SECOND MEETING OF THE WORKING GROUP OF FISHERIES MANAGERS AND SCIENTISTS IN SUPPORT OF THE WBFT STOCK ASSESSMENT

(*Prince Edward Island, Canada – 10-12 July 2014)*

1. Opening of the meeting

The Canadian Minister of Fisheries and Oceans, the Honorable Gail Shea, welcomed the participants to Prince Edward Island, noting the importance of bluefin tuna to fishing communities and the need for continued investments in data collection that will help to address the existing uncertainties in the science. She closed by noting the joint commitment to ensuring sustainability of this fishery and wishing the delegates a productive meeting (**Appendix 3**).

2. Election of Chair

Ms. Sylvie Lapointe of Canada and Dr. Josu Santiago, the SCRS Chair, were elected as co-Chairs of the Working Group.

3. Adoption of agenda and meeting arrangements

The co-Chairs stressed the importance of the ongoing scientist-manager dialogue, as it will help the SCRS tailor their work to most effectively support the needs of the Commission.

The agenda was slightly modified and adopted (**Appendix 1**).

The Executive Secretary introduced the following CPCs: Canada, EU, Japan, Mexico, and the United States. In addition, the following observers were present: American Bluefin Tuna Association; Blue Water Fishermen's Association; Ecology Action Centre; The Ocean Foundation; Pew Environment Group; and the David Suzuki Foundation. The list of participants is attached as **Appendix 2**.

4. Nomination of rapporteur

The United States offered Ms. Rachel O'Malley as a rapporteur.

5. Review of the results of the 1st Working Group of Fisheries Managers and Scientists in Support of the Western Atlantic Bluefin Tuna Stock Assessment and 23rd Regular Meeting of the Commission

Dr. Santiago highlighted some activities related to the recommendations from the 1st meeting of WBFT Scientists and Managers, as well as a timeline for the current work plans of the SCRS. A stock assessment update will be conducted for eastern and western stocks in September 2014 and there will also be a pilot assessment for the eastern Atlantic stock incorporating new information including catch-at-size data from the Mediterranean purse seine fishery. At this time, a full assessment making use of new methodologies for both stocks is still planned for 2015, and work towards the development of a full management strategy evaluation will continue. However, the work plans will be reviewed and potentially revised when the SCRS meets this fall. Dr. Santiago expressed concern that key electronic tagging data are not yet available and must be provided as soon as possible. He also noted that full funding of the Grande Bluefin Tuna Year Program (GBYP) is critical.

Canada, Japan, Mexico and the United States provided updates on relevant research activities that are underway.

6. Review of research plans developed by CPCs

Dr. Craig Brown presented the U.S. proposals for improving the scientific information for stock assessment of bluefin tuna (**Appendices 4 and 5**), which included developing a pilot study for an age-0 index of abundance for bluefin tuna and expanding the existing larval survey; enhancing the current collection of biological material;

and the development of a genomic based approach (i.e., applying a close-kin analysis to estimate spawning stock abundance).

Dr. Gary Melvin presented Canada's proposal for the development and implementation of a fishery independent index of abundance for Gulf of St. Lawrence bluefin tuna using an acoustic trolling survey (**Appendix 6)**.

Dr. Michael Stokesbury presented Canada's proposal for a bluefin tuna mark and recapture study in the Gulf of St. Lawrence (**Appendix 7)**.

Dr. Tomoyuki Itoh presented Japan's proposal for a research plan identifying areas for new or improved indices of abundance in the central North Atlantic (**Appendix 8**).

Dr. Alex Hanke (Canada) offered a presentation on the potential application of a non equilibrium surplus production model for the assessment of the western Atlantic bluefin tuna stock (**Appendix 9**).

Dr. Gary Melvin gave a presentation on considerations to improve the indices used by managers (**Appendix 10**).

Dr. Tomoyuki Itoh presented a working document on the coverage of fishery data for the western Atlantic bluefin tuna stock (**Appendix 11**).

Some approaches recently applied to study southern bluefin tuna show promise for studying the western Atlantic bluefin tuna stock. It was recognized that different initiatives could be designed to complement one another, for example by providing opportunities for collection of biological material. A coordinated approach to biological sampling might be an effective way to identify and fill data gaps. Current indices may be improved by greater efforts to take into account the effects of changing fishing patterns or practices, environmental conditions and management regulations that may affect CPUE.

It was generally agreed that sampling programs and surveys should cover as broad a geographic area as possible, although these efforts may be limited by logistical concerns and available budgets. Sampling in smaller areas or during short periods of time may reflect local abundance rather than overall trends in stock abundance. Any new indices would not yield information usable to the assessment for many years, and so should be considered as long-term investments rather than short-term solutions. There was interest in exploring the extent of possible spawning areas outside the Gulf of Mexico through new survey work.

The CPCs agreed that any new initiatives should be designed to provide information that will have a meaningful benefit for future stock assessments, including by helping to inform work related to the question of recruitment. Financial commitments to future projects should be considered in the context of potential benefits to the stock assessment process as well as practical concerns and associated costs (e.g., taking advantage of existing funding and research platforms). Some projects can be explored through pilot studies with the potential for expansion once the variables and limitations are better understood. Collaboration among the western Atlantic bluefin tuna harvesters as well as with researchers in other regions was encouraged.

In conclusion, the parties agreed that:

1) In the intersessional period, national scientists of the CPCs fishing for western bluefin tuna will work jointly to explore areas for collaboration, identify costs and develop their prioritization for the novel research proposals discussed at this meeting. The results of this work and the novel proposals will be presented to the SCRS in September 2014 for review and evaluation. At the same time, it was acknowledged that CPCs will proceed with work already underway (e.g., the expansion of existing surveys) and new projects for which funding has been secured.

2) The CPCs will collaborate in analyzing non-aggregated catch and effort data with the goal of improving the current stock abundance indices and developing a single index of abundance incorporating the data from various CPCs. Access to the data will be shared in a manner that does not violate data confidentiality concerns.

3) The CPCs will continue efforts to improve the quality and quantity of data collection and reporting, consistent with the recommendations of the SCRS. In particular, CPCs are encouraged to provide information about changes in fishing patterns and other variables that may influence the catch rate so that these factors can be incorporated into the standardization models.

7. Consideration of possible ways to improve the management of the stock

Japan suggested that maximizing the survival of juvenile western Atlantic bluefin tuna should be considered as an alternative management strategy. The United States noted that the SCRS already provided advice in 2012 on the question of size-based management measures and that further restricting catch of certain size classes would result in loss of valuable data used in the assessment. The Working Group reached agreement on the next steps relating to this agenda item (**Appendix 12**).

The Pew Charitable Trusts, Ecology Action Center, David Suzuki Foundation and The Ocean Foundation presented a statement **(Appendix 13).**

8. Other matters

Participants all agreed on the importance of continuing this dialogue, either in a 3rd meeting of the WBFT Working Group or as part of the newly established Standing Working Group to Enhance Dialogue Between Fisheries Scientists and Managers. This will be discussed within Panel 2 at the 2014 Commission Meeting. A discussion is needed to establish a mechanism for referring the recommendations of this Working Group, and the Standing Working Group of scientists and managers, to the SCRS, taking into account the heavy workload of the SCRS.

9. Adoption of Report and adjournment

The report was adopted and the Second Meeting of the Working Group of Fisheries Managers and Scientists in Support of the WBFT Stock Assessment was adjourned.

Appendix 1

AGENDA

1. Opening of the meeting
2. Election of Chair
3. Adoption of agenda and meeting arrangements
4. Nomination of rapporteur
5. Review of the results of 1st WG of Fisheries Managers and Scientists in Support of the Western Atlantic Bluefin Tuna Stock and 23rd Regular meeting of the Commission
6. Review of research plans submitted by CPCs to obtain reliable stock abundance indices for BFT of western origin
7. Consideration of possible ways to improve the management of the stock
8. Other matters
9. Adoption of Report and adjournment

Appendix 2

LIST OF PARTICIPANTS

SCRS CHAIRMAN

Santiago Burrutxaga, Josu
SCRS Chairman - Head of Tuna Research Area, AZTI-Tecnalia, Txatxarramendi z/g, 48395 Sukarrieta (Bizkaia) País Vasco, Spain
Tel: +34 94 6574000 (Ext. 497), 664303631, Fax: +34 94 6572555, E-Mail: jsantiago@azti.es; flarrauri@azti.es

CONTRACTING PARTIES

CANADA

Andrushchenko, Irene
Large Pelagic Biologist, St. Andrews Biological Station/ Biological Station, Fisheries and Oceans Canada 531 Brandy Cove Road, St. Andrews New Brunswick E5B 2L9, Canada
Tel: +1 506 529 5749, E-Mail: irene.andrushchenko@dfo-mpo.gc.ca

Atkinson, Troy
155 Chain Lake Dr, Suite #9, Halifax, Nova Scotia B39 1B3, Canada
Tel: +1 902 457 4968, Fax: 902 457 4990, E-Mail: hilincr@ns.sympatico.ca

Cherry, Mike
P.O. Box 1236, Charlottetown, Prince Edward Island, Canada
E-Mail: MICHAEL.CHERRY@DFO_PO.gc.ca

Drake, Kenneth
Prince Edward Island Fishermen's Associations, P.O. Box 154, 43 Coffin Road, Charlottetown Prince Edward Island, COA ISO, Canada
Tel: +1 902 961 3341, Fax: +1 902 961 3341, E-Mail: kendrake@eastlink.ca

Eagles, Michael
176 Portland St. Marine House, Dartmouth Nova Scotia B2Y 4T3, Canada
Tel: 1 902 426 8981, Fax: +1 902 4269683, E-Mail: michael.Eagles@dfo-mpo.gc.ca

Elsworth, Samuel G.
South West Nova Tuna Association, 228 Empire Street, Bridgewater Nova Scotia B4V 2M5, Canada
Tel: +1 902 543 6457, Fax: +1 902 543 7157, E-Mail: sam.fish@ns.sympatico.ca

Fraser, Douglas
1600 Union Road, Alberton, Prince Edward Island, Canada
Tel: +1 902 853 2793, Fax: +1 902 853 8479, E-Mail: DougFRASER@BELLALIANT.NET

Jacquard, Eric
P.O. Box 465, Lower Wedgeport, Yarmouth County, Nova Scotia B0W 2B0, Canada
Tel: +1 902 663 4419, Fax: +1 902 663 2879, E-Mail: jacko@ns.sympatico.ca

Johnson, Kate
200 Kent St., Ottawa, ON, KIA OE6, Canada
Tel: 613 993 2877, Fax: 613 993 5995, E-Mail: KateJohnson@dfo-mpo.gc.ca

Hanke, Alex
531 Brandy Cove Rd, St. Andrews, NB E5B 2L9, Canada
E-Mail: alex.hanke@dfo-mpo.gc.ca

Lapointe, Sylvie[*]
Director, Fisheries Management Plans, Department of Fisheries & Oceans200 Kent Street, Ottawa Ontario K1A 0E6, Canada
Tel: + 1 613 993 6853, Fax: + 1 613 993 5995, E-Mail: sylvie.lapointe@dfo-mpo.gc.ca

Macewen, David
548 Main Street, Montague, PEI, Canada C0A1RO, Canada
Tel: 902 838 0635, Fax: 902 838 0975, E-Mail: dgmacewen@gov.pe.ca

[*]Head delegate.

MacLean, Don
Nova Scotia Dept. of Fisheries and Aquaculture, P.O. Box 700, Pictou, NS B0K 1H0, Canada
Tel: +1902 485 7021, Fax: +1902 485 4014, E-Mail: macleand@gov.ns.ca

Mallet, Pierre
Department of Fisheries and Oceans Canada, P.O BOX 5030, Moncton, New Brunswick E1C 9B6, Canada
Tel: + 506 851 7792, Fax: +506 851 2607, E-Mail: malletP@dfo-mpo-gc.ca

Melvin, Gary
Biological Station - Fisheries and Oceans Canada, Department of Fisheries and Ocenas531 Brandy Cove Road, St. Andrews, New Brunswick, E5B 2L9, Canada
Tel: +1 506 529 5874, Fax: +1 506 529 5862, E-Mail: gary.melvin@dfo-mpo.gc.ca

Norton, Brett
Advisor, International Fisheries Management, Fisheries and Oceans Canada 200 rue Kent St., Ottawa, Ontario K1A 0E6, Canada
Tel: +1 613 993 1860, Fax: +1 613 993 5995, E-Mail: Brett.Norton@dfo-mpo.gc.ca

Ramsay, Laura
Prince Edward Island fishermen's Association, Suite 102, 420 University Avenue, Prince Edward Island Charlottetown, Canada
Tel: +902 393-2281/+902 566-4050, E-Mail: researchpeifa@eastlink.ca

Scattolon, Faith*
Regional Director-General, Maritimes Region, Department of Fisheries & Oceans 176 Portland Street, Dartmouth, Nova Scotia B2Y 1J3, Canada
Tel: +1 902 426 2581, Fax: +1 902 426 5034, E-Mail: scattolonf@dfo-mpo.gc.ca

Stokesbury, Mike
Tel: +1 902 585 1195, Fax: +1 902 585 1059, E-mail: mike.stokesbury@Acadian.ca

Turple, Justin
International Fisheries Advisor, International Affaires Directorate, Fisheries and Oceans, 200 Rue Kent St., Ottawa, Ontario K1A 0L8, Canada
Tel: +1 613 998 1524, Fax: +1 613 954 1407, E-Mail: justin.turple@dfo-mpo.gc.ca

EUROPEAN UNION

Daniel, Patrick*
Commission européenne - DG Mare Unité - B3, J-99 02/53, 1000 Bruxelles, Belgium
Tel: +322 229 554 58, E-Mail: patrick.daniel@ec.europa.eu

JAPAN

Ito, Tomoyuki
Chief, Temperate Tuna Group, Bluefin Tuna Resources Division, National Research Institute of Far Seas Fisheries5-7-1 Orido, Shimizu-Ku, Shizuoka-City, Shizuoka 424-8633, Japan
Tel: +81-54-3336-6000, Fax: +81-54-335-9642, E-Mail: itou@fra.affrc.go.jp

Miyahara, Masanori*
Adviser to the Minister of Agriculture, Forestry and Fisheries, 1-2-1, Kasumigaseki, Tokyo Chiyoda-ku 100-8907, Japan
Tel: +81 3 3502 8460, Fax: +81 3 3504 2649, E-Mail: masamiya@fra.affrc.go.jp

Tominaga, Haruo
Assistant Director, International Affairs Division, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries1-2-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8907, Japan
Tel: +81 3 3502 8460, Fax: +81 3 3504 2649, E-Mail: haruo_tominaga@nm.maff.go.jp

MEXICO

Ramírez López, Karina*
Jefe de Departamento DGAIPA-INAPESCA, Instituto Nacional de Pesca - Sagarpa, Av. Ejército Mexicano No.106 - Colonia Exhacienda, Ylang Ylang, C.P. 94298 Boca de Río Veracruz
Tel: +52 22 9130 4518, Fax: +52 22 9130 4519, E-Mail: kramirez_inp@yahoo.com;

UNITED STATES

Brown, Craig A.
Chief, Highly Migratory Species Branch, Sustainable Fisheries Division, NOAA Fisheries Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149, United States
Tel: +1 305 361 4590, Fax: +1 305 361 4562, E-Mail: craig.brown@noaa.gov

Devnew, Jack
260 Yarmouth St., Norfok, VA 23514, United States
Tel: 757 457 8399, Fax: E-Mail: jdevnew@COMPASSNORFOLK.com

Díaz, Guillermo
NOAA-Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami Florida 33149, United States
Tel: +1 305 361 4277, Fax: E-Mail: guillermo.diaz@noaa.gov

McHale, Brad
NOAA - National Marine Fisheries Service, 55 Great Republic Dr., Gloucester, MA 01930, United States
Tel: +1 978 281 9260, Fax: +1 978 281 9340, E-Mail: brad.mchale@noaa.gov

