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Bluefin Tuna (*Thunnus thynnus*) in Atlantic Canadian Waters: Biology, Status, Recovery Potential, and Measures for Mitigation

Thon rouge (*Thunnus thynnus*) dans les eaux canadiennes de l'Atlantique : biologie, situation, potentiel de rétablissement et mesures aux fins d'atténuation

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ABSTRACT

In May 2011, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determined that Atlantic bluefin tuna (*Thunnus thynnus*) in the western Atlantic was Endangered. The reason for the designation is that the current abundance of spawning individuals is the lowest observed and the abundance of spawning fish has declined by 69% over the past 2.7 generations. COSEWIC concluded that the cause of the decline, overfishing, has not ceased and that it is not clearly reversible. A Recovery Potential Assessment (RPA) was held 13-15 July 2011 at the St. Andrews Biological Station, St. Andrews, NB. The purpose of the RPA was to provide information and scientific advice required to meet various requirements of the *Species at Risk Act* (*SARA*), including public consultations, decisions regarding the listing of western Atlantic bluefin tuna in Canadian waters under the Act, and developing a recovery strategy should the species be legally listed.

In Canadian waters there is no evidence that range has been reduced and the proposed distribution target for recovery is to maintain habitat conditions allowing for a broad distribution in Canadian waters. Spawning stock biomass (SSB) shows an initial steep and steady decline from 1970 to the mid-1980s and relative stability since then, with indications of a possible slight increase in recent years. The proposed recovery target for abundance is to increase spawning stock biomass compared to 2012. The International Commission for the Conservation of Atlantic Tunas (ICCAT) estimated that the 2025 SSB would be equal to or larger than the 2012 SSB for catches of 2,250 mt or less. Maximum allowable harm was agreed to be the maximum removals by the fishery that would still result in the SSB in 2025 being greater than the SSB in 2012. The only documented human induced mortality to Atlantic bluefin tuna in Canadian waters is fishing; feasible mitigation measures to minimize the threat posed include a reduction or elimination of landings of western Atlantic bluefin tuna in directed fisheries or as a bycatch in other fisheries, and measures to increase the post-release survival of any Atlantic bluefin tuna released.

RÉSUMÉ

En mai 2011, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a déterminé que le thon rouge de l'Atlantique (*Thunnus thynnus*) dans l’Atlantique Ouest était en voie de disparition. La raison de cette désignation est fondée sur le fait que l’abondance des reproducteurs au sein de ce stock est actuellement au plus bas de ses niveaux observés à ce jour et qu’elle a diminué de 69 % au cours des 2,7 dernières générations. Le COSEPAC a conclu que la cause du déclin, la surpêche, n’a pas disparu et qu’il n’est pas clair si la situation peut être renversée. Une évaluation du potentiel de rétablissement a eu lieu du 13 au 15 juillet 2011 à la station de biologie de St. Andrews, à St. Andrews (Nouveau-Brunswick). Cette évaluation avait pour but de fournir les renseignements et l’avis scientifique nécessaires pour satisfaire aux diverses exigences de la *Loi sur les espèces en péril* (*LEP*), concernant notamment les consultations publiques, les décisions sur l’inscription éventuelle du thon rouge de l’Atlantique Ouest des eaux canadiennes sur la liste d’espèces de la *Loi sur les espèces en péril* et la conception d’un programme de rétablissement de l’espèce si elle venait à être inscrite sur cette liste.

Dans les eaux canadiennes, il n'y a aucune preuve que l'aire de répartition a diminué, et l’objectif de répartition proposé pour le rétablissement consiste à maintenir des conditions d’habitat propices à une vaste répartition dans les eaux canadiennes. La biomasse du stock reproducteur (BSR) a connu un déclin net et constant de 1970 au milieu des années 1980, puis une stabilité relative; selon certaines indications, elle pourrait avoir augmenté légèrement ces dernières années. L’objectif de rétablissement proposé est une hausse de la biomasse du stock reproducteur par rapport à son niveau de 2012. La Commission internationale pour la conservation des thonidés de l'Atlantique (CICTA) a estimé que la biomasse du stock reproducteur de 2025 serait égale ou supérieure à celle de 2012 pour les captures de 2 250 tonnes métriques ou moins. Il a été convenu que les dommages admissibles maximaux correspondraient au niveau maximal de retraits de la pêche qui permettrait que la biomasse du stock reproducteur de 2005 reste supérieure à celle de 2012. La pêche est la seule source documentée de mortalité d’origine anthropique du thon rouge de l'Atlantique dans les eaux canadiennes; les mesures qu’il est possible de prendre pour atténuer les menaces peuvent comprendre la réduction ou l’élimination des débarquements de thon rouge de l’Atlantique provenant soit de la pêche dirigée, soit de captures accessoires dans le cadre d’autres pêches, ainsi que la mise en place de moyens pour accroître la survie après remise à l’eau de tout thon rouge de l’Atlantique capturé.

INTRODUCTION

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designates aquatic species as Threatened or Endangered, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the Species at Risk Act (SARA), is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, population or designable unit (DU), threats to its survival and recovery, and the feasibility of its recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes including recovery planning.

In May 2011, COSEWIC (2011) determined that Atlantic bluefin tuna (*Thunnus thynnus*) in the western Atlantic was Endangered. The reason for the designation is that the current abundance of spawning individuals is the lowest observed and the abundance of spawning fish has declined by 69% over the past 2.7 generations. COSEWIC (2011) concluded that the cause of the decline, overfishing, has not ceased and that it is not clearly reversible.

In support of listing recommendations for Atlantic bluefin tuna (*Thunnus thynnus*) by the Minister, DFO Science has been asked to undertake an RPA, based on the National Frameworks (DFO 2007a, b). The advice in the RPA may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA (SARA 2002). The advice generated via this process will also update and/or consolidate any existing advice regarding Atlantic bluefin tuna.

SPECIES STATUS AND TRENDS IN ATLANTIC CANADIAN WATERS

Bluefin Tuna Status for Abundance and Range and Number of Populations

The distribution of Atlantic bluefin tuna in the western Atlantic ranges from Newfoundland to the Caribbean, Venezuela and Brazil (Figure 1; Scott and Scott 1988). In the eastern Atlantic, bluefin tuna occurs from the Lofoten Islands, off northern Norway, south to the Canary Islands and into the Mediterranean and Black seas (Figure 1; Scott and Scott 1988). Atlantic bluefin tuna migrates seasonally to Canadian waters between July and December. Fisheries occur on the Scotian Shelf, in the Gulf of St. Lawrence, in the Bay of Fundy, and off Newfoundland (Figures 1, 2; Scott and Scott 1988). The occurrence and abundance of Atlantic bluefin tuna in any one of these locations has varied considerably in the past and continues to do so for a combination of reasons including the size of the stock.

Bluefin tuna fisheries vary considerably both locally and globally due to environmental changes and fluctuations in biomass. Even though particularly large declines have been observed off Brazil and in the North Sea, these seem to have multiple causes (Fonteneau 2009, Fromentin and Powers 2005) and they are not considered indicative of change in range. Instead, they are considered to result from interactions between biological factors, environmental variations and fishing.

At least two main spawning groups are believed to exist, the larger one in the Mediterranean and a smaller one in the Gulf of Mexico (Anon. 2011a). Spawning may occur elsewhere in the western Atlantic as larvae and mature individuals have also been found in the Bahamas / Straits of Florida in suitable water temperatures at the time of spawning. Fisheries on Atlantic bluefin tuna are managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT) on the basis of a two stock hypothesis, separated by 45° W. Population structure is poorly understood and likely to be complex. For the purpose of this report, the two population hypothesis will be retained; keeping in mind that reality is likely to be more complex.

Interchange between the two management areas is known to occur with a sizeable contribution of eastern origin fish to North American fisheries south of Cape Cod in the mid-Atlantic Bight. Canadian fisheries harvesting larger size classes (e.g., Gulf of St. Lawrence, St. Margaret's Bay) are believed to have no or minimal eastern component, relying essentially on western origin bluefin tunas (Anon. 2011a, Neilson 2009, Rooker et al. 2008). Some smaller bluefin tuna are caught in the fisheries occurring on the Scotian Shelf. Electronic and conventional tagging studies clearly demonstrate that western origin bluefin tuna are caught east of 45° W.

While the stock structure of Atlantic bluefin tuna appears complex and may conform to the "metapopulation" concept, there is no information suggesting that bluefin tuna in Canadian waters should be divided into substocks or subpopulations. For the purpose of this report, it is concluded that there is one population in Canadian waters and the range of bluefin tuna in Canadian waters has not changed.

Spawning stock biomass (SSB) is estimated to have peaked at 51,460 mt in 1973 and the most recent estimate was 14,072 mt for 2009 (Anon. 2011a, b). Total abundance (age 1 and older) estimated in the most recent assessment was maximum in 1970 (1,266,000) and was 316,790 individuals in 2009 (Anon. 2011a, b).

Recent Species Trajectory for Abundance (i.e., Numbers and Biomass Focusing on Matures) and Range and Number of Populations

The most recent stock assessment by the Standing Committee on Research and Statistics (SCRS) of ICCAT was conducted in 2010. The SCRS report (Anon. 2011a) can be found at: http://www.iccat.int/Documents/Meetings/Docs/2010_SCRS_ENG.pdf (accessed Feb. 10, 2012); and the detailed report (Anon. 2011b) on Atlantic bluefin tuna can be found at: http://www.iccat.int/Documents/Meetings/Docs/2010_BFT_ASSESS_REP_ENG.pdf (accessed Feb. 10, 2012).

The results of the 2010 assessment are broadly consistent with those of the previous assessment. They show an initial steep and steady decline in spawning stock biomass from 1970 to the mid 1980s and relative stability since then, with indications of a possible slight increase in recent years (Figure 3).

ICCAT has consistently used 1970 to the present as the assessment period on the basis that more data were available for that period. Fewer data are available for earlier years. In 2008, as a sensitivity analysis to the base case, ICCAT made a run starting in 1960; the results (Figure 4) show that biomass was lower in the early 1960s compared to 1970 (Anon. 2009).

The distribution of Atlantic bluefin tuna extends over a very large geographical area, too large to be covered by conventional fishery-independent surveys by trawl or acoustics, etc. Stock size and exploitation rate could be estimated through relatively large scale conventional tagging programs (Fonteneau and Fromentin 2009), but none have been conducted so far for that purpose on Atlantic bluefin tuna. The ICCAT assessments for western Atlantic bluefin tuna use a combination of stock size indices from the commercial fisheries and a larval index from surveys in the Gulf of Mexico.

Twelve indices of stock size are used in the ICCAT assessment of bluefin tuna in the western Atlantic (Figure 5; Anon. 20112b). They are from left to right:

- Canadian tended line / rod and reel in the Gulf of St. Lawrence (CAN GSL);
- Canadian tended line off South West Nova Scotia (CAN SWNS);
- five indices derived from the USA Rod and Reel recreational fisheries (US RR < 145, US RR 66-114, US RR 115-144, US RR > 195, US RR > 177;
- Japanese longline fishery in Area 2 (Japanese LL Area 2);
- a larval survey in the Gulf of Mexico (Larval Survey);
- USA Pelagic longline in the Gulf of Mexico (US PLL GOM);
- Japanese longline in the Gulf of Mexico (JLL GOM); and
- tagging results.

