The TAC on plaice was dropped to 5,000 t in 1993 following the closure of the 4T cod fishery in order to protect plaice from a redirection of fishing effort from cod to other groundfish stocks. Several reductions of the TAC have followed since 1993; the current TAC of 500 t has been in effect since 2008. Several management measures have been introduced since 1993 to reduce the incidence of discarding in the 4T plaice fishery. These measures include increased mesh sizes, mandatory landing of all catches, at-sea observer coverage and dockside monitoring.

Landings declined sharply in the 1990s, particularly in 1993 when the cod fishery was closed and new management measures came into effect. Since 1993, landings have continued to decline in the 4T plaice fishery, by at least five-fold (Figure 17). In 2009, the lowest landed annual catch (126 tonnes) of the time series was registered and preliminary data for the 2010 fishery indicate landings similar to the level reported in 2009.

#### 4RS

The American Plaice fishery in NAFO 4RS has never been managed by quota. Landings in 4RS have been low compared to other stocks. From 1976 to the mid 1990's, landings averaged 2000 t of which 85% were taken as bycatch in other directed fisheries, mainly cod and witch flounder. There was a marked reduction in landings in the 1995-2010 period, averaging 182 t. In that period, bycatch represented 58% of the landings and originated from witch flounder, cod and,

turbot fisheries. Currently, a small directed plaice fishery with gillnets occurs in 4R, but there is no directed fishery in 4S. Since 2006, American Plaice landings have averaged 24 t in the directed fishery and 84 t as bycatch. The number of participants in the plaice fishery has varied from 0 to 22 annually since 2006.

4VWX

The fisheries for American Plaice on the Scotian Shelf (4VW and 4X) are managed under multi-species flatfish TACs. The component species are not required to be identified in the commercial landings data. This system may remove incentives for fishers to discard species due to quota restrictions, but confounds management measures and assessments on single species in the complex. TACs are frequently taken as bycatch in 4X cod and haddock fisheries and trawls are the dominant gear landing American Plaice. In 4VW, flatfish is one of the only open bottom trawl fisheries along with pollock and redfish. At the current level of fishing effort in 4VW, fishing mortality is negligible. Though market demand is currently low, the 1,000-tonne flatfish TAC in this area does not preclude future increases in fishing mortality. The permitted landing of flatfish species under the label “unspecified flounder” has been a major impediment to assessing the status of the various flatfish populations on the Scotian Shelf and in the Bay of Fundy. Past and potential magnitudes of landings reported as “unspecified flounder" make it difficult to use commercial catch data in stock assessments.

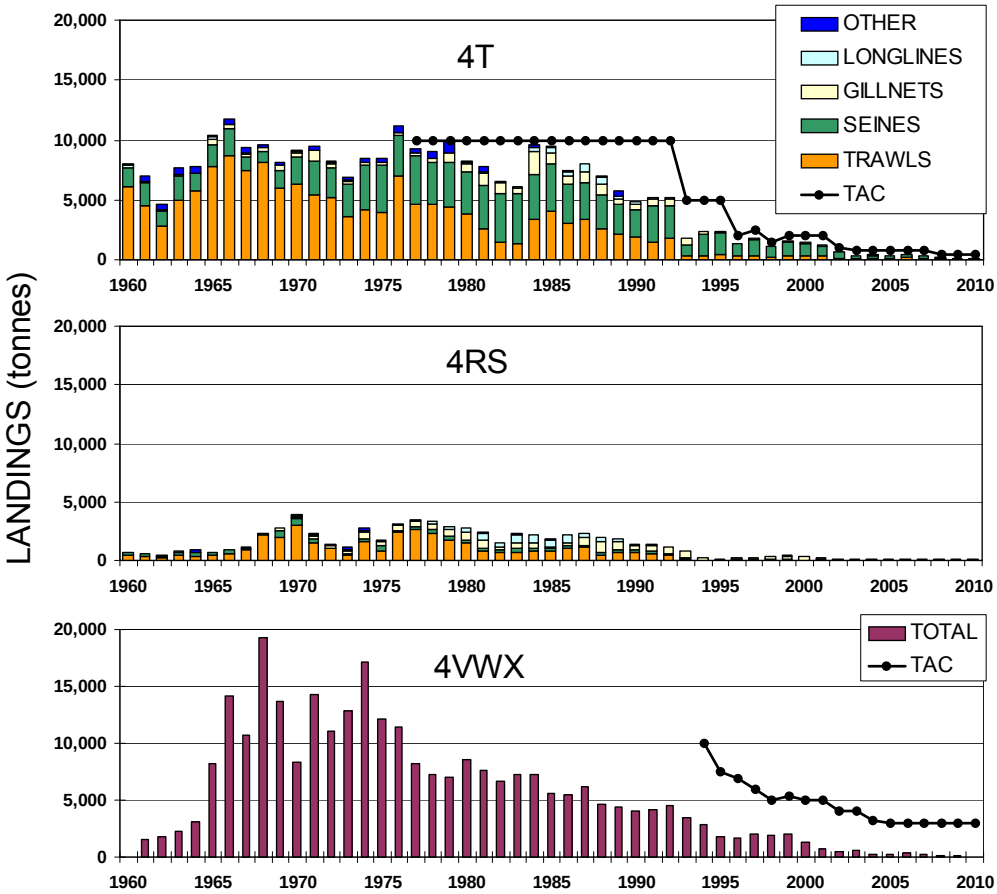



*Figure 17: American Plaice reported landings and total allowable catch (TAC) in the commercial fishery by NAFO division. The 4VWX TAC applies to a mixed fishery of four flatfish species.*

*Predation*

American Plaice are prey to various animals throughout their developmental stages, depending partially on relative size of predator and prey. Eggs and larvae are prey items for most species that feed in the upper pelagic zone during the spring. The best known (or at least best studied) predator of small American Plaice is Atlantic cod, in particular large (≥ 35 cm) cod.