McLaughlin, Sarah
Fishery Management Specialist, National Marine Fisheries Service, Highly Migratory Species Management Division 55 Great Republic Drive, Massachusetts Gloucester 01930, United States
Tel: +978 281 9279, Fax: +978 281 9340, E-Mail: sarah.mclaughlin@noaa.gov

Miller, Shana
The Ocean Foundation, 1320 19th St. NW, 5th Floor, Washington, DC 20036, United States
Tel: 631 671 1530, E-Mail: smiller@oceanfdn.org

O'Malley, Rachel
Office of International Affairs, National Marine Fisheries Service,1315 East-West Highway - Room 10653, Silver Spring, MD 20910
Tel: +1 301 427 8373, Fax: +1 301 713 2313, E-Mail: rachel.o'malley@noaa.gov

Peel, Ellen
The Billfish Foundation, 5100 North Federal Highway, Suite 200, Fort Lauderdale Florida 33308, United States
Tel: +1 954 593 1231, Fax: +1 954 938 5311, E-Mail: ellen_peel@billfish.org

Piñeiro Soler, Eugenio
Chairman, Caribbean Fishery Management Council, 723 Box Garden Hills Plaza, Guaynabo, Puerto Rico 00966
Tel: +1 787 234 8403, Fax: +1 787 834 8102, E-Mail: iris-oliveras@yahoo.com; gpsfish@yahoo.com

Smith, Russell*
Deputy Assistant Secretary for International Fisheries, Office of the Under Secretary, Room 6224, National Oceanic and Atmospheric Administration; U.S. Department of Commerce, 14th and Constitution Avenue, N.W., Washington, D.C. 20503
Tel: +1 202 482 5682, Fax: +1 202 482 4307, E-Mail: russell.smith@noaa.gov

Warner-Kramer, Deirdre
Senior Foreign Affairs Officer, Office of Marine Conservation (OES/OMC), U.S. Department of State Rm 2758, 2201 C Street, NW, Washington, D.C. 20520-7878
Tel: +1 202 647 2883, Fax: +1 202 736 7350, E-Mail: warner-kramerdm@state.gov

OBSERVERS FROM NON-GOVERNMENTAL ORGANIZATIONS

Atlantic Bluefin Tuna Association
Golet, Walter
350 Commercial Street, Portland, ME 04101, United States
Tel: 207 228 1695 Fax: E-Mail: Walter.golet@maine.edu

Blue Water Fishermen's Association
Delaney, Glenn
Blue Water Fishermen's Association, 601 Pennsylvania Avenue NW Suite 900 South Building, Washington, D.C. 20004, United States
Tel: +1 202 434 8220, Fax: +1 202 639 8817, E-Mail: grdelaney@aol.com

David Suzuki Foundation
Wallace, Scott
Senior Research Scientist, David Suzuki Foundation, 219-2211 West 4th Avenue, Vancouver BC V6K 4S2,
Tel: +1 604 732 4228, E-Mail: swallace@davidsuzuki.org

EAC- Ecology Action Centre
Grant, Catharine
EAC- Ecology Action Center, 2705 Fern Lane, Halifax BS B3K 4L3, Canada
Tel: +1 902 446 4840, Fax: +1 902 405 3716, E-Mail: cgrant@ecologyaction.ca

Grant, Heather
EAC- Ecology Action Center, 2705 Fern Lane, Halifax BS B3K 4L3, Canada
Tel: +1 902 446 4840, Fax: +1 902 405 3716, E-Mail: heatherg@ecologyaction.ca

Schleit, Kathryn
Ecology Action Centre - EAC, 2705 Fern Lane, Halifax B3K 4L3, Canada
Tel: +1 902 488 4078, E-Mail: kschleit@ecologyaction.ca

Pew Environment Group
Hopkins, Rachel
Pew Environment Group, 901 E Street, Nw, 10th Floor, Washington DC 20009, United States
Tel: +1 215 713 5383, E-Mail: rhopkins@pewtrusts.org

The Ocean Foundation
Powers, Joseph E.
The Ocean Foundation, 8465 SW 141 Street, Palmetto Bay, Fl 33149, United States
Tel: +1 225 578 7659, Fax: +1 225 578 6513, E-Mail: jepowers@lsu.edu

****

ICCAT
ICCAT SECRETARIAT, C/ Corazón de María, 8 - 6 Planta, 28002 Madrid, SPAIN
Tel: + 34 91 416 5600, Fax: +34 91 415 2612, E-Mail: info@iccat.int

Meski, Driss
Pallarés, Pilar
De Andrés, Marisa
Donovan, Karen
Pinet, Dorothée
Ballantyne, Linda
Daguerre, Christine
Dubois, Emanuelle
Dykstra, Jennifer
Fulton, Janet
Massieu, Jorge
Racette, Marie Eve
Rochon, Michelle
Santo Domingo, Gloria

Appendix 3

OPENING STATEMENT BY THE HONOURABLE GAIL SHEA, MINISTER OF FISHERIES AND OCEANS OF CANADA

Thank you all for travelling from various corners of the globe for this important meeting.

Welcome to Canada and my home province of Prince Edward Island. It is my great pleasure to be here as the Minister of Fisheries and Oceans. Last year, I returned to this portfolio and I'm so pleased to be working hard, once again, on behalf of Canadian fish harvesters.

I am very proud to say that Canada has one of the best managed tuna fisheries in the world — one that is based on scientific advice, effective management, and strict enforcement.

The Canadian Atlantic bluefin tuna fishery operates today the same way it has for decades — with small inshore vessels from many small fishing communities. A good example of this is in Tignish, where I grew up. While the fish harvesters in Tignish may only be able to catch one bluefin tuna each year, it is certainly something they all look forward to. The fishery is equally important to other tuna harvesters in the other Atlantic Canadian provinces of Newfoundland, New Brunswick, Nova Scotia, and Quebec.

This iconic species supports important fisheries on both sides of the Atlantic Ocean. The International Commission for the Conservation of Atlantic Tunas, with its 49 members, is certainly an important organization. In order for the Commission to succeed in sustainably managing the highly migratory fish stocks under its purview, meetings such as this one are essential.

Clearly, we all have a vested interest in the future of the western Atlantic bluefin tuna stock as well as the health of the eastern Atlantic bluefin tuna stock.

Probably like many of you, I have heard concerns from the Canadian industry. They are disappointed that sacrifices in the form of quota reductions and huge financial investments in scientific research have not allowed us to move forward in recent years.

I understand there was a very productive meeting in Montreal last year, which highlighted many of the uncertainties in the western bluefin tuna stock assessment and emphasized the need for new or improved data to get us past the high versus low recruitment issue.

Like many of you, we are eager to develop new approaches that will allow us to move beyond the current circumstances in which we have inconclusive scientific evidence that, practically speaking, makes it very difficult for managers to make decisions related to the stock.

Moving forward, the focus should be on developing tools for providing scientific advice that is clearer, more practical, and that ensures the health of the stock so that it can continue to provide important economic benefits to coastal communities. To do this properly, meetings such as this one — which bring together scientists and managers — are necessary and extremely helpful.

Confidence in science requires sound data and I'm proud to say that Canada has taken an active role in this regard. We continue to invest significant resources to resolve uncertainties in Atlantic Bluefin Tuna stock assessment. Indeed, the purpose of this meeting is to examine proposals to either improve existing stock status indicators or to develop entirely new indicators. It is encouraging to see proposals from Canada, the United States, and Japan in this regard.

While it will take some time for the results of any new indices to be statistically reliable, I am hopeful that these new stock indicators will form the foundation of sound science-based management decisions for the future. This will ensure the long-term sustainability of this important fishery for generations to come.

Of course, I also encourage all Parties to explore ways to reduce uncertainties in the short-term, including closely monitoring all fisheries to ensure accurate catch reporting. I also encourage you to consider alternative approaches to assessing stock trends.

I am optimistic that this meeting will set us on a path for improved data collection going forward.

On behalf of the Government of Canada, I want to stress that we are committed to ensuring the sustainability of this high-value fishery by increasing our scientific knowledge and working with our partners.

I wish you all much success this week and hopefully you will find some time to enjoy this beautiful island!

Appendix 4

DEVELOPING NEW EARLY LIFE HISTORY-BASED FISHERY INDEPENDENT INDICES FOR WESTERN ATLANTIC BLUEFIN TUNA

(document submitted by the United States[1])

Summary

Fishery independent indices based upon larval surveys have been used to estimate spawning biomass of bluefin tuna in the western North Atlantic since the late 1970s. Using recent advances in habitat modeling and sampling gears we propose to improve the existing indices by:

1) Modifying the existing sampling grid to incorporate a model-assisted sampling scheme based upon habitat models
2) Expanding depth-stratified sampling to define the vertical distribution of bluefin larvae. The efficiency of current sampling gears can then be estimated
3) Incorporating annual age and mortality estimates for larvae collected in different regions within the Gulf of Mexico.

In addition we propose the development of several new indices:

1) An index of larval prey, feeding success and growth to be used in next-generation stock assessments as an environmental driver of recruitment
2) Development of a bluefin egg sampling effort as part of the standard spring plankton survey, which will lead to a more direct index of SSB
3) Exploratory sampling efforts in the Caribbean and western North Atlantic to determine the significance and geographic extent of alternative spawning grounds. The inclusion of alternative spawning grounds in the development of indices may better reflect abundance trends.

KEYWORDS

Bluefin tuna, Recruitment, Stock assessment

Introduction and research to date

Atlantic bluefin tuna are distributed throughout the north Atlantic and are exploited with a variety of fishing gears throughout their range. The western Atlantic bluefin stock is estimated to have declined precipitously during the 1970s and early 1980s, but has been relatively stable since the implementation of quotas in 1982. There are various uncertainties in the stock assessments; one avenue for reducing these uncertainties could be improvements in the various indices used in the models to reflect relative abundance trends. Most indices developed for stock assessment of bluefin tuna are fishery dependent, however, the NOAA Southeast Fisheries Science Center has developed a fishery independent index for the western bluefin stock using larval abundances from annual ichthyoplankton surveys. These surveys have been carried out since the late 1970s, and since 1982 have been completed as part of the Southeast Area Monitoring and Assessment (SEAMAP) program (Scott *et al*., 1993, Ingram *et al*. 2010). Larvae are collected from oblique bongo net tows to 200 m depth, and surface neuston net tows across a 1 x 1° grid within the U.S. EEZ in the northern Gulf of Mexico. Sampling is conducted from late April to the end of May, with sampling continuing into June in some years. Larval abundances are converted to equivalent abundances of larvae with a first daily otolith increment per 100m^2, and standardized for

[1]John Lamkin, Barbara Muhling, Joanne Lyczkowski-Shultz, Walter Ingram, Estrella Malca, Glenn Zapfe, Trika Gerard, Andrew Millett, Sarah Privoznik.

spatiotemporal sampling variability. The resulting larval index, is used in stock assessment models to index the spawning stock biomass.

The index shows that larval bluefin were initially abundant from 1977-1983, but catches decreased substantially from 1984 – present (**Figure 1**). Because fish larvae are typically over-dispersed due to spawning behavior and transport of the eggs and larvae by ocean processes, the resultant catch data are zero-inflated, and not normally distributed. This typically results in a dataset with many zero values, and a very few large values, leading to a high coefficient of variation around the index (Ingram et al. 2010).

Gulf of Mexico plankton survey grid **Larval index, and coefficient of variation**

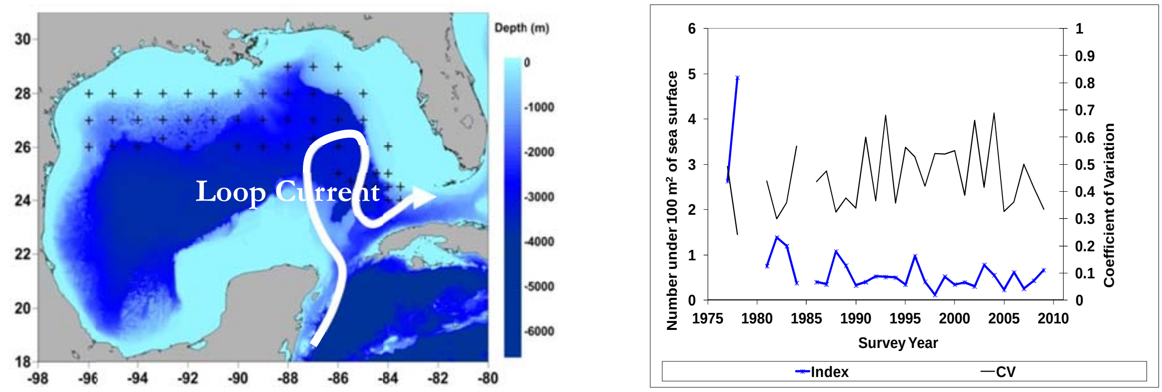


Figure 1. SEAMAP spring survey stations and the bluefin larval index and coefficient of variation.

To address this problem, work was begun in 2009 to develop a larval habitat model using historical catch data. The model used artificial neural networks to predict probabilities of larval abundance using in-situ environmental variables from CTD casts, and to therefore provide an additional means of standardizing the larval index (Muhling et al. 2010). Results showed that bluefin tuna larvae were most likely to be collected in warm (24 – 28°C), low chlorophyll waters, outside of the Loop Current. To increase the predictive utility of the habitat model, it was then reconfigured to predict larval occurrences using only remotely sensed environmental data: sea surface temperature, surface chlorophyll, surface height, and surface current velocities. This updated model delivered similar results to the in situ model, and was applied to a study of the potential impacts of the 2010 Deepwater Horizon oil spill (**Figure 2**: Muhling *et al.* 2012). Similar techniques have since been used to compare environmental constraints on bluefin tuna spawning habitat in the Gulf of Mexico vs. the western Mediterranean Sea (Muhling et al. 2013). Habitat models successfully predicted interannual variability in larval bluefin distributions, and highlighted the importance of water temperature to spawning activity in both regions.

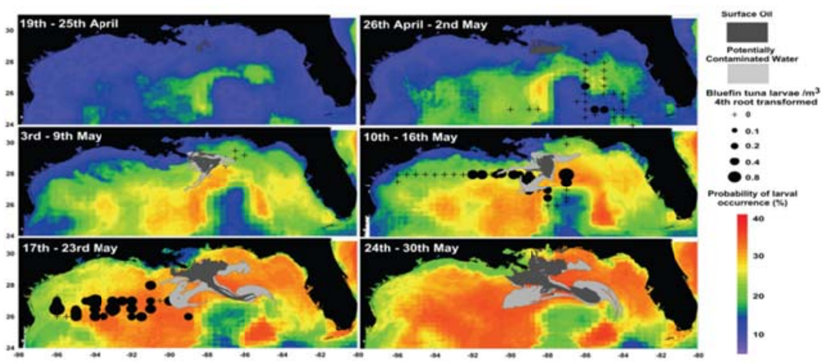
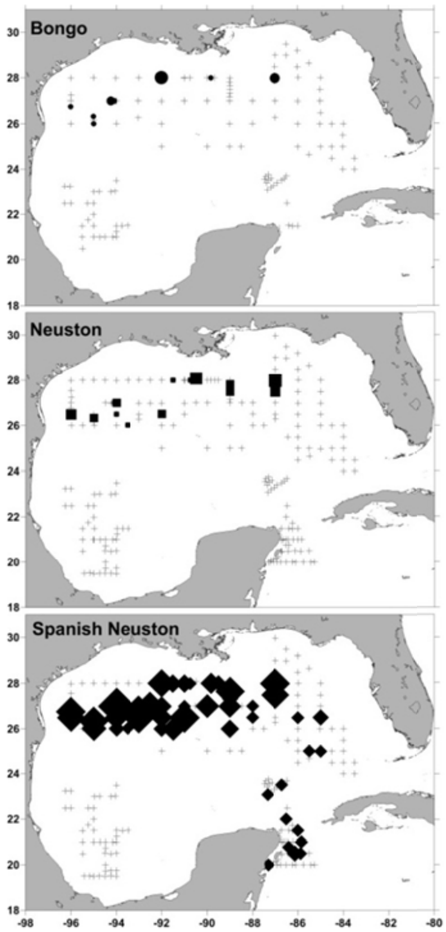


Figure 2. Predicted probabilities of occurrence for larval bluefin tuna in the northern Gulf of Mexico on a weekly basis during spring 2010. Probabilities were derived from a neural network model trained using archival larval collection data. Oil extents are derived from satellite products. Catches of larval bluefin tuna from spring 2010 (April 19th to May 23rd), are also shown.