Four of the twelve stock size indices used in the stock assessment provide information on historical abundance but do not directly influence recent estimates of trends (US RR < 145, US RR > 195, JLL GOM and tagging). Trends in the other indices are difficult to discern except for the Canadian indices which show clear increases in recent years, particularly for the Gulf of St. Lawrence.

There is not close agreement between the indices of stock size and the results of the assessment (Figure 5) and there is considerable lack of fit for the CAN GSL index. It would be possible to improve the statistical fits to the Canadian indices but this would result in considerably larger stock sizes and much lower fishing mortality estimates than the accepted assessment suggests.

The influence of each index on the results is illustrated in Figure 6. Overall, removing the indices one at a time and running the virtual population analysis (VPA) without that particular index does not have a large influence on the historical trend (upper panel of Figure 6), but over a more recent period (lower panel of Figure 6), it is clear that including the US RR > 177 results in lower stock size estimates while including the CAN GSL results in higher stock size estimates. The other indices are reasonably tightly grouped together.

As indicated above, for the purpose of this report, it is concluded that there is one population in the Canadian range of the species and that the range where bluefin tuna occurs in Canadian waters has not changed.

Current or Recent Life-History Parameters for Bluefin Tuna and Associated Uncertainties

The most recent SCRS assessment (Anon. 2011a, b) assumes that natural mortality (M) for bluefin tuna is constant at M = 0.14 for all ages (for the eastern Atlantic + Mediterranean component M varies by age) and all years. The assessment also assumes that bluefin tuna from the Mediterranean mature at approximately 25 kg (age 4) while bluefin tuna from the Gulf of Mexico mature at approximately 145 kg (age 9). Age at maturity, however, is one of the most controversial life history characteristics for the western stock. Fecundity is not routinely estimated from the assessment results. Mather et al. (1995) report the fecundity analyses that had been carried at the time they wrote their report. Fromentin and Powers (2005) report on more recent studies. Fecundity is believed to be proportional to spawning stock biomass.

Fishing mortality rate (F) of spawners increased steeply from 1970 to the early 1980s decreased sharply with the reduction in catches in 1982, increased slowly and irregularly until the early 2000s and is estimated to have decreased by about half since then (Figure 7).

Recruitment since the late 1970s is estimated to have been considerably lower than for the first part of the 1970s (Figure 8), although a strong year class has been produced in the early 2000s (the 2003 year class).

Mixing between the eastern Atlantic + Mediterranean and the western Atlantic, as well as catches of one stock component in the other management area makes the assessment uncertain. Gavaris et al. (2009) noted that several recent ICCAT assessments had predicted rebuilding under agreed catch scenarios, but that the rebuilding failed to materialize.

Expected Population and Distribution Targets for Recovery

DFO (2005) describes targets for recovery in "precautionary framework" where three zones are defined for stock status: critical, cautious and healthy. Two possible "recovery" targets are identified: a) at the critical – cautious boundary or b) at the cautious – healthy boundary. Some work has been done on a precautionary framework for bluefin tuna (Gavaris et al. 2009) but reference points have not been adopted by ICCAT.

The objective of ICCAT is to maintain or restore species/stocks to biomasses that can produce the maximum sustainable yield (MSY) (Anon. 2007), i.e., that biomass (B) should be near B_{MSY}. Specifically for western Atlantic bluefin tuna, Anon. (2011b) states that "*the Supplemental Recommendation by ICCAT Concerning the western Atlantic Bluefin Tuna Rebuilding Program [Rec. 08-04] calls for a 20-year rebuilding period starting in 1999 with the objective of recovering the stock to B_{MSY} with at least a 50% probability by the end of the Plan's time frame (through 2018)*".

Anon. (2011b) considers two different possible states of nature for bluefin tuna in the western Atlantic:

1. it is possible for future recruitment to be as large as that observed in the late 1960s to the early 1970s, the high recruitment scenario (Figure 9) that implies B_{MSY} = 91,712 mt; and
2. because of unknown changes in the ecosystem, the high recruitment of the late 1960s to the early 1970s is no longer possible and with future recruitment expected to vary among recruitment estimates from the 1975 through the 2005 year classes, i.e., the low recruitment scenario (Figure 9) that implies a considerably lower B_{MSY} of 12,722 mt.

If the high recruitment scenario is true, current biomass (B_{2009} = 14,072) is considerably below B_{MSY} = 91,712 mt (Table 1); if the low recruitment scenario is true, current (B_{2009} = 14,072) is estimated to be slightly higher than B_{MSY} = 12,722 mt (Table 1). It should be noted that B_{MSY} estimated under the high recruitment scenario (92,000 mt), is considerably higher than the maximum observed SSB (1973) of approximately 51,500 mt.

B_{MSY} could be considered as the target for recovery of western Atlantic bluefin tuna. Under the low recruitment scenario, this would mean that the target has been achieved, but not under the high recruitment scenario. An alternate target for recovery could be that the stock should increase compared with recent stock size estimates. The RPA's proposed recovery target for abundance is to increase spawning stock biomass compared to 2012.

As indicated elsewhere in this report, the occurrence of bluefin tuna in Canadian waters varies with a number of factors not related to habitat suitability, availability and to stock abundance. Given current knowledge, and the variability in bluefin tuna occurrence at specific locations, it is neither possible, nor meaningful, to identify specific distribution targets for recovery. Therefore, a general “target” for distribution would be to avoid actions which would prevent Atlantic bluefin tuna from occupying available habitat in Canadian waters resulting in a decrease in distribution, and to maintain as broad a distribution in Canadian waters as possible.

Project Expected Atlantic Bluefin Tuna Population Trajectories Over Time to Recovery Target, Given Current Atlantic Bluefin Tuna Population Dynamics Parameters and Associated Uncertainties

ICCAT (Anon. 2011a, b) assumes that western origin Atlantic bluefin tuna are mature at 9 years of age. The generation time is estimated to be 15 years.

Anon. (2011b) provides medium term projections through 2018, inclusive, for the duration of the ICCAT rebuilding plan (Figure 10 for the low recruitment scenario and Figure 11 for the high recruitment scenario). These projections are consistent with the DFO guidelines in Shelton et al. (2007). The catch, biomasses and Fs under the two recruitment scenarios are in fact relatively close for the two recruitment scenarios, but when the results are expressed as ratios to MSY references points, they are highly dependent on the assumed recruitment scenario in terms of projected status with respect to reference points.

The National Marine Fisheries Service of the USA has recently reviewed the status of Atlantic bluefin tuna (Atlantic Bluefin Tuna Status Review Team 2011) and performed projections of population trajectories under various scenarios. These are based on the assessment results from the most recent ICCAT assessment (Anon. 2011b) under the high and low recruitment scenarios and are consistent with the DFO guidelines in Shelton et al. (2007). The review team made separate projections for the western and eastern + Mediterranean as fisheries in the USA are dependent on both spawning components. As indicated earlier, fisheries in Canada are believed to be largely dependent on the western component. The review team also made longer term projections estimating at the probability of extinction under various catch scenarios assuming that both recruitment scenarios were equally plausible. The results from these projections demonstrate a low probability of extinction at the Total Allowable Catch (TAC) agreed by ICCAT for 2011 and 2012 (Table 2).

HABITAT USES OF BLUEFIN TUNA IN ATLANTIC CANADIAN WATERS

Residence Requirements

The Species At Risk Act (SARA 2002) defines residence 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*”. As indicated above, Atlantic bluefin tuna migrates seasonally to Canadian waters between July and December with occurrences on the Scotian Shelf, in the Gulf of St. Lawrence, in the Bay of Fundy, and off Newfoundland, with considerable interannual variation as a result of interactions between biological factors, environmental variations and fishing. Therefore, there is no residence requirement for bluefin tuna in Canadian Atlantic waters based on the above definition.

Functional Descriptions of the Properties of the Aquatic Habitat that Bluefin Tuna Needs for Successful Completion of all Life-History Stages

The first paragraph of the 2010 SCRS report (Anon. 2011a, BFT 1. Biology, page 75) provides a good summary of what is known about the habitat needs of Atlantic bluefin tuna: "*Atlantic bluefin tuna (BFT) mainly live in the pelagic ecosystem of the entire North Atlantic and its adjacent seas, primarily the Mediterranean Sea. Bluefin tuna has a wide geographical distribution and is one of the only large pelagic fish living permanently in temperate Atlantic waters. Archival tagging and tracking information confirmed that bluefin tuna can sustain cold as well as warm temperatures while maintaining a stable internal body temperature. Until recently, it was assumed that bluefin tuna preferentially occupy the surface and subsurface waters of the coastal and open-sea areas, but archival tagging and ultrasonic telemetry data indicate that bluefin tuna frequently dive to depths of 500 m to 1,000 m. Bluefin tuna is also a highly migratory species that seems to display a homing behavior and spawning site fidelity in both the Mediterranean Sea and Gulf of Mexico, which constitute the two main spawning areas being clearly identified today. Less is known about feeding migrations within the Mediterranean and the North Atlantic, but results from electronic tagging indicated that bluefin tuna movement patterns vary considerably between individuals, years and areas. The appearance and disappearance of important past fisheries further suggest that important changes in the spatial dynamics of bluefin tuna may also have resulted from interactions between biological factors, environmental variations and fishing"*.

Specific habitat requirements have not been defined for bluefin tuna, but the distribution of bluefin is expected to be closely related to that of its prey and its migration in Canadian waters could depend on specific species (e.g., the migratory Atlantic mackerel), although this has not been demonstrated. Both juveniles and adults are opportunistic feeders. On the northwestern Atlantic shelf, adult Atlantic bluefin tuna target high-lipid content prey, primarily Atlantic herring, mackerel, saury, and capelin, but their diet also includes squid, sandlance, haddock, krill, whiting, butterfish, and spiny dogfish (Chase 2002; Estrada et al. 2005; Golet et al. 2007; Logan et al. 2011). In Canadian waters, herring and mackerel are believed to be the primary prey of Atlantic bluefin tuna. The estimated recent declines in some prey species, notably Atlantic mackerel, do not appear to have influenced the distribution, range and availability of Atlantic bluefin tuna in Canadian waters. However, as bluefin tuna migrate in Canadian waters to feed, maintaining healthy populations of prey species could be considered as a habitat requirement.

Tuna migration and aggregation are related to oceanographic fronts (Nakamura 1969) and to the distribution of their prey. In coastal areas, aerial surveys have shown that Atlantic bluefin tuna schools are more abundant within 10 to 25 km of sea surface temperature fronts (Royer et al. 2004; Schick et al. 2004), but the presence of prey had a higher explanatory value Schick and Lutcavage 2009). If the distribution of Atlantic bluefin tuna is closely associated with prey distribution, prey could be considered a component of habitat.

Fonteneau (2009) states: "*Bluefin tuna in the Atlantic has been the tuna species showing the greatest flexibility, and permanently changing its areas of concentration and its apparent migration routes. Bluefin tuna is also and by far, among all other tuna species, the species having shown the best thermoregulation and being taken in the widest range of sea surface temperature: from sub Arctic to equatorial waters*". This suggests that usual concepts of habitat and trends in habitat may not be relevant to Atlantic bluefin tuna as long as spawning and larval and juvenile rearing habitats, which are located outside of Canadian waters, are protected.