American Plaice are also known prey items for harp and grey seals on the Scotian Shelf, Gulf of St. Lawrence and off Newfoundland. In the Gulf of St. Lawrence, plaice can be an important component of the diet of these seals.

## Scenarios for Mitigation and Alternative to Activities

### Fishery Management

Since 1993, a number of measures have been put in place to mitigate threats to existing populations of American Plaice. These measures include changes in fisheries regulations such as:

- Mandatory landing of all fish caught (i.e. discarding became a violation).
- Mesh size increases.
- Small fish protocol regulations resulting in area closures when the number of fish caught below the minimum size is more than 15% of the catch.
- Minimum levels of observer coverage on trips in directed fisheries.
- Dockside monitoring of all catches with mandatory notification on leaving and returning to port.
- By-catch limits on cod and other species in the plaice-directed fishery and vice versa have indirect effects on plaice catches, through increased monitoring and area closures.

Current management strategies in the Gulf of St. Lawrence appear to lower the risk of further decline of American Plaice stocks due to fishing. It is important to monitor and enforce bycatch limits wherever there is a potential to impact plaice stocks and to enforce existing mesh size regulations and other measures that prevent the capture of small plaice.

Despite the range of management measures listed above that also apply to American Plaice in 4VWX, the use of a multispecies TAC compromises the potential to ensure sustainability of the American Plaice stock.

In spite of low landings in the recent period there is little sign of recovery of the Maritime DU. Landings are at their lowest level on each stock in the DU and fishing effort is reduced. Landings are well below quotas, where quotas have been applied. Model projections for all stocks indicate that under current stock productivity, exploitation at recent levels has minimal impact on the projected abundance of the female spawning stock.

## Allowable Harm

For each stock, projections of the abundance of adult female population (Figures 12-15) indicate that whether the stocks remain unexploited or continue to be exploited at current harvests, there would be a minimal increase in the risk of plaice declining by 30% or more.

These projections have wide confidence intervals and an associated risk of decline to below the target that is relatively high, even without exploitation (18% to 55% for individual stocks).

## Sources Of Uncertainty

Throughout the Maritime DU, there is a lack of long term and continuous data on many aspects of the biology of American Plaice stocks, including growth and reproduction. For the northern Gulf stock, the survey time series begins with incomplete sampling in 1985 and there is no information available on growth and maturity. The sampling of commercial fisheries in the northern Gulf has been inadequate in many years. The lack of information on productivity and age structure for this stock is a major source of uncertainty.

For the southern Gulf stock, at-sea discarding in mobile gear fisheries was common in the past and has led to incomplete commercial catch-at-age data that has been compensated through various methods of estimation. The time series on sexual maturity is short and there is uncertainty as to whether the stock has undergone changes in maturity that would affect the composition of the spawning stock and rate of recruitment.

There is uncertainty in landing statistics on the Scotian Shelf-Bay of Fundy plaice stock because landings are often not identified to species. Information from the research trawl survey is limited to a restricted time period for their growth and age composition. There is uncertainty as to the degree of change in the maturity of plaice.

Due to the lack of age data in some DU components, stage structured models had to be used for projections and to estimate parameters such as natural mortality. The models that were formulated did not account for changes in growth over time. This may result, for example, in the projected decline of the southern Gulf plaice stock appearing less severe according to the stage-based model than the age-structured VPA model. These models required informative priors on some parameters. There was information to inform these priors for the 4T stock, but limited or no information for other stocks.

# CONCLUSIONS

Harvesting in the commercial fisheries was the major source of human-induced mortality and a contributing factor to stock decline in the past. However, despite declining fishing effort since the early 1990's, there is no clear evidence that plaice stocks are increasing in abundance. On some stocks, particularly the southern Gulf and the Scotian Shelf-Bay of Fundy, natural mortality appears to be high on adult plaice. This suggests that factors other than commercial fishing are preventing their recovery. In view of the uncertainty in the factors controlling plaice dynamics, caution is required in their exploitation and restricting commercial catches to current levels or lower is a practical means of reducing the risk of further declines in the Maritime DU of American Plaice.

The quantity of physical habitat does not appear to be limiting American Plaice abundance, given their wide distribution. Current or future activities such as oil and gas exploration and development, as well as the impacts of climate change, have the potential to affect American Plaice abundance, particularly through impacts on the larval and early juvenile stages. However, there is no evidence available to predict the degree or likelihood of these impacts.

In some areas, such as the southern Gulf and the Scotian Shelf-Bay of Fundy, seal populations are large and increasing in number. Seals are known to prey on flatfish, including American Plaice, but it is not possible at this point to attribute mortality patterns in plaice stocks to seal predation.

## SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, zonal advisory process meeting, March 24-25, 2011 on Recovery Potential Assessment (RPA) of the Maritime Designatable Unit of American Plaice. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)


*La version française est disponible à l'adresse ci-dessus.*

## CORRECT CITATION FOR THIS PUBLICATION

DFO. 2011. Recovery Potential Assessment of the Maritime Designatable Unit of American Plaice (*Hippoglossoides platessoides*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/043.