One hurdle to developing the habitat model has been the low number of larvae collected each year, and the large number of zero catch stations. To address this, sampling protocols were changed to include a new plankton net (S-10) in 2010. This gear is a 1 x 2 m frame with a 0.505 mm mesh net towed in an undulating fashion from the surface to 10 meters depth for 10 minutes. This sampling method resulted in significantly higher catches of bluefin larvae, and a higher overall proportion of positive stations (**Figure 3**. Habtes *et al.* in press). In view of these results, it was decided to incorporate this sampling gear into the SEAMAP surveys, and to eventually develop a new larval index using the results from this gear.

In addition, depth-stratified sampling was initiated on the 2010 cruise, using a Multiple Opening and Closing Net Environmental Sensing System (MOCNESS). This gear samples in discrete 10 m depth increments from 50 meters to the surface, and has been deployed only sporadically to this point, due to time constraints. Initial results from this gear indicate that bluefin larvae are found primarily in the upper 20 meters of the water column.

While these efforts continue to improve the existing larval index, we propose additional efforts and the development of new indices:

Improvements to the current index

1. Expand existing sampling on annual surveys

Depth-stratified sampling has been limited to date, and as a result, the vertical distribution of bluefin tuna larvae is not well known. In order to better understand the effectiveness of our other depth-integrated sampling gears, depth-stratified sampling using the MOCNESS gear should be expanded in future years, and be made a standard component of annual surveys. Information from these samples will also be useful to ongoing studies of larval transport and dispersal potential, by providing depth distribution information for the construction of Individual-Based Models (IBMs).

In addition, the current survey grid has a very coarse spatial resolution, which, when combined with the patchiness of larval distributions, can introduce high variability in the calculated larval indices. This grid may be partially modified to incorporate a model-assisted sampling scheme (Sarndal 1992), based on predictions from habitat models. Sufficient ship-time exists for the ~30 year time series of plankton sampling to be maintained, while allowing for some adaptive sampling in areas with high probability of larval occurrence.

2. Develop a dynamic age/growth mode and predictive recruitment model

Estimates of age at length are required for the standardization of raw larval abundances to an estimate of one day old larvae under 100m2 of sea surface (Ingram et al., 2010). The current estimate of age at length matrix was developed by Brothers et al., (1983) from specimens collected off South Florida more than 30 years ago. This estimate was initially used because survey catches from 1984 onwards had become too small to support annual estimates of mortality, and as a result, it has been applied to all larval index mortality estimates ever since. The recent advances in sampling methods noted above have resulted in greatly increased larval catches, which could allow the development of annual growth and age estimates. Recent work in the western Mediterranean indicates that larval bluefin tuna growth may vary considerably on an interannual basis, which may have profound effects on recruitment variability (Garcia et al., 2013). We propose to address gaps in our understanding of larval bluefin tuna growth by investigating environmental drivers of growth and mortality in the Gulf of Mexico, and developing annual age/growth curves for the eastern and western Gulf. These will be incorporated into the larval index, and will improve the accuracy of the index by accounting for interannual effects of the pelagic environment on larval growth.

Growth rates will be examined using otoliths extracted from larvae collected across a wide variety of oceanographic features from both the eastern and western Gulf of Mexico, from multiple years. Understanding these drivers is essential for improving the larval index, and also for developing a predictive recruitment model. In addition, we will examine the relationship between growth and temperature throughout the larval stage by backtracking larvae using ocean models. This will reduce variation in growth estimates and inform models of daily growth rates driven by environmental parameters. Finally, results will inform and improve the larval index by adding regional and oceanographic feature-specific growth curves.

Development of new indices

1. Larval prey, feeding success and growth index

To understand the influence of larval survival on recruitment variability, the processes that are governing larval survival must first be understood. To survive, a larva has to eat and avoid being eaten. In addition, suboptimal feeding can influence a larva's susceptibility to be consumed by a predator, by both extending the larval period via slower growth, and by reducing a larva's ability to evade predation (Houde, 1987).

Recruitment processes for bluefin tuna are not well known, but appear to be episodic, and not always closely correlated to spawning stock biomass. Apparent peaks in recruitment, as determined by abundances of 1-year old fish, may be separated by decades. Given the large departure of these peaks from long term means, it appears likely that recruitment success is determined in very early life, when larvae are subject to high and variable mortality. An improved understanding of these processes should in turn lead to improved stock assessments and more effective management (e.g. this would enable better evaluations of the likely success of stock rebuilding plans). The proposed index of larval prey, feeding success and growth will fill a long-standing gap in knowledge of larval bluefin diets, feeding and survival, and potential effects on ultimate recruitment success.

This work will combine studies of larval growth (using otoliths), larval feeding success (using gut contents) and larval prey fields (using zooplankton samples). Conditions conducive to higher feeding success, faster growth and presumed enhanced survival will be defined, initially by using existing samples from recent years (2010-present). Once favorable conditions are defined, in terms of available prey and ambient environment, an index of these can be developed. This index can be extended back to 1982, using preserved samples and specimens from the SEAMAP collection, and archived plankton samples. Results will add to knowledge of how biophysical conditions may influence larval ecology and recruitment potential, and may help to explain recruitment peaks, such as that observed in 2003. In addition, if conditions favoring high recruitment can be elucidated, we may be able to search for historical supporting evidence of any past "regime shifts", an assumption implicit in the hypothesis that the western bluefin stock-recruitment relationship has changed from High to Low Recruitment Potential. (Rosenberg et al., 2013). The uncertainty regarding these two recruitment scenarios is a key issue in the stock assessment process.

2. Develop and index of daily egg production with continuous eggs sampling and genetic analysis of eggs

An alternative approach to assessing spawning stock biomass is through the use of a daily egg production model (DEPM). This technique provides a more direct estimate of spawning biomass than larval abundances, as it avoids the additional error associated with larval growth and mortality. The DEPM approach has been thoroughly developed on the U.S. West Coast for small pelagic fishes (Lasker, 1985). However, it has traditionally only been used on species whose eggs are easily identifiable visually, which limits its application. With current advances in genetic techniques, many previously indistinguishable fish species can now be identified from eggs. This includes species whose eggs are collected during the annual SEAMAP survey, such as bluefin tuna, yellowfin tuna, blackfin tuna, billfish, swordfish, snappers, and groupers.

To develop this index, we will use the DEPM described by Parker, (1985): $B = ((P \cdot A \cdot W)/(R \cdot F \cdot S))$, where B= biomass estimate, P = daily egg production (# of eggs produced per area per day), A = total survey area, W = average weight of mature females, R = fraction of mature female fish by weight, F = batch fecundity and S = fraction of mature females spawning per day. Eggs are collected in the same plankton sampling gears that are currently used to collect larvae, and will be identified genetically. We expect that mixtures of eggs collected could contain genomes from many species. However, it is now possible via massively parallel DNA sequencing to identify individual collections of eggs to species, and to simultaneously yield a reasonable estimate of relative abundance. We have already designed genetic assays for many species in the Gulf of Mexico, and these genetic assays can be used to identify most fish. Species not currently in our database can be identified via searches of the Fish Barcode of Life (FISBOL) or GenBank sequence repositories or the primary literature.

3. Extension of sampling efforts in the Caribbean and western North Atlantic

Several exploratory cruises in the western Caribbean Sea and Bahamas regions have been completed during spring between 2009 and 2013. Scattered collections of bluefin tuna larvae have been found in the Yucatan Channel, east of the Yucatan Peninsula, and north of the Bahamas. However, the relative amount of spawning activity that takes place in these areas is currently unknown. Current assessment models assume that larvae collected in the Gulf of Mexico encompass all of the western spawning stock. The relative importance of alternate spawning grounds therefore needs to be determined, to better test this assumption. Genetic testing of bluefin larvae collected can be used to assess the closeness of the relationship between larvae collected inside and outside the Gulf of Mexico. In addition, hydrodynamic backtracking analyses will be used to estimate original spawning locations of larvae from the Caribbean and Atlantic. This information can be combined to focus sampling efforts on particular regions in space and time, and repeated sampling across several years should be completed to determine the importance of previously unknown spawning grounds.

Of the two alternative spawning grounds identified, the area north of the Bahamas is potentially the largest (**Figure 4**). Habitat models suggest that potential spawning grounds are extensive, though it is unknown how much of the area may be utilized. The cruise in 2013 sampled only a portion of the area (**Figure 5**) but results suggest some level of spawning activity, though the extent is unknown. We propose a series of cruises in May and June over two years in this area that would cover a larger geographical extent. Approximately 200 samples would be taken in each cruise concentrated in areas identified as high probability for larval bluefin habitat.

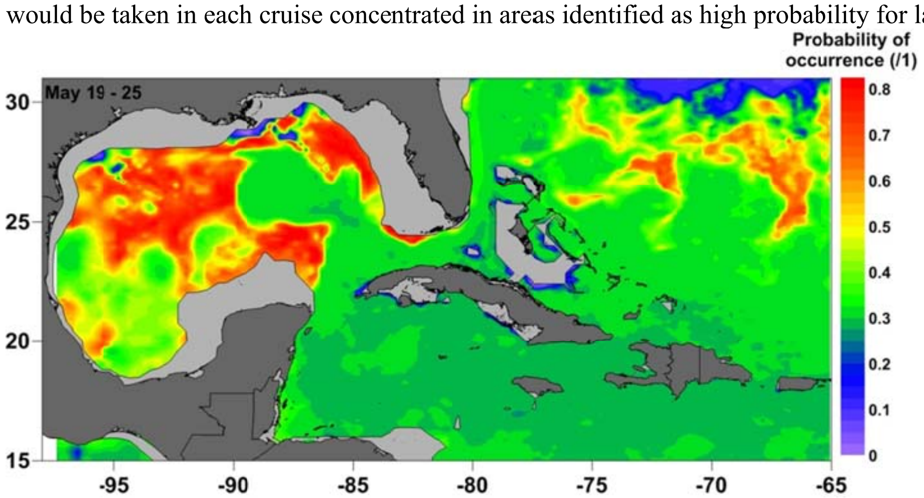


Figure 4. Probability of occurrence of bluefin tuna larvae.

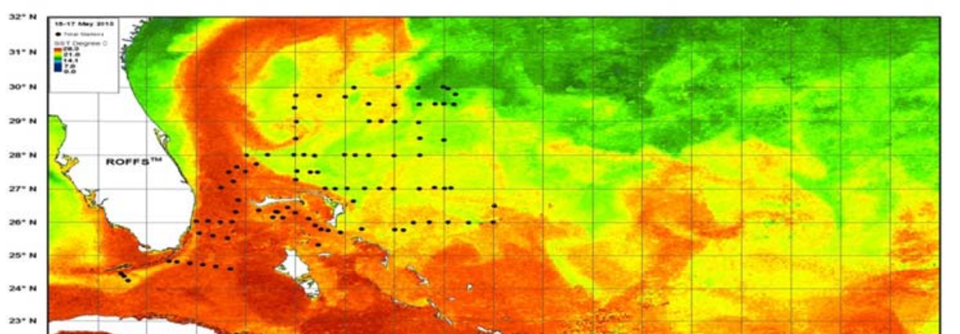


Figure 5. Stations sampled and possible extent of similar habitat.

Literature cited

Brothers, E. B., Prince, E. D. Lee, D. W. (1983) Age and growth of young-of-the-year bluefin tuna, *Thunnus thynnus*, from otolith microstructure. Pages 49-60 in E. D. Prince and L. M. Pulos, eds. Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, bill fishes, and sharks. NOAA Tech. Rep. NMFS 8. 211 pp.

Ingram, G.W., Richards, W.J., Lamkin, J.T., Muhling, B.A. (2010) Annual indices of Atlantic bluefin tuna (Thunnus thynnus) larvae in the Gulf of Mexico developed using delta-lognormal and multivariate models. Aquatic Living Resources 23: 35-47.

Lasker, R. (1985). An egg production method for estimating spawning biomass of pelagic fish: application to the northern anchovy, Engraulis mordax.

Muhling, B.A., Lamkin, J.T., Roffer, M.A. (2010) Predicting the occurrence of bluefin tuna (*Thunnus thynnus*) larvae in the northern Gulf of Mexico: Building a classification model from archival data Fisheries Oceanography 19: 526-539.

Muhling, B.A., Roffer, M.A., Lamkin, J.T., Ingram, G.W. Jr., Upton, M.A., Gawlikowski, G., Muller-Karger, F., Habtes, S., Richards, W.J. (2012) Overlap between Atlantic bluefin tuna spawning grounds and observed Deepwater Horizon surface oil in the northern Gulf of Mexico. Marine Pollution Bulletin 64:679-687.

Muhling, B.A., Reglero, P., Ciannelli, L., Alvarez-Berastegui, D., Alemany, F., Lamkin, J.T., Roffer, M.A. (2013) Comparison between environmental characteristics of larval bluefin tuna Thunnus thynnus habitat in the Gulf of Mexico and western Mediterranean Sea. Marine Ecology Progress Series 486: 257–276.

Garcìa, A., Cortés, D., Quintanilla, J., Ramirez, T., Quintanilla, L., Rodriguez, J. M., & Alemany, F. (2013). Climate□induced environmental conditions influencing interannual variability of Mediterranean bluefin (*Thunnus thyn*nus) larval growth. Fisheries Oceanography, 22(4), 273-287.

Habtes S., F. Muller-Karger, M. Roffer, J. T. Lamkin, B. A. Muhling, (in review) A comparison of sampling methods for larvae of medium and large epipelagic fish species during spring SEAMAP ichthyoplankton surveys in the Gulf of Mexico Limnol. Oceanogr. Methods.

Houde, E. D. (1997). Patterns and consequences of selective processes in teleost early life histories. In early life history and recruitment in fish populations (pp. 173-196). Springer Netherlands.

Parker, K. 1985. Biomass Model for the Egg Production Method. in Lasker, R., ed. An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, *Engraulis mordax*. NOAA Technical Report NMFS 36. p. 5-6.

Rosenberg, A., Cooper, A., Maunder, M., McAllister, M., Methot, R., Miller, S., ... & Walter, J. (2013). Scientific examination of western Atlantic bluefin tuna stock-recruit relationships. Collect. Vol. Sci. Pap. ICCAT, 69(2), 1016-1045.

Sa¨rndal, C.-E., Swensson, B., and Wretman, J. 1992. Model assisted survey sampling. Springer-Verlag, New York.

Scott, G.P., Turner, S.C., Grimes, C.B., Richards, W.J., Brothers, E.B. (1993) Indices of larval bluefin tuna, *Thunnus thynnus*, abundance in the Gulf of Mexico: Modeling variability in growth, mortality, and gear selectivity: Ichthyoplankton methods for estimating fish biomass. Bulletin of Marine Science 53: 912-929.

Appendix 5

UNITED STATES PROPOSALS FOR IMPROVING THE SCIENTIFIC INFORMATION FOR STOCK ASSESSMENT OF ATLANTIC BLUEFIN TUNA

(Document submitted by U.S. Scientific Delegation to ICCAT SCRS)

SUMMARY

The United States scientific delegation to the SCRS recognizes the need to improve the scientific information for stock assessments of western Atlantic bluefin tuna. To this end the delegation proposes a three-part approach: 1. Improve existing and/or develop new indices for stock assessments, including advancements to the existing larval survey and development of an age-0 survey. 2. Improve the collection and processing of biological material (otoliths, spines, tissue samples) from the fishery, either on vessels, at ports of landing or in markets. 3. Develop a genomic-based approach to assessment of BFT similar to the close-kin estimates of spawning biomass of southern bluefin tuna.