Anon. (2011a, page 75) describes the feeding habits of bluefin tuna as follows: "*Juvenile and adult bluefin tuna are opportunistic feeders (as are most predators). However, in general,* *juveniles feed on crustaceans, fish and cephalopods, while adults primarily feed on fish such as herring, anchovy, sand lance, sardine, sprat, bluefish and mackerel*". In Canadian waters, herring and mackerel are believed to be the primary prey of bluefin tuna.

It is not possible to provide functional descriptions (as defined in DFO 2007b) of the properties of the aquatic habitat that bluefin tuna needs for successful completion of all life-history stages and it may not be relevant as far as Canadian waters are concerned.

Provide Information on the Spatial Extent of the Areas in Bluefin Tuna's Range in Canada that are Likely to have These Habitat Properties

The worldwide distribution of Atlantic bluefin tuna is illustrated in the Figure 1.

As indicated above, it is not possible to provide functional descriptions (as defined in DFO 2007b) of the properties of the aquatic habitat that bluefin tuna needs for successful completion of all life-history stages and it may not be relevant as far as Canadian waters are concerned. Areas where bluefin tuna have been or are normally caught in Canadian waters include an area between Georges and Browns Bank off southwest Nova Scotia known as the Hell Hole, in the southern Gulf of St. Lawrence, in St. Margaret's Bay traps, off northeastern Nova Scotia, in coastal fishing areas off Nova Scotia, in the lower Bay of Fundy and on the Tail of the Grand Banks of Newfoundland. Location of Canadian Atlantic bluefin tuna catches by gear are illustrated in Figure 12. The perception of distribution and range is measured primarily by the distribution of the fishery (Figure 12), but some information is also available from electronic tagging experiments in recent years (Figure 13).

The occurrence and abundance of bluefin tuna in any one of these locations varies considerably from one year to the next. Actual abundance and availability is believed to be related to overall abundance but also to the age and size structure, to water temperature and currents, as well as to prey availability, related to oceanographic conditions, and migration (Fromentin and Powers 2005).

There is no evidence that the range of Atlantic bluefin tuna in Canadian waters has decreased. Local Atlantic bluefin tuna distribution is ephemeral as it is linked to their prey distribution and oceanographic features and that they spend only a portion of their time in Canadian waters. The main source of data to evaluate distribution is fisheries data (Figure 12). Fishing locations are influenced by factors other than fish distribution (e.g., fuel prices, market demands, and management regimes) and, therefore, are unlikely to reflect the entire range Atlantic bluefin tuna in Atlantic Canada.

Research Recommendations to Complete Habitat-Use Terms of Reference

Continuing the existing electronic tagging program and analyzing results to date is likely to contribute to the increased understanding of the habitat requirements of Atlantic bluefin tuna in Canadian waters.

Activities most Likely to Threaten the Habitat Properties that give the Sites Their Value and Extent and Consequences of These Activities

Anthropogenic noise such as seismic activity was identified as an additional potential threat to Atlantic bluefin tuna due to deleterious effects it may have on behaviour and physiology of Atlantic bluefin tuna and its prey (McCauley et al. 2003; Weilgart 2007). Anthropogenic ocean noise is mainly the result of underwater explosions, seismic exploration, naval sonar operations, and shipping. Ongoing seismic noise from oil and gas exploration exists in the Canadian range of Atlantic bluefin tuna. Imminent increases in oil and gas development and seismic testing in the Gulf of St. Lawrence may pose a threat to Atlantic bluefin tuna and their prey.

Considering the Deepwater Horizon oil spill, the potential effects on the future abundance of western Atlantic bluefin tuna was evaluated by comparing the projections made by the ICCAT SCRS (Anon. 2011a) with similar projections that assume the number of yearlings (one-year-old fish) in 2011 will be reduced by 20% (Atlantic Bluefin Tuna Status Review Team 2011). The value of 20% was based on the recent report by the European Space Agency that suggested that about 20% of the spawning habitat was oiled. The Atlantic Bluefin Tuna Status Review Team indicated that the reduction in the 2010 year-class strength will likely result in less than a 4% reduction in future spawning biomass. However, those analyses concluded that if a significant fraction of adult Atlantic bluefin tuna were killed or rendered infertile by the spill, then subsequent year-classes might also be reduced, leading to greater reductions in spawning biomass than estimated above. To date, however, there has been no evidence that any portion of adults were deleteriously affected.

Overfishing of Atlantic bluefin tuna forage species (i.e., herring and mackerel) in Canadian waters could be an activity which could threaten Atlantic bluefin tuna habitat, since prey species abundance/aggregations could be considered as an important proxy for habitat. Schick and Lutcavage (2009) demonstrated that the presence of prey in the Gulf of Maine was identified as an important explanatory variable in terms of Atlantic bluefin tuna distribution (i.e., shifts in Atlantic bluefin distribution were associated with shifts in the distribution of prey).

Global climate change could also be a potential threat to Atlantic bluefin tuna habitat in Canadian waters.

Likelihood that the Current Quantity and Quality of Habitat is Sufficient to Allow Population Increase, and Would be Sufficient to Support a Population that has Reached its Recovery Targets

There is no indication that current quantity and quality of habitat is insufficient to allow the population to increase and reach the targets.

Magnitude by Which Current Threats to Habitats have Reduced Bluefin Habitat Quantity and Quality in Canadian Waters

There are no indications that habitat quantity and quality for Atlantic bluefin tuna have been reduced in Canadian waters.

SCOPE FOR MANAGEMENT TO FACILITATE THE RECOVERY OF BLUEFIN TUNA IN ATLANTIC CANADIAN WATERS

Magnitude of Each Major Potential Source of Human-Induced Mortality Identified in the Cosewic Status Report

COSEWIC (2011) identifies overfishing as the single largest threat to the western population of Atlantic bluefin tuna. Similarly, the lack of recovery (assuming the high recruitment scenario) is attributed to overfishing with a large proportion of the catch being immature fish (COSEWIC 2011).

Golet et al. (2007) reported decreased condition of bluefin tuna in USA fisheries in the Gulf of Maine area and Neilson et al. (2009) made similar observations in the southern Gulf of St. Lawrence. These remain unexplained and appear to have reversed, at least in the southern Gulf of St. Lawrence.

Killer whales (*Orcinus orca*), pilot whales (*Globicephala melaena*), and mako sharks (*Isurus oxyrinchus*) are occasional predators of adult bluefin tuna (Scott and Scott 1988), but the main human induced cause of mortality in Canadian water is due to fishing. Song et al. (2006) appeared to discount the possibility of damage by seismic testing based on the morphology of the inner ear. Climate change and oil pollution in the Gulf of Mexico could have large impact on the recruitment success. The consequences of the Deepwater Horizon oil spill in 2011 remain to be estimated but could be large on the 2010 year class of bluefin tuna.

Catches of western Atlantic bluefin tuna in the western Atlantic have been under strict restriction for more than 25 years yet the stock does not appear to have rebuilt. This could be due to unaccounted mortality of western Atlantic bluefin tuna east of 45° W. Catches and discards by gear and by country for 1985 to 2009 are provided in Tables 3-5, based on Anon. (2011a). The TACs for 2011 and 2012 have been set such as to allow growth in the stock under both recruitment hypotheses.

Probability that the Recovery Targets can be Achieved Under Current Rates of Atlantic Bluefin Tuna Population Dynamics Parameters, and Under Different Mortality and Productivity

The results of ICCAT's 2010 assessment show an initial steep and steady decline in SSB from 1970 to the mid-1980s and relative stability since then; with indications of a possible slight increase in recent years. The RPA's proposed recovery target for abundance is to increase spawning stock biomass compared to 2012. Under the ICCAT low recruitment scenario (two-line model), SSB targets have been achieved and SSB has rebuilt. Under the low recruitment scenario 2025 SSB would be equal to or larger than the 2012 SSB for catches of 2,250 mt or less. Under the ICCAT high recruitment scenario (B-H model), SSB targets have not been achieved and the stock is not rebuilt. Both scenarios project an increase in SSB at the TAC (1,750 mt) agreed to for 2011 and 2012.

SCENARIOS FOR MITIGATION AND ALTERNATIVE TO ACTIVITIES

Feasible Measures to Minimize/Mitigate the Impacts of Activities that are Threats to the Species and its Habitat

The measures that are in place to control and monitor the Canadian Atlantic bluefin tuna fishery make it a model for sustainable fishery practices. Along with the mandatory international obligation for a bluefin tuna catch document for each bluefin tuna landed, the Canadian fishery has many additional measures in place to ensure that all landings are accounted for both in the directed fishery, as a bycatch in other fisheries, and assumed mortalities for catch and release in the charter boat fisheries. The bluefin tuna fishery is a limited entry fishery and only fishermen with a bluefin tuna licence or pelagic longline fishermen, that are permitted to retain their bycatch of bluefin tuna, are permitted to land bluefin tuna. The mandatory tagging of each individual fish as well as strict rules on hail out, hail in, limits on fleet landings (individual quotas (IQ), one fish per day per fisher), and third party monitoring of all landings allows the fishery to be prosecuted close to the annual Canadian quota without exceeding the annual allotted amount that Canada receives from ICCAT. Canada has significant measures in place to ensure that it does not overharvest this stock based on annual ICCAT allocations.

The current rebuilding plan in place at ICCAT for western Atlantic bluefin tunas is expected to see the biomass continue to grow under existing current fishing practices and TACs.

If a reduction in harvest was determined to be required, feasible mitigation measures to minimize the threats include:

- reduced or no authorization for a directed harvest of Atlantic bluefin tuna in either a commercial or charter boat fishery;
- mandatory release of any incidentally harvested bluefin tuna in any fishery (dead or alive) reducing the incentive to target bluefin as a bycatch or ensure that a tuna is dead when retrieved;
- time and area closures of other directed fisheries (e.g., large pelagic longline, trap, weirs, gillnets or purse seine fisheries for small pelagics) to reduce bluefin tuna bycatch;
- gear configuration changes in other directed fisheries to reduce incidental harvests(e.g., weak hooks for pelagic longline fishery for swordfish and other tunas, changes to reduce the entry of bluefin into traps or seines for small pelagics, elimination of the use of kites in the shark fishery);
- identification of locations/fisheries where incidental harvests of bluefin are significant and where seasonal or area closures could reduce impacts on bluefin; and
- reduction in overall fishing effort by other gear types associated with bluefin tuna bycatch mortality (e.g., pelagic longline fisheries, small pelagic traps, weirs, gillnets or purse seines).

Increased post-release survival of any Atlantic bluefin tuna released is another feasible mitigation measure to minimize threats. Such measures could include:

- the development and implementation of guidelines to ensure that the release of incidentally harvested bluefin ensures maximum survival;
- change in gear types in other fisheries that would facilitate the release of incidentally caught bluefin; and
- change in gear to reduce the incidental take of bluefin.

As indicated above, no specific habitat requirements have been defined for Atlantic bluefin tuna.

Reasonable Alternatives to the Activities that are Threats to the Species and its Habitat

Other fisheries in Atlantic Canada have a bycatch of bluefin tuna. Large pelagic fisheries can have notable bycatches of bluefin when using longline gear. However the pelagic longline fleet is also permitted to fish with harpoon and trolling gear in addition to their longline gear when directing for swordfish and other tunas. Alternative fishing methods such as rod and reel or tended line for could result in increased survivability for released incidentally caught bluefin tuna but could affect harvests of these target species.

While for the most part bluefin tuna occurring in small pelagic fish traps or weirs can be released alive, other small pelagic directed gear types such as purse seine, gillnet, midwater trawl could have incidental catches that would have a higher mortality rate. If bluefin mortality associated with small pelagics fisheries is considered significant, alternative fishing gears or reduced harvesting may be required in small pelagic fisheries.

Activities that Could Increase the Productivity or Survivorship Parameters

There are currently no activities identified or planned for the purpose of increasing productivity or general survival of bluefin tuna in Atlantic Canadian waters. The mitigation measures outlined above to limit impacts on the stock would be consistent with a goal of increasing survivorship in domestic waters.

Reduction in Mortality Rate Expected by each of the Mitigation Measures or Alternatives and the Increase in Productivity or Survivorship Associated with each Measure

In recent years, Canada has harvested approximately 500 mt per year, or 28-30% of all of the reported mortalities of western Atlantic bluefin tuna on an annual basis; the majority of other mortality is associated with Japanese and USA fisheries. Total elimination of any directed fishing for western Atlantic bluefin by Canadian fish harvesters could result in an approximate 24% reduction in the overall western Atlantic bluefin tuna mortality from fishing (the 4-6% difference is attributed to by-catch mortality). Based on current assumed mortalities from the Canadian bluefin tuna charter boat fishery, elimination of this catch and release fishery would result in less than a 1% reduction in western Atlantic bluefin tuna mortality.

The mandatory release of any Atlantic bluefin tuna caught incidentally in any fishery in Atlantic would likely result in an additional reduction in overall human induced mortality of 2-3% (based on elimination of 70-100 mt of bycatch in pelagic longline fisheries for swordfish and other tunas or from mackerel traps with an assumed 40-60% survival of released bycatch). Seasonal or area closures combined, change in gear configurations and reduced fishing in other fisheries that harvest Atlantic bluefin tuna incidentally would likely only result in a small reduction in mortality from fishing.

Switching gear types in other fisheries (from pelagic longline to harpoon for swordfish or to fish traps from seines for small pelagics) would be expected to have a small reduction in the overall mortality of western Atlantic bluefin tuna associated with these fisheries.

Expected Population Trajectory and time of Reaching Recovery Targets

Projections of SSB were estimated under various catch scenarios (from 0 catch to 3,500 mt per year) for the low recruitment scenario (Figure 10) and high recruitment scenario (Figure 11), to gauge the potential effects of additional management measures. All projections were based on the strength of the 2003 year class that may be overly optimistic. The weights at age were not updated for projections.

It was decided that all projections should be based on the low recruitment scenario which assumes that the high recruitments of the late 1960s to the early 1970s are no longer possible because of unknown changes in the ecosystem. The low recruitment scenario was preferred for use in the projections as spawning stock biomass levels at MSY under the high recruitment scenario are nearly 80% higher than the highest observed spawning stock biomass levels. Further, such high spawning stock biomass levels are inconsistent with the Anon. (2009) sensitivity analysis, which employed the older (back to 1960) catch and effort data. The group decided that high recruitment scenario was not plausible. The RPA indicates that two options were available but that only one was chosen in the end.

Western Atlantic bluefin tuna projection results were examined relative to 2012 under various catch scenarios for the low recruitment scenario (Figure 10). These approximate the following mitigation scenarios: 0 mt - no catch in the western Atlantic; 250 mt - bycatch only by all in the western Atlantic; 1,250 mt - no Canadian catch, others status quo catches in the western Atlantic; 1,500 mt - ½ Canadian catch, others status quo catches in the western Atlantic; 1,750 mt - current western Atlantic total allowable catch; 2,250 mt - 2010 ICCAT scientific advice. F_{MSY} and $F_{0.1}$ projections were also discussed. The main assumption for the catch scenarios was that the Canadian-only reductions in catch would not be allocated to the TAC of other nations (Japan, USA).

Parameter Values for Population Productivity and Starting Mortality Rates Required for Exploration of Additional Scenarios as Part of the Assessment of Economic, Social, and Cultural Impacts of Listing the Species

ICCAT (Anon. 2011a, b) assumes that western origin Atlantic bluefin tuna are mature at 9 years of age. Age at maturity in the eastern stock is estimated to be 4 to 5 years of age. No new information was available to compare growth rates or size at age over time. The natural mortality rate is estimated to be 0.14 and the generation time is estimated to be 15 years. Recent studies documented decreases in the somatic condition of Atlantic bluefin tuna from the late 1990s through 2005 in the Gulf of St Lawrence (it increased in 2006 and has varied slightly though 2007, 2008, and 2009) (Paul et al. 2011) and Gulf of Maine (Golet et al. 2007). The 14-year period of decline in Atlantic bluefin tuna condition observed in the Gulf of Maine was mirrored in large herring size classes (Golet et al. unpublished data; Golet 2010). The reasons for the decline are unknown, but the trend has reversed.

ALLOWABLE HARM ASSESSMENT

Maximum Human-Induced Mortality Which the Species can Sustain and not Jeopardize Survival or Recovery of the Species

Agreed TACs for 2011 and 2012 imply growth in the western stock that is already at ICCAT's target under the low recruitment scenario. Under the high recruitment scenario, biomass is projected to increase but ICCAT's target is not reached during the recovery period.

Given that the RPA's proposed recovery target is an increase in SSB compared to 2012, maximum allowable harm was agreed to be the maximum removals by the fishery that would still result in the SSB in 2025 being greater than the SSB in 2012 under the low recruitment scenario. The probabilities that an increase would not occur by 2025 for catch scenarios ranging from 0 to 3,500 mt are presented in Table 6.

REFERENCES

Anon. 2007. Basic Texts (5th revision). Int. Comm. Conserv. Atl. Tunas: 117 pp.

Anon. 2009. Report of the 2008 Atlantic bluefin tuna stock assessment session (Madrid, Spain, 23 June to 4 July 2008). Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 64: 1-352.

Anon. 2011a. Report of the Standing Committee on Research and Statistics. Int. Comm. Conserv. Atl. Tunas Rep. for Bien. Per. 2010-2011, Part 1: 1-265. http://www.iccat.int/Documents/Meetings/Docs/2010_SCRS_ENG.pdf (accessed February 10, 2012).

Anon. 2011b. Report of the 2010 ICCAT bluefin tuna stock assessment session (Madrid, Spain, 6 to 12 September 2010). Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 66: 505-714. http://www.iccat.int/Documents/Meetings/Docs/2010_BFT_ASSESS_REP_ENG.pdf (accessed February 10, 2012).

Atlantic Bluefin Tuna Status Review Team. 2011. Status Review Report of Atlantic bluefin tuna (*Thunnus thynnus*). Report to National Marine Fisheries Service, Northeast Regional Office. March 22, 2011: 104 pp.

Chase, B.C. 2002. Differences in the diet of Atlantic bluefin tuna (*Thunnus thynnus*) at five seasonal feeding grounds on the New England continental shelf. Fish. Bull. 100:168-180.

COSEWIC. 2011. COSEWIC assessment and status report on the Atlantic bluefin tuna *Thunnus thynnus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 30 pp.

DFO. 2005. A framework for developing science advice on recovery targets for aquatic species in the context of the Species at Risk Act. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/054.

DFO. 2007. Revised protocol for conducting Recovery Potential Assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/039.

DFO. 2007. Documenting habitat use of species at risk and quantifying habitat quality. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/038.

Estrada, J.A., Lutcavage, M., and Thorrold, S. 2005. Diet and trophic position inferred from stable carbon and nitrogen isotopes of Atlantic bluefin tuna (*Thunnus thynnus*). Mar. Biol. 147: 37-45.

Fonteneau, A. 2009. Atlantic bluefin tuna: 100 centuries of fluctuating fisheries. Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap. Madrid 63: 51-68.

Fonteneau, A., and Fromentin, J.-M. 2009. Menaces sur le thon rouge. Pour la Science 381: 32-38.

Fromentin, J.-M., and Powers, J.E. 2005. Atlantic bluefin tuna: population dynamics, ecology, fisheries and management. Fish and Fisheries 6: 281-306.

Gavaris S. (Chair), Hazin, F., Neilson, J.D., Pallares, P., Porch, C., Restrepo, V.R., Scott, G., Shelton, P., and Wang, Y (editors). 2009. Proceedings of the Joint Canada-ICCAT 2008 Workshop on the precautionary approach for western bluefin tuna (Halifax, Nova Scotia, 17-20 March, 2008). Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 64: 353-379.

Golet, W. 2010. Somatic condition, growth and distribution of Atlantic bluefin tuna (*Thunnus thynnus*) in the Gulf of Maine. Ph.D. Dissertation. Univ. of New Hampshire, Durham, NH. 2010.

Golet, W.J., Cooper, A.B., Campbell, B., and Lutcavage, M. 2007. Decline in condition of northern bluefin tuna (*Thunnus thynnus*) in the Gulf of Maine. Fish. Bull. 105: 390-395.

Logan, J.M., Rodriguez-Marin, E., Goñi, N., Barreiro, S., Arrizabalaga, H., Golet, W., and Lutcavage, M. 2011. Diet of young Atlantic bluefin tuna (*Thunnus thynnus*) in eastern and western Atlantic forage grounds. Mar. Biol. 158: 73-85.

Maguire, J.-J., Sissenwine, M., Csirke, J., Grainger, R., and Garcia, S. 2006. The state of highly migratory, straddling and other high seas fishery resources and associated species. FAO Fisheries Technical Paper. No. 495. Rome FAO. 84p.

Mather, F.J. Jr., Mason, J.M., and Jones, A. 1995. Historical document: life history and fisheries of Atlantic bluefin tuna. NOAA Technical Memorandum NMFS-SEFSC-370, Miami, 165pp.

McCauley, R.D., Fewtrell, J., and Popper, A.N. 2003. High intensity anthropogenic sound damages fish ears. J. Acoust. Soc. Am. 113: 638-642.

Nakamura, H. 1969. Tuna Distribution and Migration. London, Fishing News (Books) Ltd.

Neilson, J.D. 2009. Available information for preparation of the western Atlantic bluefin tuna (*Thunnus thynnus*) COSEWIC Status Report . DFO Can. Sci. Advis. Sec. Res. Doc. 2009/035. VI + 13 p.

Neilson, J.D., Smith, S., Ortiz, M., and Lester, B. 2009. Indices of stock status obtained from the Canadian bluefin tuna fishery. Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 64: 380-404.

Paul, S.D., Hanke, A., Vanderlaan, A.S.M., Busawon, D., and Neilson, J.D. 2011. Indices of stock status from the 2009 Canadian bluefin tuna fishery. Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 66: 1170-1203.

Rooker, J.R, Secor, D.H., De Metrio, G., Schloesser, R., Block, B.A., and Neilson, J.D. 2008. Natal homing and connectivity in Atlantic bluefin tuna populations. Science 322: 742-744.

Royer, F., Fromentin, J., and Gaspar, P. 2004. Association between bluefin tuna schools and oceanic features in the western Mediterranean. Mar. Ecol. Prog. Ser. 269: 249-263.