The United States recognizes the need to improve the scientific information for stock assessment of Atlantic bluefin tuna. To this end the U.S. proposes a three-part approach:

1. Improving existing and/or developing new indices for stock assessments. The U.S. supports initiating an index for age-0 bluefin tuna and welcomes collaboration on the design and methodology. Fish of this size are rarely encountered in U.S. fisheries, however 41 BFT (267-413 mm FL) were captured while trolling in waters off Miami, FL during the late summer (Brothers *et al*. 1982). This suggests that it may be possible to initiate a trolling survey for age-0 BFT (**Addendum 1 to Appendix 5**). The U.S. has also proposed expansion of the existing larval survey (Lamkin *et al*. 2014**)** to encompass more of the potential spawning area of WBFT and to increase the efficiency of the sampling. Both of these projects address key time periods (early juvenile and larval, respectively) in the life history of BFT, as well as provide known-origin samples to support projects in (3), below.

   Current indices may also be improved by better accounting for the effects of environmental factors and regulations that affect interpretation of CPUE (a process that is ongoing at the SCRS and recommended by the SCRS Methods working group). We note, however, that indices only provide value to assessments after several years of standardized data collection. Furthermore, indices of relative abundance are only one of many pieces of information that go into a stock assessment and simply adding additional indices will not solve many of the key uncertainties for ABFT.

2. Improving the collection and processing of biological material (otoliths, spines, tissue samples) from the fishery, either on vessels, at ports of landing, or in markets. This is critical for improving stock assessments, for otolith microchemistry and for the analyses proposed in item (3) below. These improvements are simple in concept - initiate and support comprehensive collection of tissues for routine estimation of age and stock composition, but often difficult to achieve due to sampling logistics.

3. Develop a genomic-based approach for the assessment of BFT (**Addendum 2 to Appendix 5**). The recent success of applying a close-kin analysis to estimate the spawning stock abundance of southern bluefin (Bravington *et al.* 2013), coupled with the rapid increase in resolution (and decrease in costs) of advanced genetic techniques as a result of the human genome project make the application of genomic approaches particularly relevant. First, the increased resolution provided by Restriction-site Associated DNA (RAD) provides thousands of loci for identifying population-level and individual-level differences, vastly increasing resolution over the much smaller number of microsatellites currently available. This increases the potential to determine stock of origin, and - beyond this, provides the potential for genetic mark recapture experiments such as close-kin analysis to estimate absolute abundance, mortality rates or migration, addressing directly some of the key uncertainties in BFT assessments. In particular the close-kin analysis could provide a *fishery-independent estimate of the WBFT spawning stock numbers.*

References

Bravington MV, Grewe PG, Davies CR (2013). Fishery-independent estimate of spawning biomass of Southern Bluefin Tuna through identification of close-kin using genetic markers. FRDC Report 2007/034. CSIRO, Australia.

Brothers, EB, Prince, ED and Lee, DW. 1982. Age and growth of young-of-the-year bluefin tuna, *Thunnus thynnus*, from otolith microstructure. In: Prince E. D., Pulos L. M., editors. Proceedings of the International Workshop on Age Determination of Oceanic Pelagic Fishes: Tunas, Billfishes and Sharks. NOAA Technical Report NMFS, 8; 1983. p. 49-59.

Lamkin. J. B. Muhling, J.Lyczkowski-Shultz, W. Ingram, E. Malca, G. Zapfe, T. Gerard, A. Millett, S.Privoznik 2014. Developing new early life history-based fishery independent indices for western Atlantic bluefin tuna. ICCAT SCRS BFT data prep workshop paper

Addendum 1 to Appendix 5

A FEASIBILITY STUDY ON THE DEVELOPMENT OF ANNUAL RELATIVE ABUNDANCE INDICES FOR YOUNG-OF-THE-YEAR BLUEFIN TUNA (*THUNNUS THYNNUS*) IN THE STRAITS OF FLORIDA

The SCRS recognized that "large uncertainty in stock status is exacerbated by the lack of appropriate information/data and scientific surveys" (ICCAT SCRS REPORT 2013). Current and future stock assessment models rely upon relative abundance indices. The youngest ages for which an index is available are ages 2 and 3. The availability of indices for the youngest age classes is particularly useful for improving the estimates of number of fish in these age classes in the most recent years of the data series, as there are fewer years of data available in the catch for these cohorts. Recruitment indices of Age 1 Southern bluefin tuna are developed for that species by a trolling survey off the coast of Western Australia, and considered for informing the management of fish when they enter the fishery two years later (Itoh *et al.* 2013).

Abundance indices for western Atlantic young-of-the-year (YOY/Age 0) will improve the assessment and management of the stock (albeit after the index has several some years of continuous information). However, such indices have not been developed, as bluefin of this young age are generally regarded as insufficiently available. Bluefin of this size are not targeted in the U.S. fisheries. Some Age 0 fish have been collected as part of targeted research projects, but even during such efforts, encounter rates are generally low. However, Brothers *et al*. (1983) collected a number of YOY during a study reporting on the growth of western Atlantic larval and juvenile BFT in 1982. Their approach to sampling juvenile BFT in the Straits of Florida was to request that local Miami charter boat operators retain YOY BFT. Forty-one (41) fish were caught on hook and line using techniques such as trolling small feather lures from mid-August through October of 1979-1980, ranging in size from 267 to 413 mm fork length. Although no similar effort has been made to acquire juvenile western Atlantic BFT of this size category in the years since, it is possible that such fish can still be found in the area and the season described by Brothers *et al*. (1983). Local fishermen may not identify these small tunas as BFT as at this small size they can be easily confused with blackfin tuna (*Thunnus atlanticus*). Hence, a primary step is determining the feasibility of developing a BFT YOY index is to ascertain the availability of these YOY fish.

It is reasonable to assume that a large fraction of the YOY of the Western Atlantic population spawned in the Gulf of Mexico pass through the Straits of Florida after leaving the Gulf of Mexico for Atlantic waters. Therefore, Phase One of the proposed feasibility study will be to characterize the availability (in time, location, vulnerability to various gears/techniques) of the Age 0 fish in the Florida Straits, to determine if YOY BFT can be collected in numbers sufficient to enable the development of indices of abundance for these young fish.

Phase One should be continued for 2 -3 years, to evaluate consistency of year-to-year availability. If warranted based on the data collected through Phase One, trials of standardized methods to collect data for ongoing abundance indices (Phase Two) can begin in parallel as early as year two of the study. Ideally, the availability and feasible logistics will permit the development of a scientific survey, perhaps employing methodologies similar to those of Itoh *et al.* (2013). Alternatively, some form of fishery dependent indices may be required.

Methods

We propose to make a comprehensive effort to access the availability of YOY BFT by liaising with the commercial and recreational (private and charter) fishing community fin the Florida straits (from West Palm Beach to Key West). From our initial query, we will identify fishers willing to participate but who are also conscientious in terms of communicating with the research team and procuring samples. To justify participants taking time to locate and catch small tuna during the presumed duration of presence in the Florida Straits (from mid-August through mid-October), monetary compensation may be necessary. Species identification information will be distributed to each participating boat captain. For YOY bluefin, the size and number of gill rakers on the first arch (34-43) is an easy distinguishing characteristic vs blackfin tuna (19-25), the most common similar scombrid in this area (Gibbs and Collette 1967). Communications to all participants when and where the schools of tuna are sighted will be essential. All cooperating participants would have to obtain an exempted fishing permit under NOAA's scientific permitting system, and an exemption under ICCAT regulations may be required. It is anticipated that the total catch from this feasibility study would still be quite minimal so as to not affect the stock or have any impact upon U.S. quotas of BFT.

Personal visits and regional face to face meetings will be an important aspect of program implementation. Brothers *et al*. (1983) made multiple in-person visits to talk to captains, most importantly at the beginning of the collections. As BFT enter the straights of FL at Key West, communications of first sighting in this location will raise awareness of the presence of YOY BFT. Some accommodation for freezer holding facilities may be required. One option may be to purchase small freezers for placement near cleaning stations at marinas or public ramps. This approach has been used successfully to obtain biological samples in some other surveys (e.g. Large Pelagic Biological Survey). As compensation, marina operators could be offered shared use of the freezers during survey operations, and exclusive use at other times. Participating fishers can leave whole or cleaned (head and attached skeleton only) specimens in the freezer, inside bags with id tags. Vessel interactions with YOY bluefin tuna will require log-book documentation so that time, date, location, fishing methods and catch rates are recorded and made available to the researchers.

Collection of additional information on catch rates and methodology will provide the necessary information for developing a full statistical design and power analysis for an operational survey. Information on timing, duration of passage and spatial distribution will be essential for designing a full survey. Data on capture and encounter rates, as well as successful fishing methods such as gear, lures, trolling speed, time of day and detection and identification of schools, will provide critical methodological details.

Phase Two of the project, if determined to be feasible based on the data collected in Phase One, would be the design and implementation of a pilot survey (fishery-independent designed survey or, if necessary, a fishery dependent survey). This could begin as early as Year Two of the project, while Phase One is continued in parallel, to confirm year-to-year consistency in availability.

The methodology employed in a scientific design may be similar to those used in by Itoh *et al.* (2013). Alternatively, other approaches may be considered. For example, YOY BFT have been caught in mid-water trawls in the Gulf of Mexico.

Budget

Costs for Phase One may include possible monetary compensation for participating fishery constituents, funds for travel to regularly meet with participants and recover specimens, securing freezer/ refrigerator facilities, and partial salary for a contracted scientist. Duration of the pilot is expected to be at least 2 or 3 years. The cost of design and implementation of a pilot scientific survey will depend upon the results of Phase One and the difficulty and complexities involved.

Anticipated results of feasibility study

1. Data on the availability, timing and duration of passage of YOY BFT through the Straits of Florida.
2. Data on the capture and encounter rates which will be critical for power and sample size analyses for an operational index.
3. Data on successful capture methodologies, such as gear, lures, trolling speed, time of day and detection and identification of schools to determine the most efficient sampling protocols.
4. Biological samples of known stock origin for genetics, age and growth analyses.

5. (Depending on results of Phase One) Survey design for the development of YOY BFT abundance indices. Pilot survey to test suitability.

References

Itoh T, Sakai O, and D Tokuda. 2013. Report of the piston-line trolling monitoring survey for the age-1 southern bluefin tuna recruitment index in 2011/2012. CCSBT-ESC/1208/33.

Brothers EB, Prince ED, Lee DW. 1983. Age and Growth of Young-of-the-Year Bluefin Tuna, *Thunnus thynnus*, from Otolith Microstructure. NOAA Technical Report NMFS 8:49-59.

Gibbs RH and Collette, BB. 1967. Comparative Anatomy and Systematics of the Tunas, Genus Thunnus. Fishery Bulletin 66(1):65-130.

ICCAT. Report of the 2012 Atlantic Bluefin Tuna Stock Assessment Session. 2013. Collect. Vol. Sci. Pap. 69(1): 1-198.

Addendum 2 to Appendix 5

DEVELOPMENT OF A GENOMIC-BASED APPROACH TO ASSESSMENT OF BFT

Introduction

The rapid development of high-throughput, high resolution genetic analytical methods coupled with the rapid decrease in the cost of these analyses has made quantitative genomics a powerful technology for population assessments. In contrast to previous methodologies (microsatellites, single nucleotide polymorphisms, etc.), that provided relatively few (10s) markers for resolution, restriction-site associated DNA sequencing (RAD) analysis produces thousands of genetic markers per individual (Baird *et al*. 2008, Davey and Blaxter 2011), vastly increasing the resolution of markers for population-level differences and allowing for the unique identification of individuals or their progeny. Improved population level resolution increases the potential for resolving one of the key uncertainties in ABFT- stock of origin in mixed fisheries. Unique identification of individuals provides the potential for mark-recapture analyses that eliminate several nuisance parameters, namely tag loss and reporting rates. Furthermore, the thousands of available loci from RAD analysis make it possible to conduct parentage analysis which provides the critical information for estimation of spawning abundance through close-kin analysis (CKA), an approach that allows for abundance estimation from sampling of spawners and juvenile.

In contrast to many other methods of assessing populations, genetic approaches offer some desirable properties. First is the potential to identify individuals and their progeny, a property that expands genetics as a tool for conducting mark-recapture type studies. Along these lines, genetic methods offer the potential for non-invasive tagging with a mark that cannot be shed, potentially augmenting any conventional tagging program. Lastly, the resolving power is increasing and the costs are decreasing quite rapidly due to the economy of the human genome project, making the genotyping of thousands of samples possible.

We propose a pilot project to evaluate the utility of using advanced RAD DNA methods to evaluate stock mixing, to identify individual BFT and their parents and to evaluate the existing sampling framework (larval surveys and biological sampling of the fishery) for conducting a full close-kin analysis to estimate spawning abundance, independently from and complimentary to traditional stock assessment approaches. The proposal objectives follow:

1. Estimate the feasibility of identifying stock origin using RADseq technology from previously collected samples of known stock origin (East and West).
2. Analyze existing western Atlantic bluefin tuna larval samples collected from the Gulf of Mexico to estimate diversity of parents to determine if the larval survey provides effective samples for close-kin analysis.
3. Initiate/evaluate sampling design to collect DNA samples from adult BFT.
4. Provided (1), (2) and (3) work, then initiate close-kin analysis to estimate the absolute abundance of spawning western Atlantic tuna.

Methods

RAD sequencing

Restriction-site associated DNA sequencing (RADseq) is a relatively new methodology for rapidly and cost-effectively obtaining 1000s of genetic markers per individual and analyzing a large number of samples concurrently (Baird *et al* 2007, Davey and Blaxter 2011). In conjunction with methodologies for parallel processing of samples, RADseq becomes a very efficient tool for genetic studies. In contrast to earlier means of identifying genetic diversity (microsatellites, single nucleotide polymorphisms, etc) which were costly to develop and limited usually to only a few markers in number, RADseq provides thousands of markers, of which some will indicate population-level differences, and others differences at the individual level. The output of the RADseq analysis is a table of presence/absence of a particular loci (of which there may be thousands) for each individual sequenced. Then a principal components analysis is performed to determined combinations of loci that distinguish individuals or groups.

Close-kin analysis (CKA)

Close-kin analysis was originally proposed for minke whales (Skaug, 2001) and has, most recently, been successfully applied to Southern Bluefin tuna (Bravington *et al* 2013) as a means to estimate spawning abundance in situations where conventional tagging, and standard surveys or indirect assessment methodology proves difficult or highly uncertain. This is certainly the case for ABFT. The method proceeds as follows: take a random sample of juvenile fish and random sample of spawners, compare the genetic composition of each juvenile and each spawner to determine if any of the spawners could be a parent and then count the number of matches - juveniles that had a parent in the spawners, or the Parent – Offspring Pairs (POPs). If the spawning population is high, there will only be a small proportion of the sampled juveniles will result in POPs. The estimate of absolute spawning stock numbers ($\widehat{N}$) is then obtained from a mark-recapture model where the unique parental genetic contributions (one each from mother and father) present in juveniles serve as a tag that can be recaptured from adults in the fishery. The model follows below:

$$\widehat{N} = 2 * J * A/POP$$

where *J* is the number of juveniles sampled and *A* is the number of adults sampled. Relatively independent of the population size, the target level for estimating the abundance of spawners is 50 POPs as the variance of the population size estimate stabilizes at that level. Secondarily, if the analysis is conducted over multiple years, observing the presence of the same adult (generally one spawning) in the juveniles over multiple years gives information on survival of adults.

Target levels of sampling for adults and juveniles to obtain 50 POPs is approximately 10*(*N*)^.5, so for a spawning population of 60,000 fish (current WBFT VPA estimates) one would need 2500 total fish (e.g. 1250 age-0 and 1250 adults).

Numerous other details will require further analysis for the full CKA, once the pilot project determines the feasibility of proceeding.

Sampling

One of the key requirements for a genomic approach to succeed will be obtaining adequate samples. To achieve the pilot part of this proposal all samples are currently archived and available. For the full CKA, the current larval survey averages between 1000 -1500 fish per sampling season, indicating that it may be sufficient for CKA, if the samples meet the genetic diversity requirement (i.e. larvae are sufficiently mixed such that individual larvae demonstrate high spawner diversity).