SARA. 2002. Bill C-5: The Species at Risk Act. Available at: http://www.parl.gc.ca/About/Parliament/LegislativeSummaries/bills_ls.asp?lang=E&ls=C5&Parl=37&Ses=1&source=Bills_House_Government. (accessed February 10, 2012).

Schick, R.S., and Lutcavage, M.E. 2009. Inclusion of prey data improves prediction of bluefin tuna (*Thunnus thynnus*) distribution. Fish. Oceanogr. 181: 77-81.

Schick, R.S., Goldstein, J., and Lutcavage, M.E. 2004. Bluefin tuna (*Thunnus thynnus*) distribution in relation to sea surface temperature fronts in the Gulf of Maine (1994-96). Fish. Oceanogr. 13: 225-238.

Scott, W.B., and Scott, M.G. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Shelton, P.A., Best, B., Cass, A., Cyr, C., Duplisea, D., Gibson, J., Hammill, M., Khwaja, S., Koops, M., Martin, K., O'Boyle, R. Rice, J., Sinclair, A., Smedbol, K., Swain, D., Velez-Espino, L., and Wood, C. 2007. Assessing recovery potential: long-term projections and their implications for socio-economic analysis. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/045.

Song, J., Mathieu, A., Soper, R.F., and Popper, A.N. 2006. Structure of the inner ear of bluefin tuna (*Thunnus thynnus*), J. Fish Biol. 68: 1767–1781.

Weilgart, L.S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. Can. J. Zool. 85: 1091-1116.

TABLES

Table 1: The median estimates for F_{MSY}, MSY and B_{MSY} (from Table 12 from Anon. 2011b).

	Low Recruitment	High Recruitment
F_{MSY}	0.16	0.06
MSY	2,585 mt	6,331 mt
B_{MSY}	12,722 mt	91,712 mt

Table 2: Forecasted probability that the western Atlantic bluefin tuna distinct population segment will go extinct by year and catch level, assuming the ICCAT high and low recruitment potential scenarios are equally plausible (Table 9.2 from Atlantic Bluefin Tuna Status Review Team 2011). Current management recommendations under ICCAT specify a TAC of 1,750 mt.

Catch Level (mt)	**Probability of Extinction**							
	2010	**2011**	**2020**	**2030**	**2040**	**2050**	**2060**	**2100**
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1250	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1500	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
1750	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02
2000	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.05
2250	0.00	0.00	0.00	0.01	0.04	0.08	0.12	0.15
2500	0.00	0.00	0.00	0.02	0.09	0.19	0.25	0.30
2750	0.00	0.00	0.00	0.04	0.20	0.34	0.42	0.54
3000	0.00	0.00	0.00	0.07	0.33	0.51	0.62	0.78
3500	0.00	0.00	0.00	0.18	0.63	0.84	0.91	0.95
4000	0.00	0.00	0.00	0.35	0.85	0.96	0.98	0.99
5000	0.00	0.00	0.00	0.73	0.99	1.00	1.00	1.00

Table 3: Canadian Atlantic bluefin tuna landings and discards (mt) by gear type (Anon 2011a).

Year	Gillnet	Harpoon	Longline	Purse Seine	Handline, Rod and Reel	Tended Line	Trap	Unclassi-fied	Discards	Total
1980					259		47	18		324
1981				105	279		41			425
1982						213	68	10		291
1983					71	355	7			433
1984					1	260	3			264
1985					1	121	20			142
1986			32		2	39				73
1987			33		1	32	17			83
1988			104		7	268	14			393
1989			53			579	1		14	633
1990			4		28	404	2			438
1991			6		32	447				485
1992			9		30	403	1			443
1993		33	25		88	284	29			459
1994		34	5		71	203	79			392
1995		43	4		195	262	72			576
1996		32	22		155	298	90			597
1997		55	12		245	138	59		6	509
1998		36	32		303	172	68		16	611
1999		38	31		348	125	44		11	587
2000		18	47		433	81	16		46	595
2001	<1	20	20		402	79	16		13	537
2002		13	53		508	39	28		37	641
2003		10	28		407	42	84		14	571
2004		7	43		421	49	32		15	552
2005		14	36		497	44	8			600
2006		20	48		629	35	3		2	735
2007		17	58		389	23	4			491
2008		24	30		471	24	23	4	1	576
2009		18	64		390	37	23		3	533

Table 4: Western Atlantic bluefin tuna landings (mt) by country (Anon. 2011a) where ARG = Argentina, BR = Brasil, CAN = Canada, CTAIP = Chinese Taipe, CUB = Cuba, FRSP = France St-Pierre and Miquelon, JPN = Japan, KOR = Korea, MEX = Mexico, NEI (ETRO) = Not Elsewhere Include East tropical, NEI (Flag) = Not Elsewhere Included under a country flag, SLC = San Lucia, TT = Trinidad & Tobago, USA = United States of America, UKB = United Kingdom Bermuda, and URU = Uruguay.

Landings	ARG	BR	CAN	CTAIP	CUB	FRSP	JPN	KOR	MEX	NEI (ETRO)	NEI (Flag)	SLC	TT	USA	UKB	URU
1985	6	1	142	3			1092						1	1424		16
1986			73	3			584							1142		6
1987	2	2	83	4			960					1		1352		
1988			393				1109					3		1289		2
1989	1	2	619	20			468			30		2		1483		
1990	2	1	438				550			24		14		1636		
1991			485				688			23		14		1582		1
1992			443				512			17		14		1085		
1993			459				581					2		1237		1
1994			392				427		4			43		1163		
1995			576				387					9		1311		2
1996			597				436		19		2	3		1285	1	
1997			503	2			322		2					1334	2	
1998			595				691		8					1235	2	
1999		13	576			1	365		14		429			1213	1	
2000			549				492		29		270			1212	1	
2001			524				506		10		49			1583	1	
2002			604		74	3	575		12					1840	1	1
2003			557		11	1	57		22					1426		
2004			537		19	10	470		9					899		
2005			600		27	5	265	1	10					717		
2006			733		19		376	52	14					468		
2007			491			4	277		7					758		
2008			575			3	492		7					764		
2009			530			2	162		10					1068		

Table 5: Western Atlantic bluefin tuna discards (mt) by country (Anon. 2011a) where CAN = Canada, JPN = Japan, and USA = United States of America.

Discards	CAN	JPN	USA
1985			0
1986			514
1987			99
1988			102
1989	14		119
1990			115
1991			128
1992			211
1993			88
1994			83
1995			138
1996			171
1997	6	8	155
1998	16		110
1999	11		149
2000	46		176
2001	13		98
2002	37		174
2003	14		218
2004	15		167
2005			131
2006	2		147
2007			100
2008	1		158
2009	3		160

Table 6: Probability that SSB in each year (from 2018 to 2025) will be less than the SSB in 2012, for catch scenarios from 0 to 3,500 mt (at 250 mt increments; based on the Anon. 2011b assessment from the low recruitment scenario and provided by the ICCAT Secretariat for this RPA); and for mitigation scenarios referred to in Figure 10.

Catch Scenario (mt)	**Mitigation Scenario (corresponds approximately to)**	**Probability $SSB_{year} < SSB_{2012}$**							
		2018	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
0	No catch in the western Atlantic	0	0	0	0	0	0	0	0
250	Bycatch only by all in the western Atlantic	0	0	0	0	0	0	0	0
500		0	0	0	0	0	0	0	0
750		0	0	0	0	0	0	0	0
1000		0	0	0	0	0	0	0	0
1250	No Canadian catch, others status quo catches in the western Atlantic	0.01	0.01	0.01	0	0	0	0	0
1500	½ Canadian catch, others status quo catches in the western Atlantic	0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.01
1750	Current western Atlantic TAC	0.14	0.10	0.08	0.06	0.05	0.04	0.04	0.04
2000		0.26	0.25	0.22	0.18	0.17	0.14	0.13	0.10
2250	2010 ICCAT Scientific (SCRS) Advice (ICCAT 2011a)	0.48	0.46	0.41	0.41	0.39	0.36	0.32	0.29
2500		0.67	0.66	0.66	0.62	0.61	0.59	0.57	0.54
2750		0.86	0.81	0.82	0.81	0.79	0.78	0.78	0.77
3000		0.93	0.93	0.92	0.92	0.92	0.92	0.93	0.93
3250		0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98
3500		0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00

FIGURES

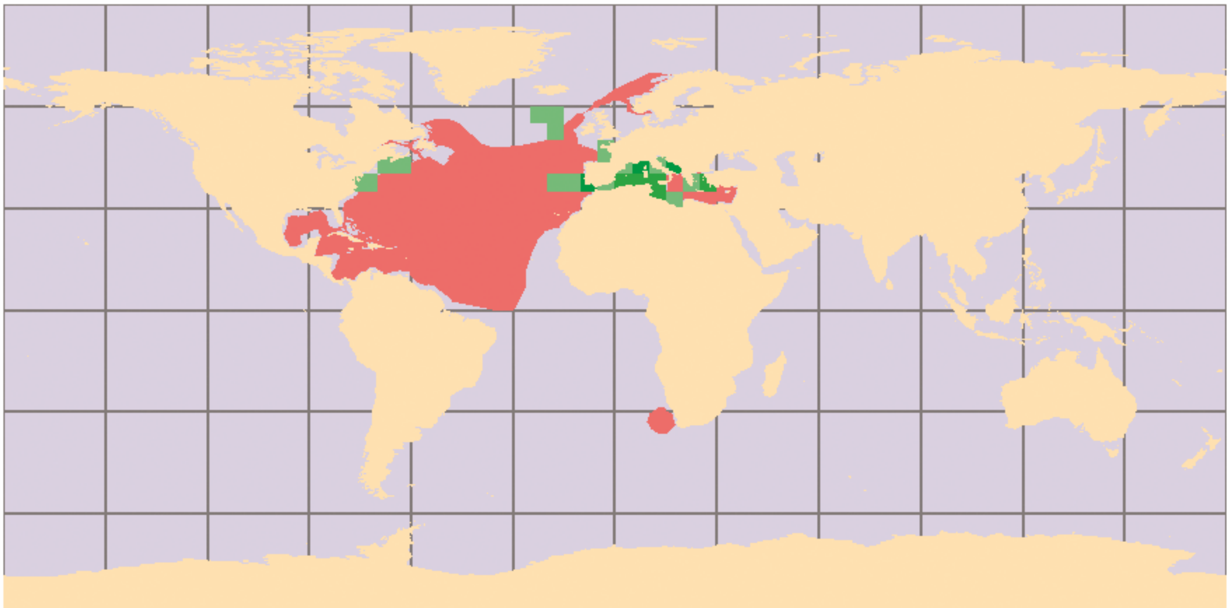

Figure 1: Worldwide distribution of Atlantic bluefin tuna (from Maguire et al. 2006).

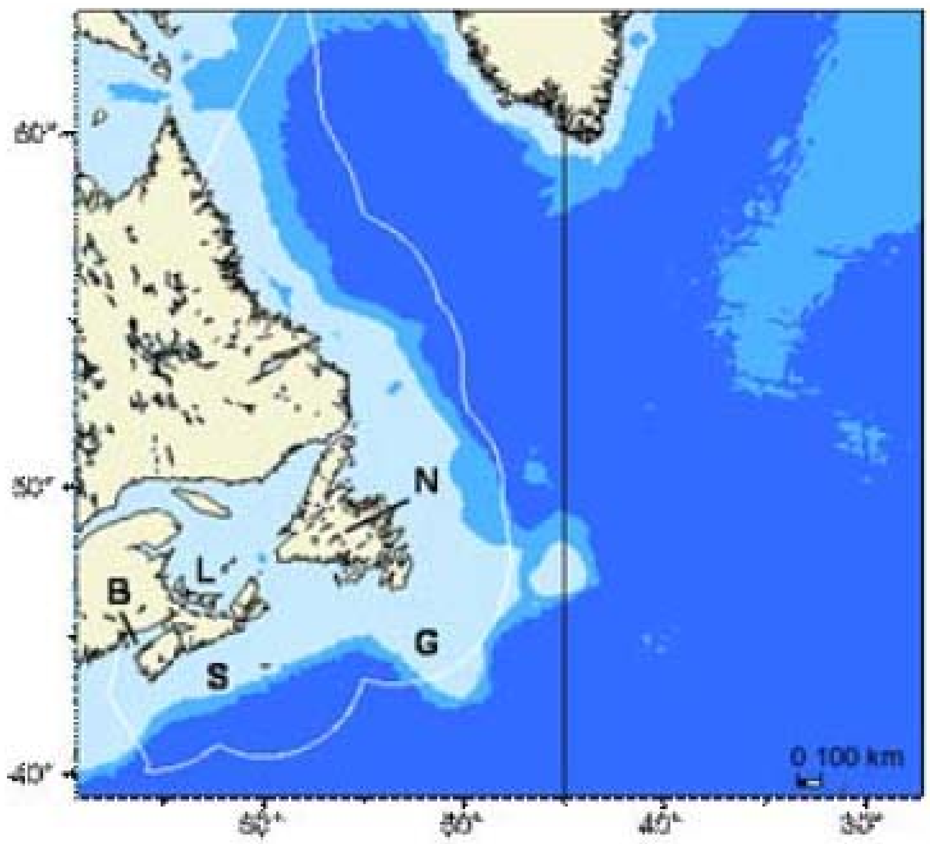

Figure 2. Areas mentioned in text. The black line represents the ICCAT management unit boundary between eastern and western Atlantic stocks (45º W), white line represents boundary of Canada's Exclusive Economic Zone and L= Gulf of St. Lawrence, N= Newfoundland, G=Grand Banks, S=Scotian Shelf, and B=Bay of Fundy.

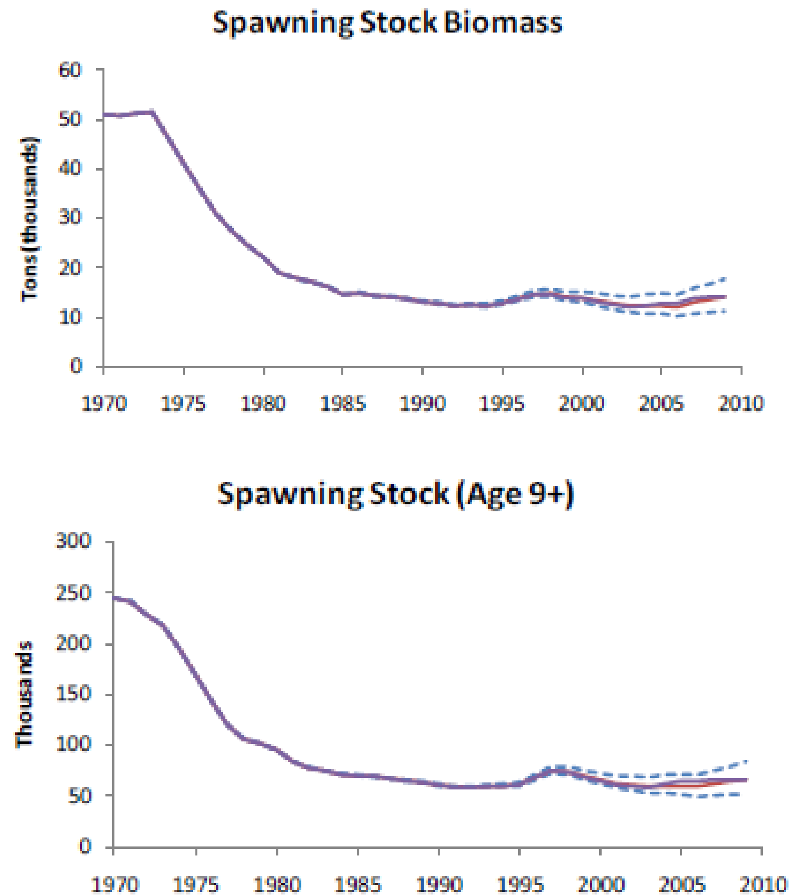

Figure 3: Median estimates of western Atlantic bluefin tuna spawning stock biomass and spawning stock numbers (age 9+) for the ICCAT base case virtual population analysis (VPA). The 80% confidence intervals are indicated with dashed lines. The recruitment estimates for the last three years have been replaced by the median corresponding to the low recruitment scenario (red line). (Figure 53 from Anon. 2011b.)

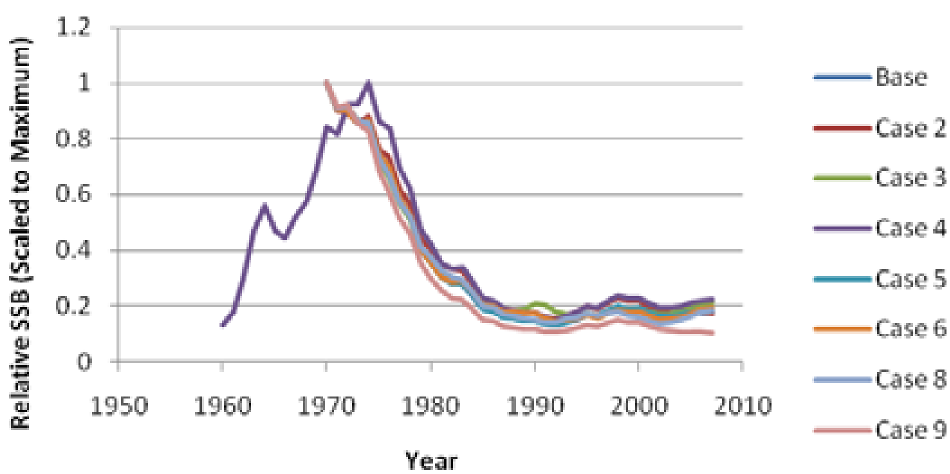

Figure 4: Trends in western Atlantic bluefin tuna relative spawning stock biomass shown for various scenarios explored by the ICCAT SCRS during their 2008 assessment (Figure 35 from Anon. 2009), along with the base case. Case 4 extended the time series back to 1960.

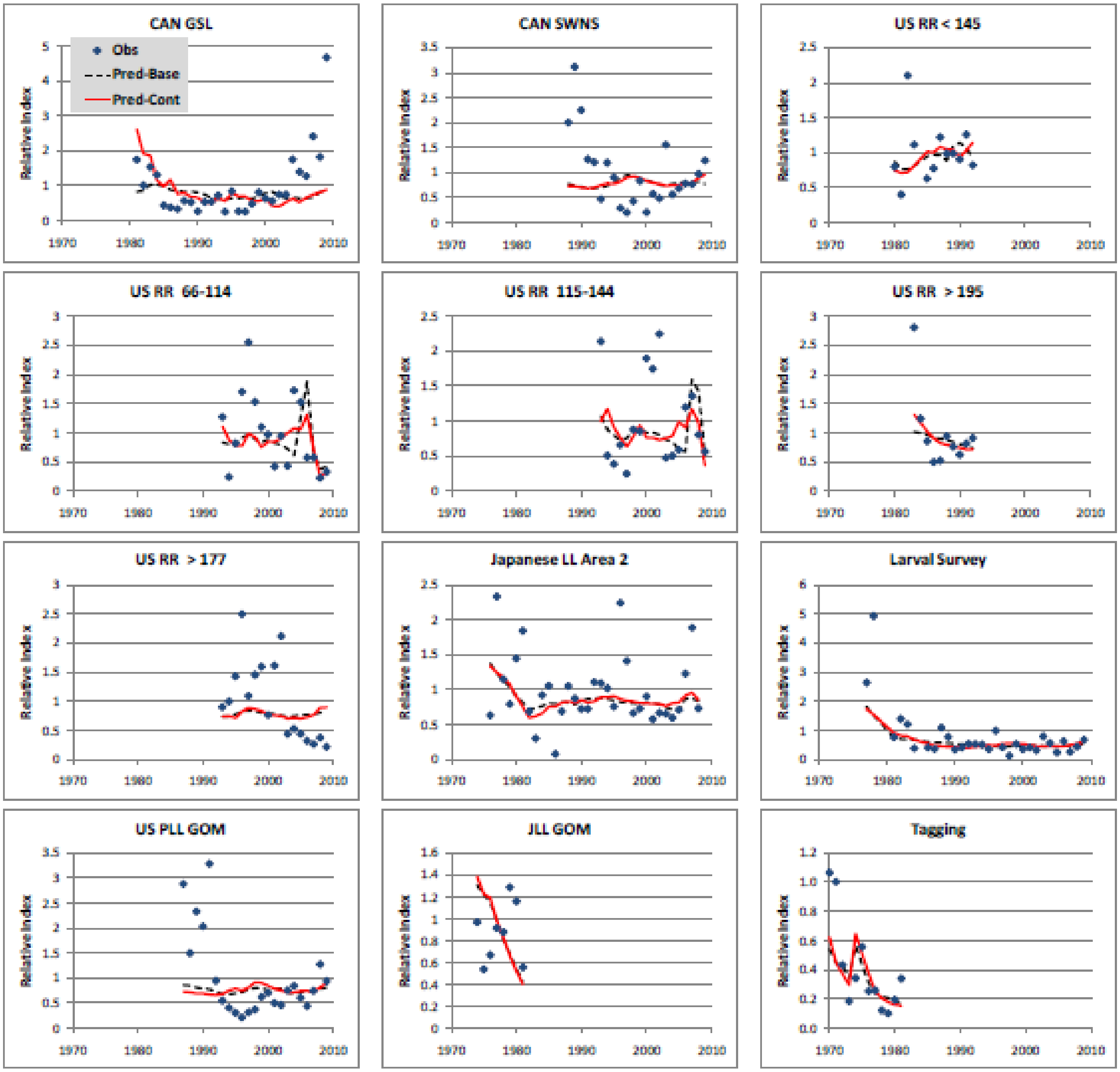

Figure 5: Indices of stock size used in the 2010 ICCAT assessment and fits to these indices for western Atlantic bluefin tuna continuity VPA (solid line) and base VPA (dashed line). (Figure 47 from Anon. 2011b.)