To obtain 1250 adult samples it may require some substantial sampling of the U.S., Canadian, Japanese or Mexican (the primary CPCs capturing Western origin BFT) fisheries, particularly as some of these fish could be of Eastern origin. Given that the total catch in any given year is ~7000 spawners (age 8+ fish) this would require obtaining a tiny tissue sample (~1 milligram, or a less than a pencil eraser size) from about 20% of the total catch.

Pilot project

The initial pilot project will be to determine the feasibility of determining stock origin with RAD analysis with existing samples of known origin collected from the spawning grounds in the Gulf of Mexico and Mediterranean Sea, and to evaluate genetic diversity in larvae. Collaborators on this pilot include Jan McDowell, John Graves (VIMS), Peter Grewe and Mark Bravington (CSIRO) and the large Pelagics Lab at University of New Hampshire (Lutcavage lab). Initial project costs are in **Table 2**.

Table 2. Initial costs for pilot project and close-kin genetic work (note that the initial cost of $50 per fish should decrease about $20 on an operational basis. Costs are in U.S. dollars and do not include labor, scientific support, travel or sample collection needed for part 3).

1. To screen known origin fish to determine whether stock origin can be determined			
	Target fish	Cost per sample	Total
Western origin	100	50	5000
Eastern origin	100	50	5000
2. Larval to determine number of parents and half-sibling within and between samples			
	Target fish	Cost/sample	Cost
Larval from 2009-2011	1000	50	50000
		Total	$60,000
3. Close kin analysis			
Larvae/juveniles	1250	50	62500
Adults	1250	50	62500
			$125,000

Expected results

a. Estimation of stock proportion

We expect that we will be able to evaluate the feasibility of stock identification through RAD analyses fairly soon. If this works, it will provide a relatively inexpensive and non-lethal means of determining stock origin.

b. Estimation of parentage diversity of larval samples

If unique parentage can be determined, this analysis will provide the necessary information to determine whether the larval survey provides samples with enough spawner diversity (number of parents) to be able to be considered a random sample of the juvenile. The analysis will evaluate, through rarefaction curves the number of unique parents as a function of number of larvae sampled, both within a larval tow and between larval tows. This will help determine whether it is better to sample more larvae in a location, if spawner diversity is high within a tow, whether it is necessary to sample more stations in time and space, or, if spawner diversity is low both within and between stations, whether the larval survey will not provide the necessary platform for randomly sampling juveniles.

c. Full close-kin analysis

Provided that parts (1) and (2) succeed and that an adequate number of spawners can be obtained from the fishery, then a full close-kin analysis can proceed which will provide an estimate of absolute abundance of the spawners that produced the juveniles in a given year. It is critical that adults that could have produced the juveniles in a given year be sampled, so the full CKA may need to be updated in future years as past spawners are encountered and included in the prior year's data.

Estimates of absolute spawning stock number will provide an independent check upon existing stock assessment estimates, increasing certainty in the abundance of the stock. Further, if ongoing, these estimates will greatly enhance the ability to estimate the stock-recruitment relationship as the spawning stock estimates will be independent of the recruitment estimated in the assessment model. These estimates can also be formally incorporated into the management procedure approach (MP) proposed for BFT (ICCAT 2013).

References

Bravington MV, Grewe PG, Davies CR (2013). Fishery-independent estimate of spawning biomass of Southern Bluefin Tuna through identification of close-kin using genetic markers. FRDC Report 2007/034. CSIRO, Australia.

Baird NA, Etter PD, Atwood TS, Currey MC, Shiver AL, Lewis ZA, Selker EU, Cresko WA, Johnson EA. (2008) Rapid SNP discovery and genetic mapping using sequenced RAD markers. PLoS One. 3(10):e3376.

Davey JL and Blaxter ML 2011. RADSeq: next-generation population genetics. Brief Funct Genomics. 9(5-6):416-23.

ICCAT. 2013. Report of the bluefin stock assessment methods meeting. Gloucester, MA.

Skaug, H. 2001. Allele-sharing methods for estimation of population size. Biometrics, 57:750-756.

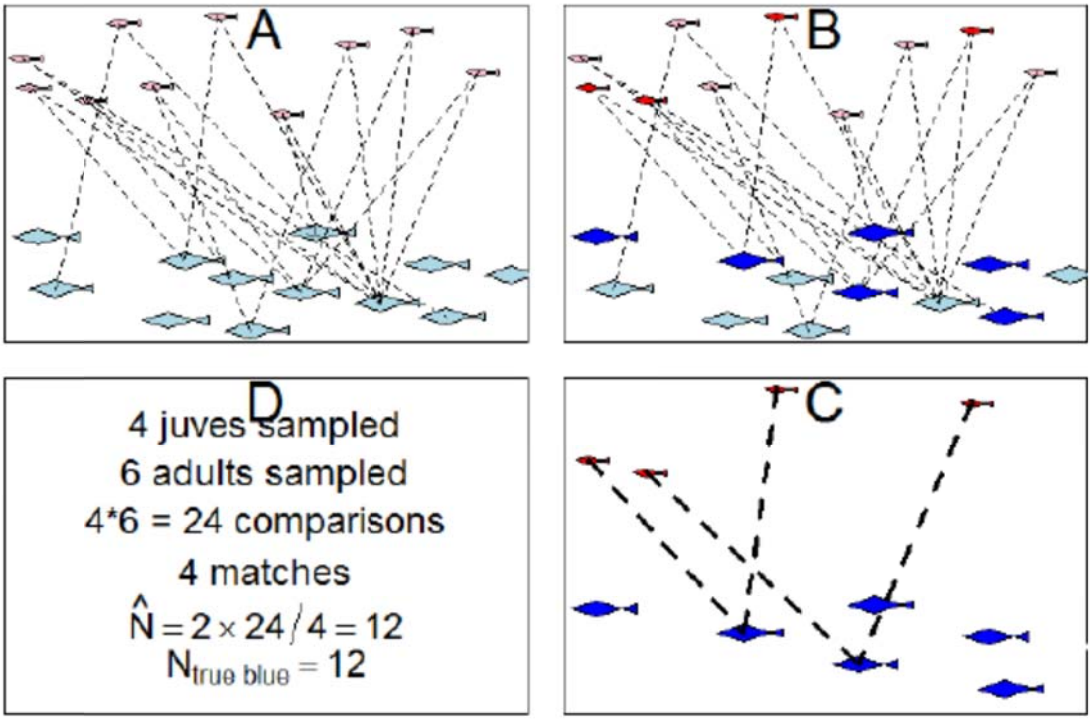


Figure 1 (reprinted with permission from Bravington *et al* 2014). Cartoon of close-kin: the DNA profile of the juvenile "tags" its two parents, and we check to see how many tags are recaptured. Clockwise from top left: A shows all the adults (blue), juveniles (pink), and parental relationships; B shows sampled juveniles (red) and sampled adults (deep blue); C shows only what we can actually observe, i.e. the samples and the identified POPs; D shows the calculation of the estimate, which in this slightly contrived example happens to be exactly equal to the true number. Note that two juveniles match to the same adult, but this still counts as two POPs.

Appendix 6

CANADIAN PROPOSALS FOR THE DEVELOPMENT AND IMPLEMENTATION OF FISHERY INDEPENDENT INDICES OF ABUNDANCE FOR THE GULF OF ST LAWRENCE BLUEFIN TUNA

(Document submitted by Canada)[2]

1. Background

Analytical assessment models for Atlantic bluefin tuna (BFT), *Thunnus thynnus*, are calibrated using primarily fishery dependent catch per unit effort (CPUE) indices of abundance that rely solely on fishery information. In recent years, the Standing Committee on Research and Statistics (SCRS) has expressed concern about the representativeness of these indices and their ability to track trends in abundance due to changing fishing patterns and management imposed initiatives for both the eastern and western BFT stocks. In the latest report, the SCRS strongly recommends the development of fishery independent abundance indices for both stocks to complement the existing indices (ICCAT 2013, 2013a). Currently, Canada provides 2 indices of abundance, both CPUE based, for calibrating the western BFT assessment; Gulf of St Lawrence (1981-2013) and SWNS (1988-2013) rod and reel index (**Figure 1**). Both index time series have been influenced by external factors that may reflect annual changes in the index not directly associated with changes in abundance. The introduction of mandatory submission of logbooks in 1996, the implementation of individual transferable quotas in 2004, changing fishing practices, and in some areas, fishing restrictions imposed by the regional associations have affected the timing of the fishery, and all contribute to trends in the indices. Uncertainty related to the large increase in the GSL index resulted in the exclusion of the 2010 data from the 2012 assessment. The GSL index remained relative high in 2011 and 12 and proposed changes in exclusion may further affect the index.

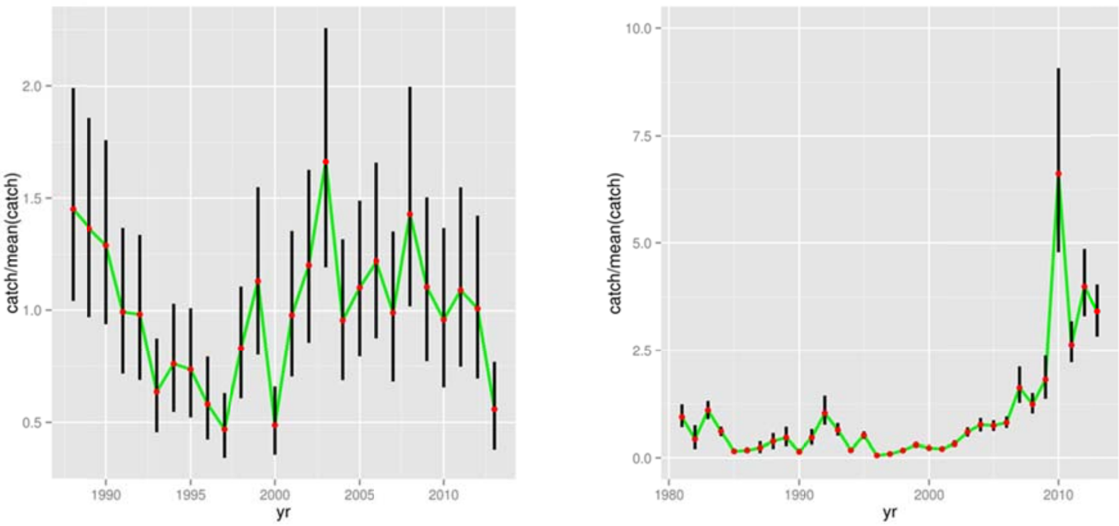


Figure 1. Standardized BFT index of abundance with 95% confidence intervals for Southwest Nova Scotia (left) and the Gulf of St Lawrence (right).

The main uncertainty regarding these changes in trends relates to the impact they have on the assumption of constant catchability of the fishery dependent indices over time, and whether or not the index trends (i.e., changes in indices) reflect actual changes in abundance and/or changes in management initiatives or the fishery. There are several examples on both sides of the Atlantic where changes or adaptions in management and the fishery have potentially affected the indices of abundance used in the eastern and western bluefin tuna assessments. In fact real concern was expressed at the last SCRS meeting that several of the indices for the eastern stock may be lost in the near future due to management changes. This has led the SCRS to recommend

[2] Dr. Gary D. Melvin, Head Pelagic Unit, Fisheries and Oceans, St Andrews Biological Station, St Andrews, NB E5B 2L9, E-mail: gary.melvin@dfo-mpo.gc.ca
Dr. Michael Stokesbury, Canada Research Chair in Ecology of Coastal Environments, Biology Department, Acadia University, 33 Westwood Avenue, Wolfville, NS, B4P 2R6 Canada, E-mail: michael.stokesbury@acadiau.ca

the development of fishery independent indices of abundance which tend to be relatively consistent over time in terms of gear, coverage and survey design. It is also important to note that the development a new fishery independent index of abundance will require 7-10 years before it has an influence on the assessment output results.

2. Proposals

Below we present 2 independent proposals to develop and implement fishery independent indices of abundance for the Gulf of St Lawrence; the first acoustic-trolling survey based index and the second a mark-recapture study. Each proposal on its own would provide a new fishery independent index of BFT abundance. Furthermore, while there are aspects of each approach that could be integrated into the other survey design, simply combining both approaches will not satisfy the requirements of either index. For the acoustic-trolling survey, coverage would be limited by the tagging proposal. Conversely, the number of BFT available for tagging, and their distribution, under the acoustic-trolling survey would be substantially reduced, albeit available for conventional tagging. Fish captured by trolling could however be used to apply popup satellite tags (PSAT) and /or uniquely coded acoustic tags (V16 Vemco Inc., NS, Canada) as proposed in the mark recapture study. Neither proposal is ranked regarding priority.

Combining the acoustic-trolling survey with the mark-recapture study would provide limited access to bluefin tuna for tagging; however, the two proposals have different requirements/assumptions to estimate abundance. The acoustic trolling survey is designed to cover a broad area in search of acoustic signals associated with tuna for enumeration of the number of fish. The trolling will be used to collect a representative sub-sample for identification of targets and estimation of size distribution. Additional fish could be obtained by collaborating with the commercial fishing fleet in each stratum if insufficient quantities are available from the survey vessel. This would of course add additional vessel costs to the proposal. The aim of the mark-recapture study is to catch and mark as many fish as possible in the time available, thereby narrowing the confidence intervals of the biomass estimate. The mark-recapture study proposal recommends fishing for tuna over a broad area (4 regions) in the Gulf of St Lawrence for increased coverage. Unfortunately, fishing for tuna to tag does not require vessel movement once the fish are located. While this limited movement would meet all the requirements for a mark recapture study, it would severely restrict the acoustic coverage which requires almost continuous movement. Consequently, while there are some options for combining the acoustic-trolling survey with the mark recapture study, doing so would compromise both approaches. It is thus recommended that only one or both proposals be put forward for funding.

2.1 Proposal 1 – Acoustic-Trolling Survey

"Development and Implementation of a Fishery Independent Index of Abundance for the Gulf of St Lawrence Bluefin using Acoustic-Trolling survey."

2.1.1 Context

The first proposal to develop a fishery independent index of abundance for Gulf of St Lawrence (GSL) bluefin tuna combines a traditional approach (trolling) of capturing large pelagic species with state of the art acoustic technology (split-beam echo-sounder and multi-beam sonar). Currently the Gulf of St Lawrence rod and reel index of abundance is based on catch and effort from the logbooks of the commercial fishery which tends to be stationary during fishing. No acoustic information is available from the commercial bluefin tuna fleet, although fishers commonly use acoustics to observe tuna. The survey will employ acoustic to improve coverage within a predefined area or stratum and trolling to catch and sample fish. In essence, the acoustic technology will be used to quantify and count bluefin tuna like targets in the water column and the trolling to estimate catch rates and target identification/validation for backscatter estimation. The approach integrates the technology and capture gear such that two fishery independent indices of abundance will be available from a single survey. Data for both indices will be collected concurrently from the same vessel(s).

2.1.2 Objectives

The primary objectives of the proposed survey are to:

1) Develop one or more long term fishery independent indices of abundance for bluefin tuna in the Gulf of St Lawrence. This approach will involve the implementation of a combined trolling and acoustic survey that could result in two independent indices of abundance from the same survey design and vessel.

2) Enhance Biological sampling (size data and otoliths). In addition to standard measurements for all captured fish, a sub-sample of bluefin tuna caught during trolling could be retained for biological sampling (otoliths, sex/maturity, stomach content etc.) assuming scientific quota is available.

3) Collaborate with, and support, of other bluefin tuna research and researchers. Fish captured during trolling could be tagged (traditional or PSAT) or a tissue/genetic sample collected before the fish is released.

2.1.3 Equipment

Standard commercial baited trolling gear will be utilized to catch and to estimate the CPUE using standardized protocols during the survey. The specific configuration will be finalized after discussion the industry and international scientists. Options to strengthen the line will also be explored to decrease fish retrieval time and increase acoustic survey time. The size of bluefin tuna captured in the Gulf of St Lawrence has ranged from <10kg to >650kg between 1972 and 2013. Mean raw and flank sizes by year are described in **Table 1**.