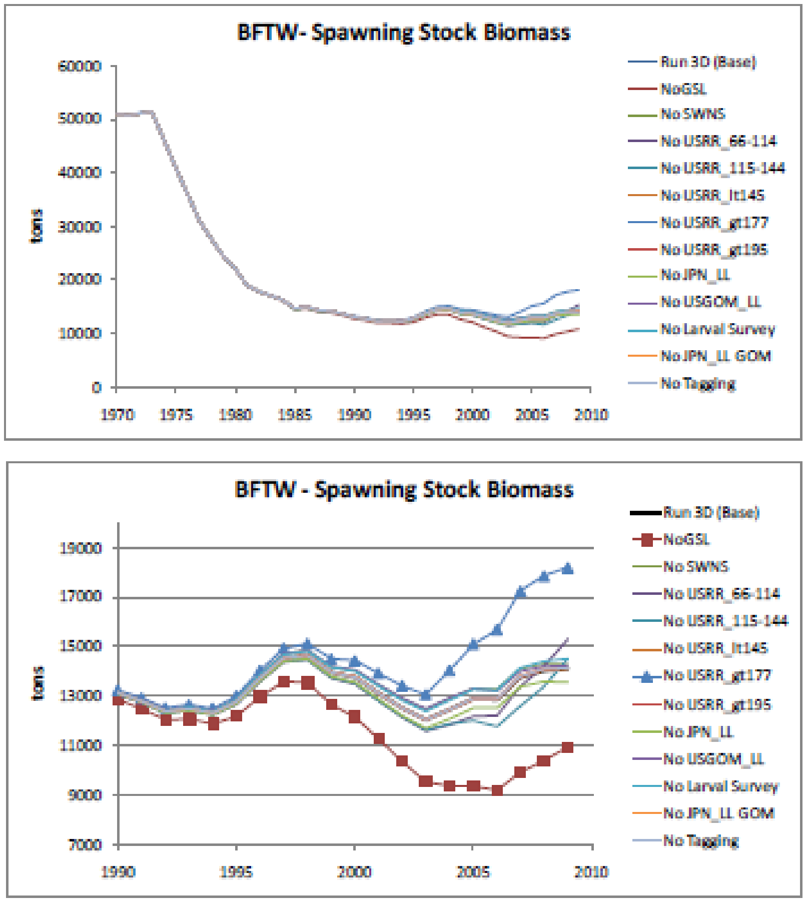

Figure 6: Examination of the influence of individual stock size indices used in the assessment by removing them one at a time (Figure 55 from Anon. 2011b). The upper panel shows the period 1970-2009, and the lower panel shows 1990-2009.

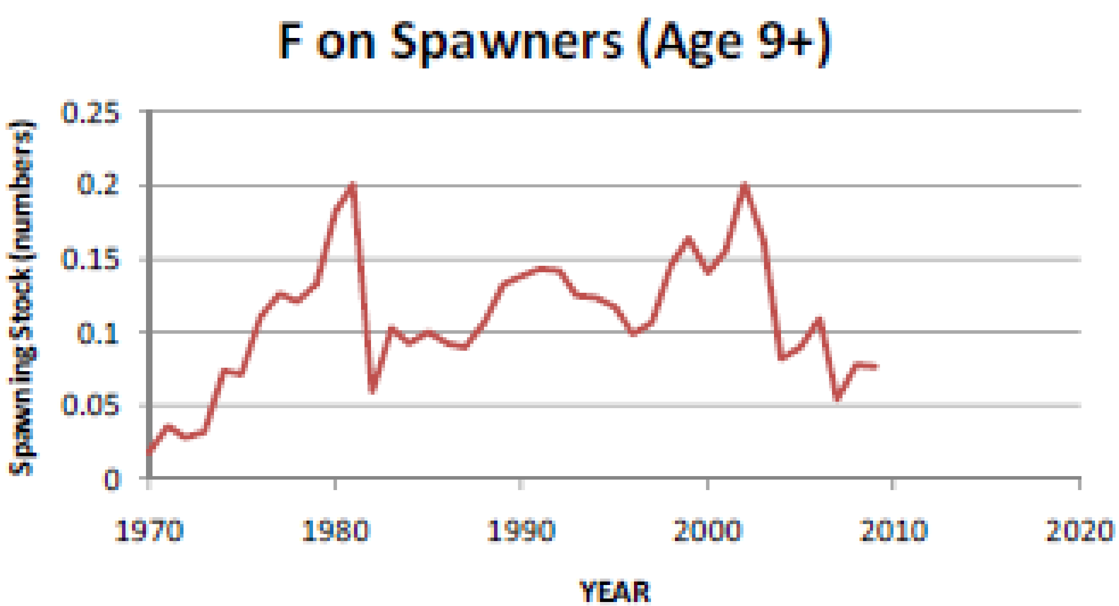

Figure 7: Trends in fishing mortality on spawners from the 2010 ICCAT assessment for Atlantic bluefin tuna. (Anon. 2011b.)

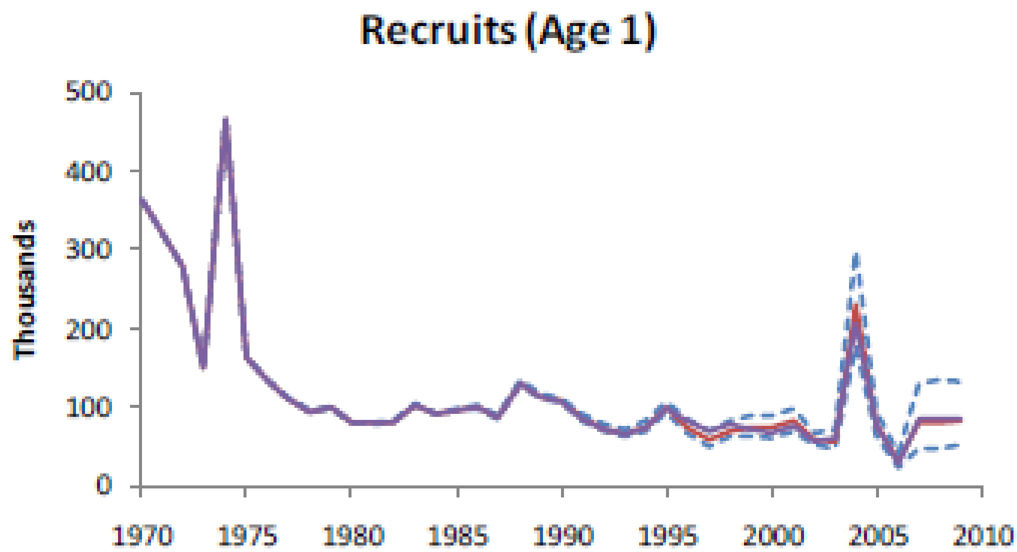

Figure 8: Median estimates of western Atlantic bluefin tuna recruits for the ICCAT base case virtual population analysis (VPA). The 80% confidence intervals are indicated with dashed lines. The 2007-2009 estimates have been replaced by values from the two line stock and recruitment relationship (red line). (Figure 53 from Anon. 2011b.)

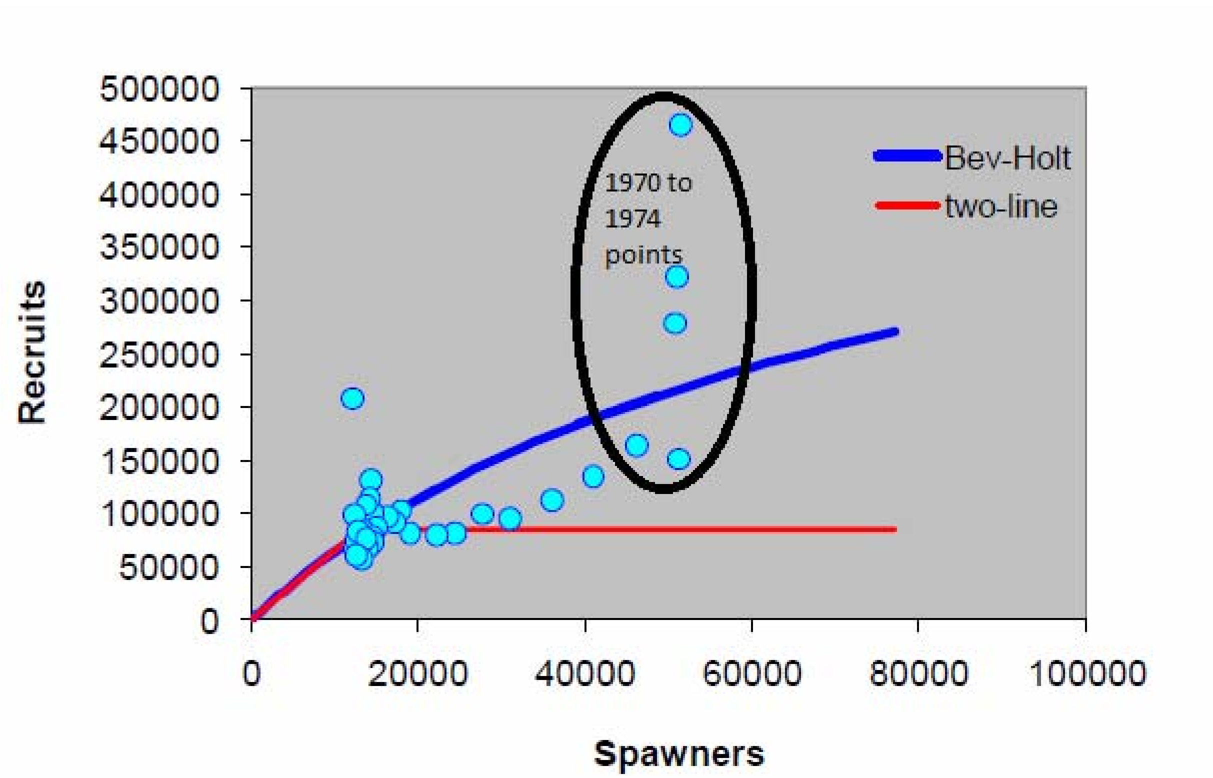

Figure 9: Western Atlantic bluefin tuna stock and recruitment observations (Figure 57 from Anon. 2011b).

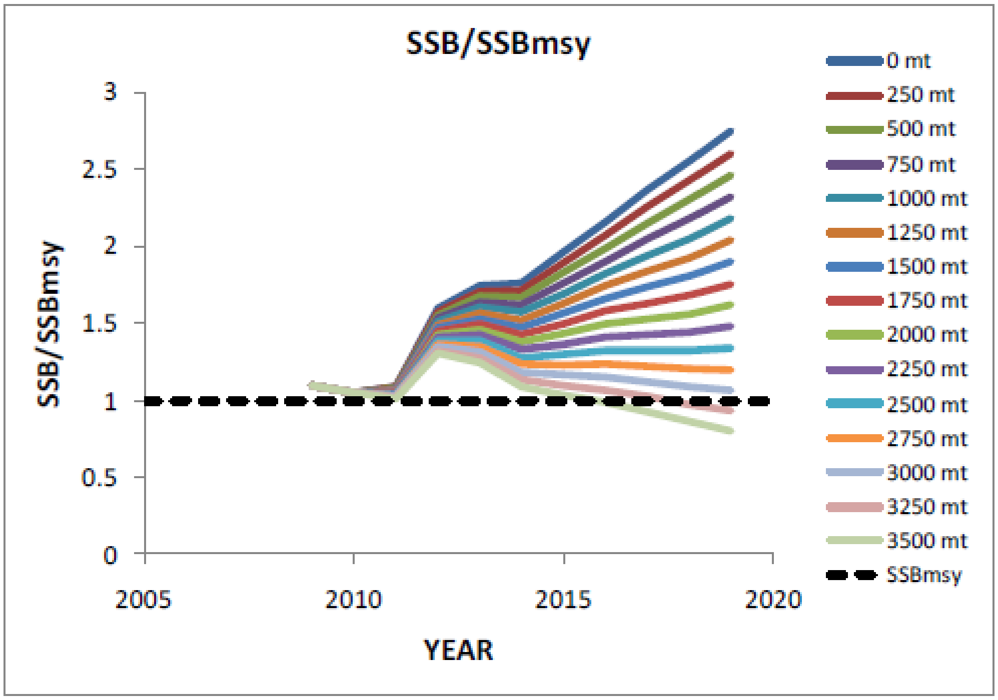

Figure 10: Western Atlantic bluefin tuna projection results relative to 2012 under various catch scenarios, low recruitment scenario (Figure 65 from Anon. 2011b). These approximate the following mitigation scenarios: 0 mt - no catch in the western Atlantic; 250 mt - bycatch only by all in the western Atlantic; 1,250 mt - no Canadian catch, others status quo catches in the western Atlantic; 1,500 mt - ½ Canadian catch, others status quo catches in the western Atlantic; 1,750 mt - current western Atlantic total allowable catch; 2,250 mt - 2010 ICCAT scientific advice.