The Department of Fisheries and Oceans own and operates several acoustic monitoring systems suitable for a bluefin tuna survey. It is proposed to utilize a calibrated 120kHz Simrad EK60 scientific echosounder (7 degree beam angle) combined with a 500kHz high resolution Mesotech M3 multi-beam sonar (range approximately 100m, swath 120 degrees and variable beam angles) to conduct the survey. The vessel mounted sounder would be orientated downward and the sonar forward. If more than one vessel is utilized an alternative configuration of a EK 60 echosounder (same beam angle) and a 200kHz MS2000 multi-beam sonar (180 degree swath) could be deployed. Both systems will be pole mounted to the side of the survey vessel, for easy deployment and retrieval, if possible. An example of bluefin tuna in an echogram is presented in **Figure 2.1.1**.

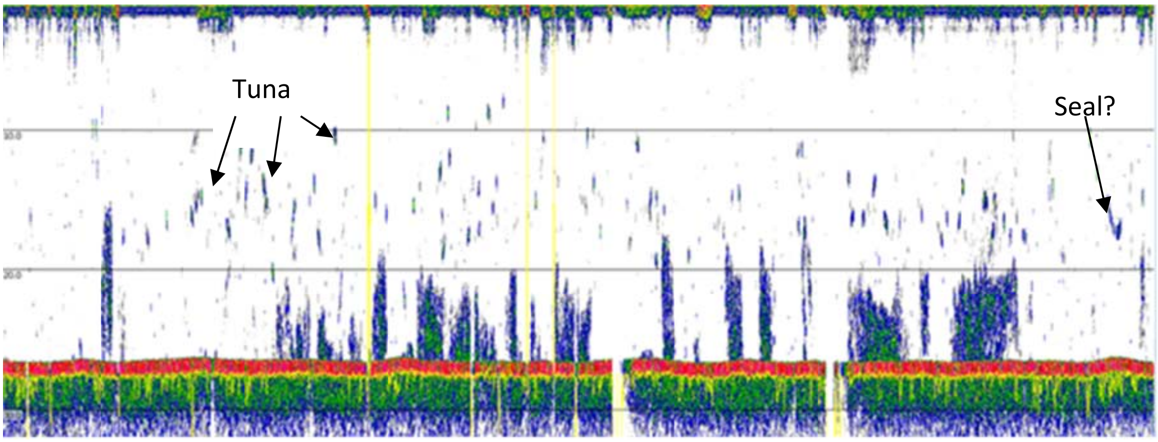


Figure 2.1.1 Echogram of herring schools and bluefin tuna observed on Fisherman's Bank September 28, 2013 recorded by a fishing vessel as it search for herring during a commercial fishing operation (below).

Several options are available for vessels to deploy the trolling and acoustic equipment. Given it compact size, the equipment can be deployed from almost any commercial, recreational or scientific vessel, however because of the shallow water around PEI it is recommended that only smaller vessels be consider for the survey (<85', preferably 45' or less).

2.1.4 Survey design

The actual survey design is not finalized, but will incorporate historical data on bluefin tuna catches and up to date information from the fishing/recreational industry. Figure 2.1.2 illustrates the location of bluefin tuna catches from 1997 to 2013 and **Figure 2.1.3** the same information annually. Based on this information it is evident that bluefin tuna tend to be concentrated in a few locations and within a 15-20 km distance along the northern shore of PEI, as well as in a 10-20km band that extends from Fisherman's Bank to coast of Cape Breton from Port Hood to Inverness, broadening slightly near Cape Breton. The areas of concentrations include 1) North Cape eastward to Malpeque Bay, 2) Crowbush to East Point, 3) Fisherman's Bank eastward to about half way between PEI and Cape Breton, and 4) the southwestern coast of Cape Breton.

The Gulf will be divided into 5 or 6 stratum (**Figure 2.1.4**) and effort focused in those strata where bluefin tuna are known to concentrate, however, the coordinates of the strata may change slightly after discussions with the tuna industry. The amount of time spent in each stratum will depend upon the amount of vessel time available. A series of transects (either systematic parallel or zig-zag) will be established in each stratum based on historical catches and recent effort. It is anticipated that 2 surveys of 10-12 day duration will be conducted each year, one in August and one in late September. Acoustic data will be collected continuously throughout the survey.

Acoustic data will be analyzed using Echoview and in-house software and the results presented as acoustic backscatter, observed biomass, and the number of observed tuna per stratum. Trolling data will be expressed in terms of CPUE where effort will be per hour or multiple hours fished.

Biological measurements will be undertaken when the bluefin tuna are alongside the survey vessel. It is the intent of this survey to release all captured bluefin tuna alive, unless they are required for specific studies and a quota source has been identified. Incidental mortalities (expected to be few) will use the ICCAT research mortality allowance (Total 20t annually) to accommodate any unforeseen mortality.

2.1.5 Reporting

An annual report on the project's progress and results will be provided/presented to the industry, DFO and the SCRS.

Table 1. Summary of Gulf of St Lawrence bluefin tuna mean lengths and weights from 1997 to 2013.

	Raw Weight (kg)				Flank length (cm)			
Year	Number	Average	Min	Max	Number	Average	Min	Max
1997	226	426.8	19.5	595.1	226	288.3	104.9	321.3
1998	227	421.1	281.2	600.6	227	288.2	251.3	326.6
1999	385	371.7	23.1	586.9	385	275.7	110.9	319.8
2000	573	354.9	38.6	658.2	573	272.2	131.9	332.1
2001	376	305.6	151.5	505.8	376	260.6	208.4	309.0
2002	597	272.7	24.0	493.5	597	250.6	112.3	303.9
2003	590	257.3	95.3	460.8	590	247.6	178.8	295.6
2004	736	252.2	70.8	437.3	736	246.1	160.0	298.7
2005	792	251.0	100.2	421.8	792	245.1	181.9	295.1
2006	962	257.0	72.1	466.3	962	246.7	162.8	296.6
2007	586	281.4	4.5	505.3	586	251.2	65.0	304.5
2008	736	279.3	117.9	478.1	736	251.7	193.2	299.1
2009	802	317.7	68.5	585.6	802	260.4	158.3	319.6
2010	585	335.6	86.2	537.1	585	263.7	170.6	310.7
2011	637	300.4	59.0	504.4	637	255.2	152.2	304.3
2012	817	276.3	90.7	527.5	817	247.6	175.9	308.9
2013	734	297.7	133.8	489.9	734	254.3	197.1	301.5
Total	10361	295.0	4.5	658.2	10361	255.4	65.0	332.1

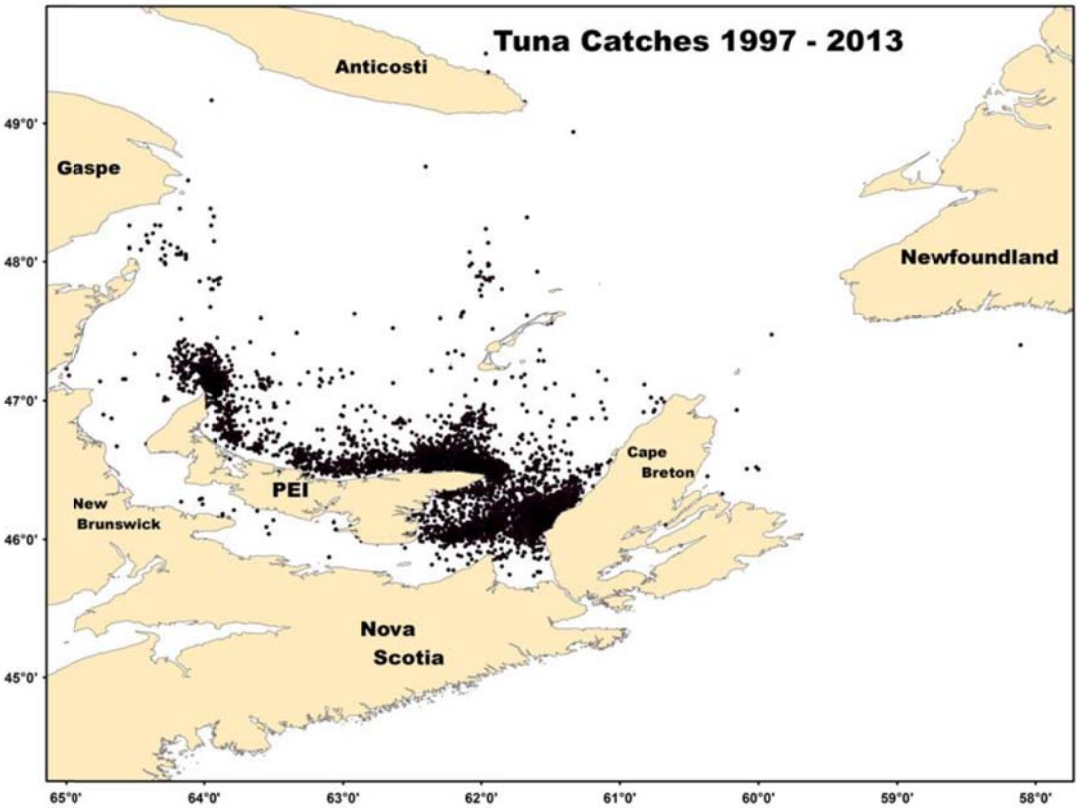


Figure 2.1.2 Location of bluefin tuna catches in the Gulf of St Lawrence from 1997 to 2013. Each point represents a single fish.

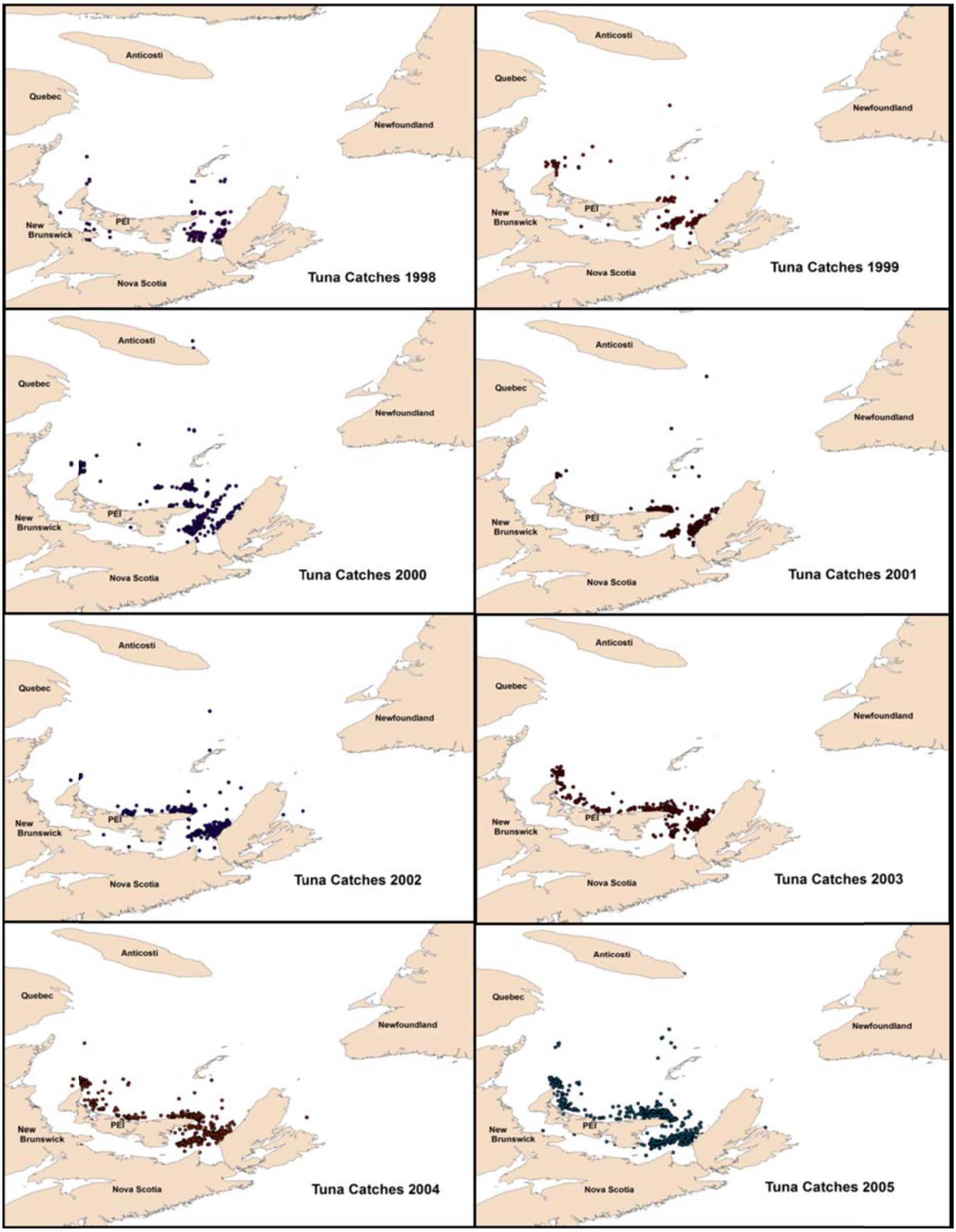


Figure 2.1.3a Location of bluefin tuna catches in the Gulf of St Lawrence by year from 1998 to 2005. Each point represents a single fish.

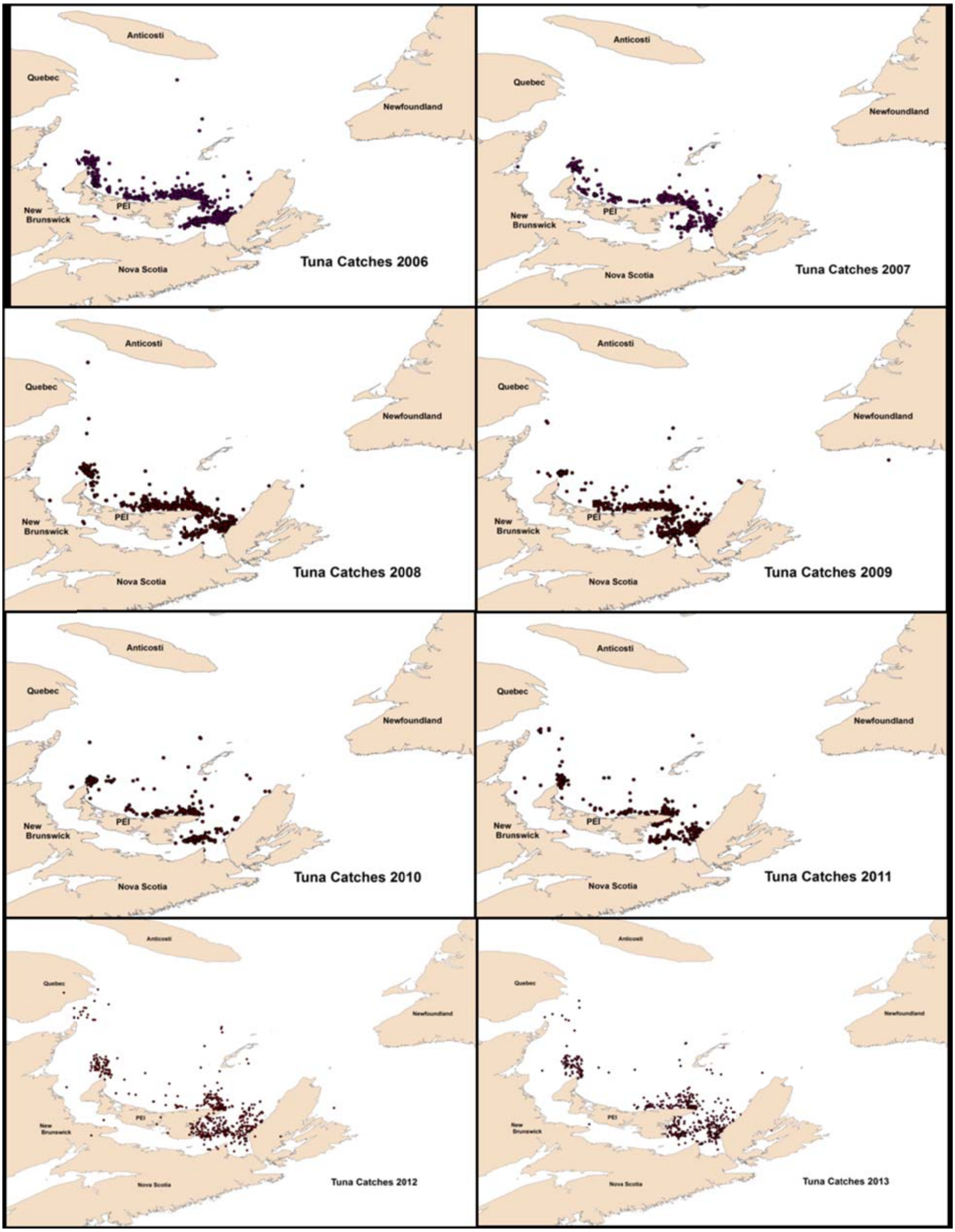


Figure 2.1.3b Location of bluefin tuna catches in the Gulf of St Lawrence by year from 2006 to 2013. Each point represents a single fish.