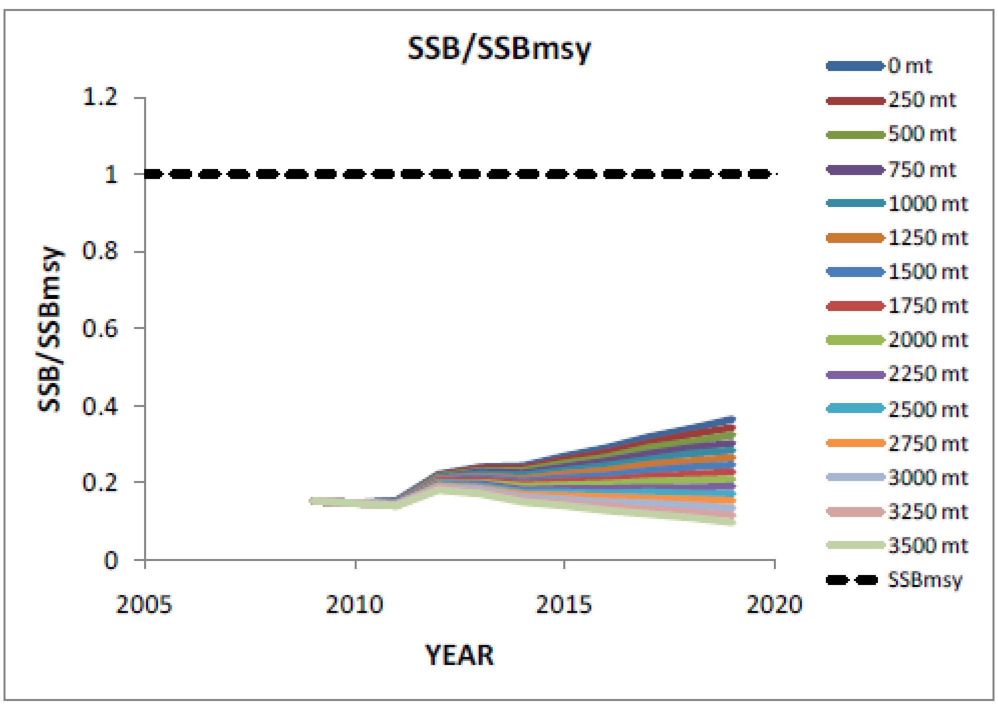

Figure 11: Western Atlantic bluefin tuna projection results under various catch scenarios, high recruitment scenario (Figure 66 from Anon. 2011b).

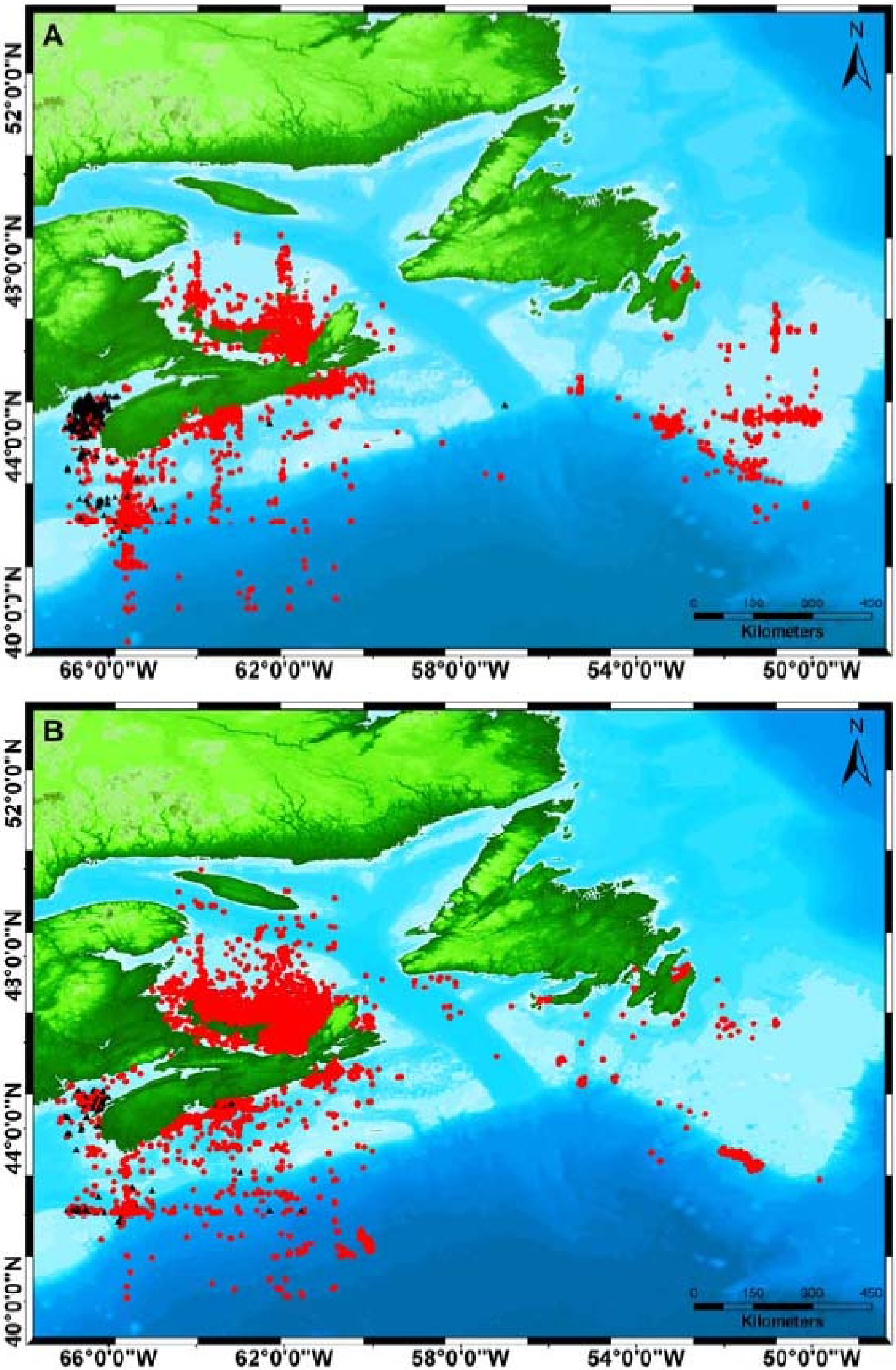

Figure 12: Location of Canadian Atlantic bluefin tuna catches by gear (red circle = hook line and black triangle = harpoon) in the Gulf of St. Lawrence, Maritimes and Newfoundland regions from logbook records from 1990-1999 (A) and 2000-2009 (B) (Figure 5 from COSEWIC 2011).

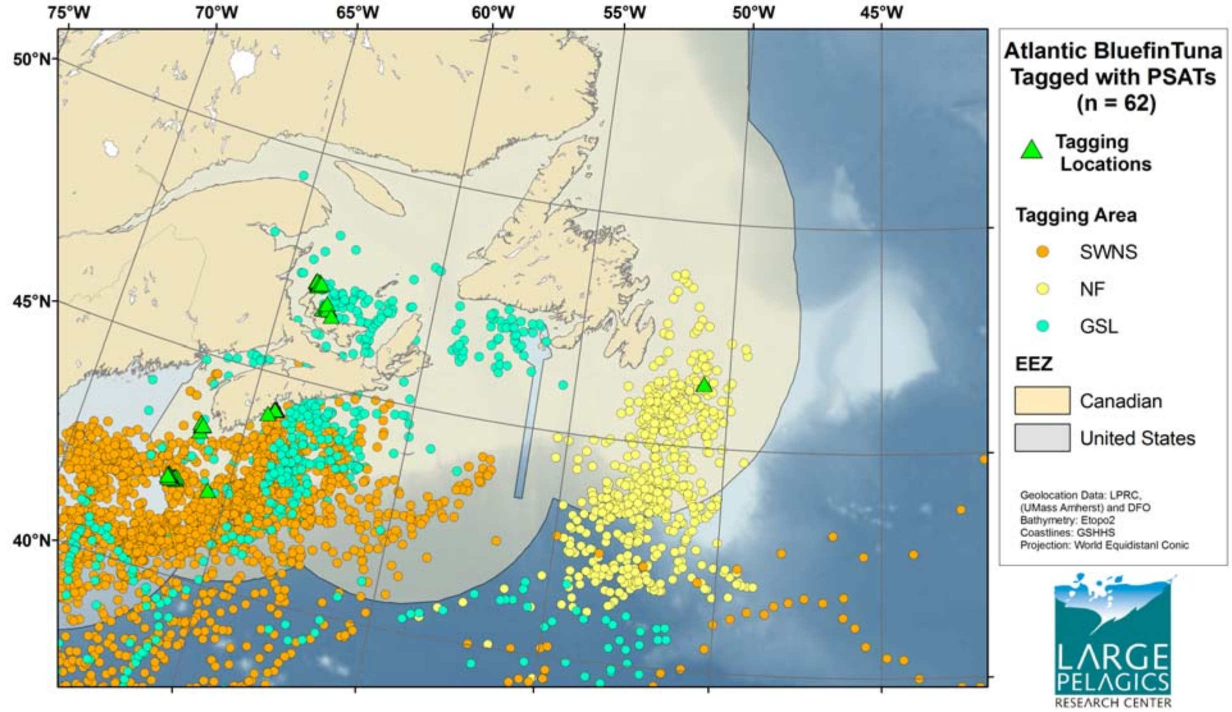

Figure 13: Daily geolocation estimates of 62 Atlantic bluefin tuna tagged off the Canadian Atlantic Provinces from 2005 to 2009. Tagging areas were southwestern Nova Scotia (SWNS), the Gulf of St. Lawrence (GSL) and the Grand Banks of Newfoundland (NF). Position information was estimated using sea surface temperature inclusive of Kalman filtering and bathymetric correction. Exclusive Economic Zone (EEZ) boundaries show residency and cross boundary movements of tagged Atlantic bluefin tuna. (Lutcavage et al. unpublished data; permission for use outside the context of this RPA requires the permission of the authors.)