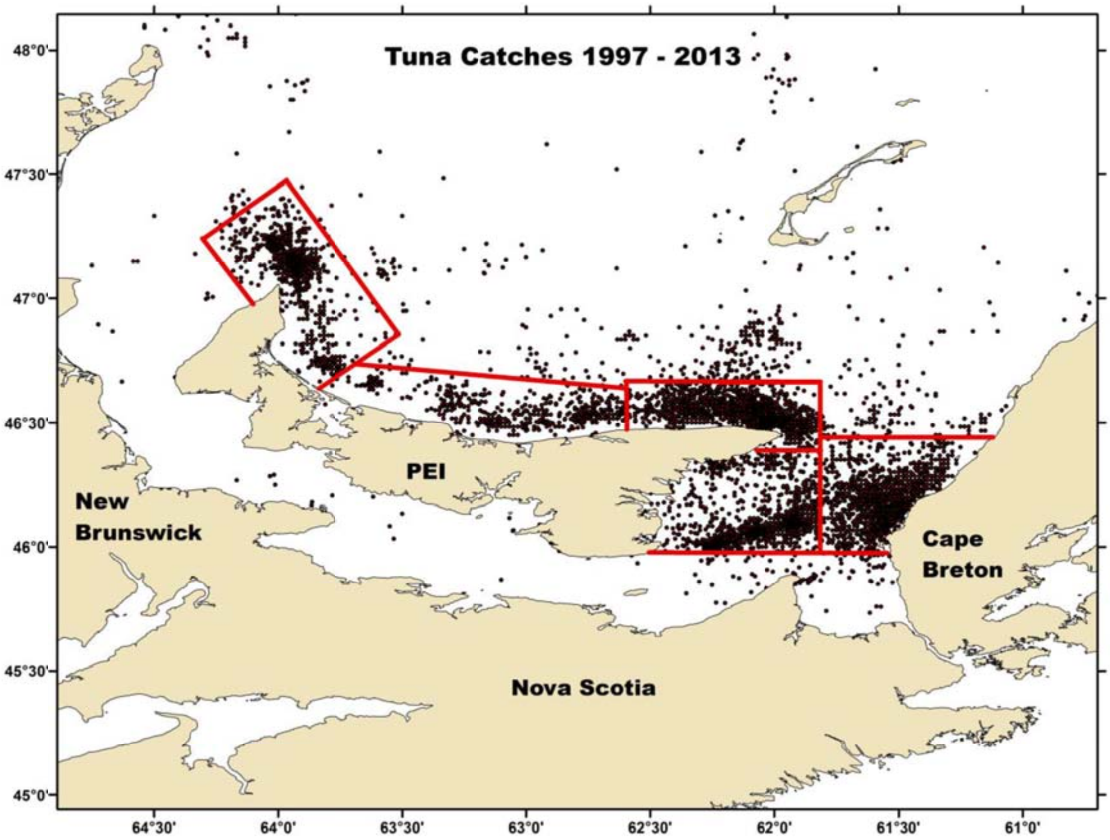


Figure 2.1.4 Approximate location of the Gulf of St Lawrence trolling-acoustic survey strata with the catches from 1997 to 2013. Transects will defined for the stratum one the amount of vessel time is determined.

2.2 Proposal 2 – Mark-Recapture Study

"A Mark and Recapture Experiment to Determine the Abundance of Atlantic Bluefin Tuna Present on a Seasonal Basis each Year in the Gulf of St. Lawrence, Canada".

2.2.1 Overview

Accurate estimates of bluefin tuna abundance are vital for both sustainable commercial and recreational exploitation and conservation, but are difficult to achieve due to their highly migratory behaviour. In this multi-year project, in collaboration with both commercial and recreational fishers from the Gulf of St. Lawrence, we will deploy both conventional and electronic tagging technology inside a Jolly-Seber open population mark and recapture experimental framework to obtain an abundance estimate for bluefin Tuna in the Gulf of St. Lawrence. The critical assumptions of a Jolly-Seber mark and recapture abundance models for open populations are: 1) Every animal has the same probability of capture; 2) marked animals have the same probability of survival; and 3) marks are not lost or overlooked. Based on our past tuna tagging work in the Gulf, we are certain there will be no or extremely limited tagging mortality, so the stock will be unaffected. All fishers in the Gulf of St. Lawrence will be encouraged to participate (see attached letters of support). Also, this proposal can benefit from, and add value to proposed broad band acoustic surveys and otolith collection by DFO by leveraging human resources, ship time and increased tagging opportunities. Critical infrastructure is already in place including lines of acoustic telemetry receivers at the entrances to the Gulf of St. Lawrence operated by Dalhousie University's Ocean Tracking Network (OTN). A portion of project support has been secured from the National Research and Engineering Council of Canada through the Discovery Grant Program to MJWS.

2.2.2 Context

Studying large-pelagic, highly migratory marine fishes is difficult due to the expense of access and monitoring of movement (Donaldson *et al*. 2008). Fisheries dependent methods (i.e., Catch Per Unit Effort (CPUE)) have been used to estimate abundance for large pelagic fishes though the shortcomings of these methods have been well documented (Hilborn and Walters 1992). Large pelagic fishes are difficult to census by traditional population assessment methods, such as mark and recapture, as access to fish for release is often minimal. Regardless, interest in fish tagging data for stock assessment has increased (Anon. 2007) and tagging data may provide the only viable alternative to traditional fisheries dependent methods for the measurement of population abundance (Polacheck *et al*. 2006).

Atlantic bluefin tuna (*Thunnus thynnus*) are a large marine, highly migratory, pelagic fish that breed in tropical waters but feed throughout tropical and temperate areas. Bluefin tuna have the ability to retain heat through counter current heat exchangers (Carey and Teal 1966) and can have internal temperatures that are 5^0C to 13^0C above the ambient water temperature (Graham and Dickson 2001), which allows them to range widely into cool productive oceanic waters in the western and eastern Atlantic Ocean, including the southern Gulf of St. Lawrence.

In the North Atlantic Ocean, Atlantic bluefin tuna are fished commercially by fishers from more than 40 countries (National Research Council 1994). Atlantic bluefin tuna are managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT) as two separate stocks; a western stock that breeds in the Gulf of Mexico and an eastern stock that breeds in the Mediterranean Sea (National Research Council 1994). The abundance of western Atlantic bluefin tuna has been severely reduced with a currently estimated population of approximately 98,000 individuals (age 8 and older; Anon 2012) that is considered to be approximately 25 to 36 % of the 1970 level (Anon 2012). Because of low abundance, in 2010 Atlantic bluefin tuna were proposed for listing and protection under the Convention on International Trade in Endangered Species (CITES), although the proposal was not accepted by CITES member nations. Recently (2011) bluefin have been recommended for listing as Endangered under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; http://www.cosewic.gc.ca) and assessment for a listing by the Species At Risk Act (SARA) is underway. Because of conservation concerns commercial quotas for Atlantic bluefin tuna in Canadian waters have been reduced in recent years as managers attempt to rebuild the western stock (**Figure 1**).

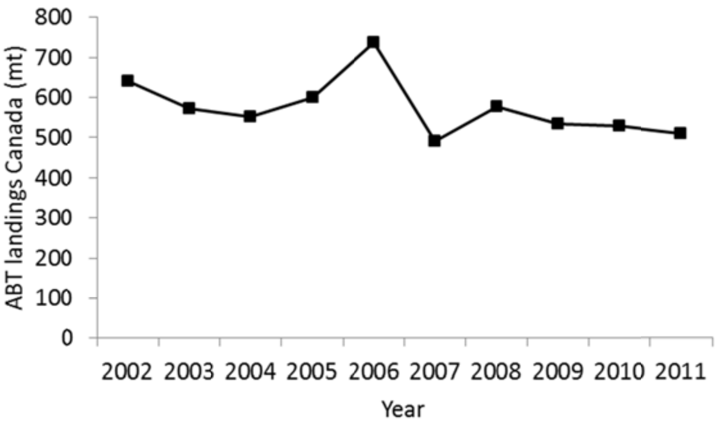


Figure 2.2.1 Atlantic bluefin tuna landings and discards in metric tonnes by year 2002-2011 (from DFO 2011, and Hanke *et al*. 2013).

Atlantic bluefin tuna migrate seasonally into Canadian waters to feed on abundant prey including Atlantic Mackerel (*Scomber scombrus*), Atlantic Herring (*Clupea harengus*) and Atlantic Saury (*Scomberesox saurus*). They are accessed in two main regions in the Maritime Provinces of Canada, in southwest Nova Scotia and in the Gulf of St. Lawrence. In the southern Gulf of St. Lawrence they are fished by fleets from Quebec, New Brunswick, Prince Edward Island, and Nova Scotia. Bluefin tuna are generally present in Canadian waters from June to December and are fished by Canadian fleets in the Bay of Fundy, on the Scotian Shelf, in the Gulf of St. Lawrence and off Newfoundland (**Figure 2**). Atlantic bluefin tuna fished in the southern Gulf of St. Lawrence are part of the western Atlantic Ocean stock (Rooker *et al*. 2008).

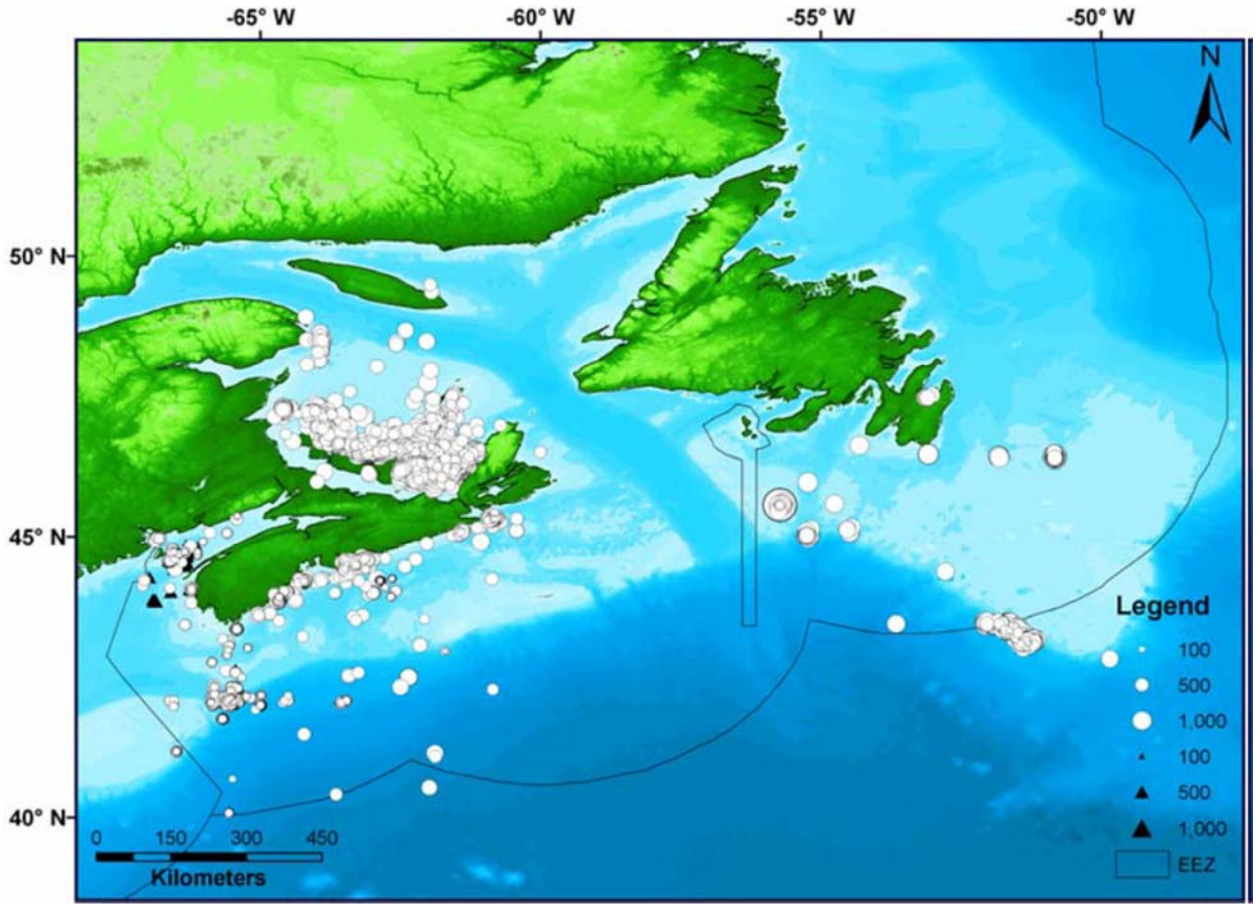


Figure 2.2.2 Location and landed weight in lbs from logbooks of Atlantic bluefin tuna caught by Canadian fishers from 2000-2009. Symbols represent landed weight by gear (white circles = hook and line; black triangles = electric harpoon). Black line is the boundary of the Canadian Exclusive Economic Zone (Figure from DFO 2011).

The CPUE for Atlantic bluefin tuna has risen dramatically in the last few years in the southern Gulf of St. Lawrence (**Figure 1**) to the point where in 2010 the Prince Edward Island fleet (310 licenses) caught their entire quota in 3 days (Hanke *et al*. 2013). Historically this took months to achieve. These data and similar observations have caused both fishers and scientists to question the accuracy of the current western Atlantic tuna abundance estimates (Bluefin RPA meeting, St. Andrews, New Brunswick, 2011).

There are other indications of stock resurgence of bluefin tuna including the data from 59 pop-up archival satellite tags that we deployed on Atlantic bluefin tuna in the southern Gulf of St. Lawrence two weeks prior to the opening of the Prince Edward Island, Gulf Nova Scotia and Gulf New Brunswick commercial fisheries in 2010 (Stokesbury *et al*. 2011). After approximately 533 Atlantic bluefin tuna were harvested from the southern Gulf of St. Lawrence (Hanke *et al*. 2013) only 2 fish with satellite tags were re-captured. However 53 of 59 tags (4 failed to report) reported from live fish after the close of the commercial season (Stokesbury *et al*. 2011). Though not rigorous, this indicates that there may be more Atlantic bluefin tuna present in the southern Gulf of St. Lawrence than have been previously estimated.

In summary, for proper management and conservation, there is a significant and timely need to development accurate indices of abundance Atlantic bluefin tuna in the southern Gulf of St. Lawrence. The goal of this project is to obtain this information through a multi-year mark and recapture experiment using a Jolly-Seber open population model (Jolly 1965, Seber 1965, Ricker 1975, Amstrup 2005).

2.2.3 Experimental design

Study site - The Gulf of St. Lawrence is bounded by Nova Scotia, New Brunswick, Quebec and Newfoundland and Labrador. It is similar to an inland sea as it has distinct physical characteristics and is partially isolated from the North Atlantic Ocean (**Figure 2**). Historical micro constituent analysis (Rooker *et al.* 2008) and archival tagging (Wilson *et al.* 2010) have established that Atlantic bluefin tuna in the Gulf of St. Lawrence belong almost exclusively to the western stock.

Approach - We will design and test a procedure that utilizes both mark and recapture using conventional dart tags (Ricker 1975, Amstrup 2005, Stokesbury *et al.* in press), and spatial and temporal animal movement data derived from acoustic (Stokesbury *et al.* 2005) and archival satellite tags (Stokesbury *et al.* 2004, Block *et al* 2005, Stokesbury *et al.* 2007, Stokesbury *et al.* 2011). Historical data from archival satellite tagging and new data from acoustic and conventional tagging will be used to address the assumptions that are required for estimating abundance through mark and recapture for an open population.

An "open" population changes in abundance during the study due to births, deaths, immigration and emigration (Krebs 1989). For a Jolly-Seber estimate (Jolly 1965, Seber 1965, Ricker 1975, Pollack *et al.* 1990) mark-recapture samples are taken on three or more occupations. The key point is that you must determine, "When was the individual last captured?" The time interval can vary between captures but fish must be individually marked. The population size is calculated from dividing the size of the marked population by the proportion of animals marked (number of animals caught in a sample compared to how many of those animals were marked; Krebs 1989). The increase in the numbers of bluefin tuna that will be examined for marks in the Gulf of St. Lawrence due to the growing catch-and-release charter fishery (catch and release 600 to 800 fish per year) and therefore the increase in tags that will be recaptured, will allow this experiment to be conducted at a higher level of precision than has been possible previously.

A Jolly-Seber mark and recapture experiment will be performed in collaboration with Fisheries and Oceans Canada, the Prince Edward Island Fishermen's Association, the Gulf Nova Scotia Fishermen's Association (see included letters of support) and other bluefin tuna fishers from the region. There is now a recreational charter fishery for Atlantic bluefin tuna in the southern Gulf of Saint Lawrence. Many tuna are now captured in this recreational fishery, and released back into the population. By tagging bluefin tuna captured in this fishery, as well as the wide spatial distribution provided by tagging with commercial fishers, there is an opportunity to apply conventional tags (Floy spaghetti streamers) to large numbers of tuna during the summer and early autumn. Researchers will be deployed on fishing boats in four locations during the months of August to November (North Lake and Tignish PEI, Port Hood and Arasaig NS; **Figure 4**) and two locations where opportunistic tagging can occur (Richibucto, NB, Magdalen Islands PQ; **Figure 4**) to attach conventional tags to bluefin tuna captured and released by fishers. Returns of marked animals will occur, both through recapture in the charter fishery and through the commercial fisheries that open in the autumn.

2.2.4 Implementation and staff

2014 – Preparation for execution of the project will start during the summer of 2014. Multiple years of tagging and tag recapture will be required to provide the first valid estimate of abundance. This procedure is necessary as the number of tagged fish must build up over at least two seasons to provide enough tagged fish and tag returns to create a valid estimate of abundance. Based on the recapture of our archival tags in 2010 in relation to the total estimated catch ($2/55 = u = 0.036$) we suggest a provisional population of ~ 14,000 tuna are now in the Gulf each year, keeping in mind that this is only a portion of the total stock abundance as not all bluefin tuna enter the Gulf of St. Lawrence each year. Based on the estimated provisional population we will be required to tag between 200 to 250 tuna a year to obtain a valid estimate that will have either the 25 or 10 % probability of accuracy that is required for management and scientific study, respectively (Krebs 1989).

One Post-Doctoral Fellow (Post-Doc) will be hired to work on the project year round. This responsible scientist will assist in experimental design, lead the field crews and assist in data analysis, report preparation and information dissemination to fishers and managers. The field research team will consist of the responsible scientist and three technicians who will be hired for 3-4 months a year augmented with field assistance from the study P-I's and fishers. Post-Doc and technicians will undergo training including safety training (MEDS A-3 Dartmouth Survival Systems Inc.), training in conventional and acoustic tagging techniques, otolith and tissue removal and sample preparation, metadata recording and data analysis.

To perform the experiment we will be required to tag approximately 200-250 bluefin tuna/yr in regions of the Gulf where we anticipate, from past years knowledge, that they will randomly mix with the population. The study design will consist of either the Post-Doc or technicians being stationed in all four locations (**Figure 4**; North Lake and Tignish, PEI and Port Hood and Arasiag NS) that geographically coincide with past areas of high catch rates (**Figure 1**). Also, tagging will be performed from ports in New Brunswick and the Magdalen

Islands when possible. Opportunistic tagging opportunities are also expected (tagging that is not directly chartered for). Each researcher in each region will be responsible for: 1) Deploying conventional and acoustic tags; 2) gathering recaptured tags from fishers; 3) providing information to fishers regarding the projects objectives and experimental design and 4) dockside sampling of otoliths and tissue for the DFO monitoring program examining mixing rates of eastern and western bluefin tuna through otolith structure.

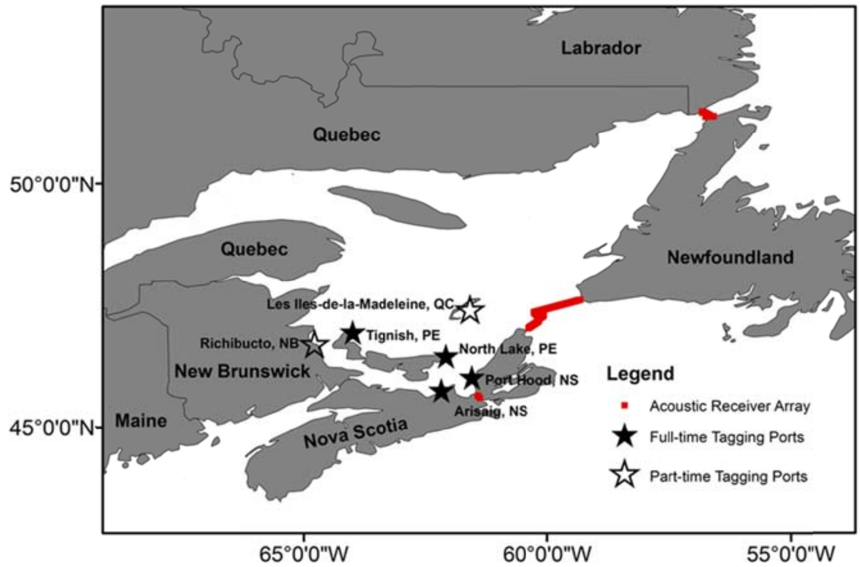


Figure 4. Map of the Gulf of St. Lawrence with positions of hydroacoustic receiver lines operated by the Ocean Tracking Network, Dalhousie University, and positions of proposed placement of our Atlantic bluefin tuna team for tagging operations in 2014.

In each of these regions we will have a local draw where each fisher from PEI (in the two PEI locations) or Nova Scotia (in the two Nova Scotia locations) regardless of whether they fish commercially or in the charter fishery, will have an equal chance to take a researcher on their boat to tag tuna. No commercial capture will be allowed during this process, so there is no possibility of high-grading. The fisher will be paid $700 per day and will be responsible for all costs (including fuel, tackle, bait, and wages for crew). This amount of money is meant only to offset costs and money made by fishers will be negligible. We have budgeted for 80 tagging day trips (20 per location). We also anticipate opportunistic tagging opportunities that may present themselves such as collaboration with other projects answering this call for proposals, or when fishers with the blessing of their associations provide tagging opportunities.

During tagging, tuna will be captured using rod and reel, and fishers will only use barbless circle hooks to reduce impact on fish. Hooked tuna will be fought and brought to the side of the boat where they will be tagged with either 1 or 2 Floy conventional tags, sampled for a DNA plug, weight estimated and the fish will then be released. While tagging takes place the tuna will be held at side of a boat while the boat slowly moves forward allowing the fish to ram ventilate as described in Stokesbury *et al*. (2011).

Our tagged tuna will be recaptured during tagging operations and during regular charter and commercial fishing activities. Tags must be returned to researchers. To ensure this, we will work diligently to introduce all fishers to the project, objectives and experimental design. Also, to provide added incentive for tag return a yearly lottery will be held with a single $5k prize. Each conventional tag returned by a fisher will provide one opportunity to win the prize. Our project will provide yearly estimates of relative abundance based on exploitation rate as well as a final, valid population estimate. Activities for the first 3 years (2014-2016) are shown in the Grant chart (**Figure 5**).

2.2.5 Chronology

Figure 5. Grant chart of activities (2014-2016) for a mark and recapture experiment to estimate relative abundance of Atlantic bluefin tuna annually present in the Gulf of St. Lawrence, Canada.

	2014		2015				2016			
Task	July-Sept	Oct-Dec	Jan-Mar	Apr-June	July-Sept	Oct-Dec	Jan-Mar	Apr-June	July-Sept	Oct-Dec
Experimental Design Refinement	XXX	XXX	XXX				XXX			
Hiring of Post-Doc & Techs	XXX	XXX		XXX				XXX		
Training of Post-Doc & Techs (sampling)	XXX			XXX				XXX		
Survival Systems Inc. training	XXX			XXX				XXX		
Field training Post-Doc and Techs (tagging)	XXX				XXX				XXX	
Field logistics (accommodation etc.)	XXX		XXX				XXX			
Ordering tagging supplies	XXX		XXX				XXX			
Meetings with fishers & associations	XXX	XXX		XXX	XXX			XXX	XXX	
Conventional tagging	XXX	XXX			XXX	XXX			XXX	XXX
Acoustic tagging	XXX	XXX			XXX	XXX			XXX	XXX
Tag recapture	XXX	XXX			XXX	XXX			XXX	XXX
Otolith & Tissue sampling	XXX				XXX	XXX			XXX	XXX
Data Analysis			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
OTN line download (OTN Dalhousie)		XXX				XXX				XXX
Lottery for tagging trips	XXX			XXX				XXX		
Tag prize lottery ($5k)		XXX				XXX				XXX
Lottery for tagging trips	XXX			XXX				XXX		
First relative abundance estimate						XXX				
Annual Relative abundance estimate						XXX				XXX

2.2.6 Tagging

Each year 30 Atlantic bluefin tuna will be tagged with uniquely coded acoustic tags (V16 Vemco Inc., NS, Canada). Bluefin tuna enter and exit the Gulf of St. Lawrence through the Cabot Strait in the south or the Strait of Belle Isle in the north. The Ocean Tracking Network at Dalhousie University (www.OceanTrackingNetowrk.org) has both of these passages completely covered with a continuous line of hydroacoustic receivers that will log on data from acoustic tags that allow individual identification of fish and provide a time and location stamp when the fish enters or leaves the Gulf. Report authors (MJWS, SJC and MJD) are primary investigators in the Ocean Tracking Network and have many years of experience with electronic and conventional tag data capture, storage, access and analysis.

Acoustic tags with a 10 year life span will be utilized in this study. Therefore we will have a record each time an individual acoustic tagged tuna enters or exits the Gulf of St. Lawrence. These data will allow us to gain critical information on immigration and emigration for the Jolly-Seber population estimate that we can use to validate the model and allows a measure of what portion of the tuna return to the Gulf of St. Lawrence on an annual basis. These data, when applied to the numbers of tagged tuna in the Gulf of St. Lawrence, will give us an accurate estimate of the number of tuna that are present in the Gulf of St. Lawrence from each year of tagging and provide an accurate estimate of M_i (The number of marked animals in the population at the time of the *i*th sample; **Table 1**). The project will take place over several years so that the marked population will gradually build up, and the recaptures over years will provide accurate and robust estimates of abundance over time.

Table 1. Key Parameters and Statistics necessary for the execution of a Jolly-Seber mark-recapture experiment (Information from Pollack *et al*. 1994; **Table 4.1**).

Parameters	Definition
M_i	The number of marked animals in the population at the time the *i*th sample is taken (i = 1,…, k; $M_1 = 0$).*
N_i	The total number of animals in the population at the time the *i*th sample is takes (i = 1,…, k).
B_i	The total number of new animals entering the population between the *i*th and the (i + 1)th sample and still in the population at the time of the (i+1)th sample is taken (i = 1,…, k – 1).**
Ө	The survival probability for all animals between the *i*th and (i + 1)th sample (i = 1,..., k – 1).
p_i	The capture probability for all animals in the *i*th sample (i = 1,…, k).
Statistics	
m_i	The number of marked animals captured in the *i*th sample (i = 1,…, k).
u_i	The number of unmarked animals captured in the *i*th sample (i = 1,… k).
n_i	$m_i + u_i$, the total number of animals captured in the *i*th sample (i = 1,…, k).
R_i	The number of the n_i that are released after the *i*th sample (i = 1,..., k – 1). This may not be all of the n_i due to losses on capture.
r_i	The number of the R_i animals released at I that are captured again (i = 1,…, k – 1).
z_i	The number of animals captured before I, not captured at I, and captured again later (i = 2,…, k – 1).

*Each year 40 Atlantic bluefin tuna will be tagged with uniquely coded acoustic tags (V16 Vemco Inc., NS, Canada). Bluefin enter and exit the Gulf of St. Lawrence through the Cabot Strait in the south or the Strait of Belle Isle in the North. The Ocean Tracking Network at Dalhousie University has both of these passages completely covered with a continuous line of hydroacoustic receivers that will log on data from acoustic tags that allow individual identification of fish and provide a time and location stamp, when the fish enters or leaves the Gulf. This will determine the ratio of tagged fish returning to the Gulf on a yearly basis.

**Estimates of immigration will be obtained from an examination of historical monthly trends in CPUE through the year. These data when compared with estimates of rate of emigration from acoustically tagged fish will give an estimate of immigration to the aggregation.

Assumptions: A Jolly-Seber (Ricker et al. 1975, Pollock *et al*. 1990, Amstrup 2005) mark- recapture model for an open population has three critical assumptions that must be fulfilled for the accurate and unbiased assessment of abundance. They are: 1) Every animal has the same probability of capture; 2) marked animals have the same probability of survival; 3) marks are not lost or overlooked. Assumptions will be fulfilled as: 1) Bluefin tuna will be fished with non-selective gear, on a broad geographical scale (tagging locations very similar to areas of high commercial catch). 2) All marked animals will have the same probability of survival as tags will not affect catchability after the 14 day period used to provide random mixing of tagged fish back into the population. 3) We will double tag a portion of the tuna (20%) to obtain an estimate of tag shedding (tag loss).

Additionally, we will invest a large amount of effort to include fishers in the project as well as provide project information to the public through outreach programs in order to increase the accuracy of the tag return data. It is well known that regulation of fisheries can cause problems and a decline in tag return accuracy (Stokesbury *et al*. 2009). Our research team will attempt to talk to every captain fishing in the area, singly or in groups, to impress upon them the importance of tag return data to the overall project and how the information will help them and DFO manage the resource. Also, as mentioned above, there will be lottery ($5,000 prize) held each year with one chance to win for each tag that you have returned, to add extra incentive for tag return.

2.2.7 Significance of work

By improving estimates of abundance we will make possible the development of sustainable management targets for commercial harvest and for setting conservation targets.

3. References

Amstrup, S.C., McDonald. T. L. and B.F.J. Manly. Handbook of capture-recapture analysis. p. 313.Princeton University Press. Princeton, NJ (2005).

Anon. 2007. IATTC workshop on using tagging data for fisheries stock assessment and management strategies. Report (compiled by Mark. N. Maunder), La Jolla, California (USA). 16-19 October 2007.

Anon. 2012. BFT Stock Assess. Meeting report. Doc. No. SCI-033/2012. 124 pp.

Block, B.A., Teo, S.L.H., Walli, A., Boustany, A., Stokesbury, M.J.W., Farwell, C., Williams, T., Weng, K. and H. Dewar. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature 434: 1121-1127.

Carey F. G. and J. M. Teal 1966. Heat conservation in tuna fish muscle. Proc. Nat. Acad. Sci. USA 56: 1464-1469.

Donaldson, M.R, Arlinghaus, R., Hanson, R. and S. J. Cooke. 2008. Enhancing catch-and-release science with biotelemetry. Fish Fish.: 9:79-105.

DFO. 2011. Recovery potential assessment for western Atlantic bluefin tuna (*Thunnus thynnus*) in Canadian Waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/056.

Graham J. B. and K. A. Dickson. 2001. Anatomical and physiological specializations for endothermy. In Block, B. A. and Stevens, E. D. eds. Tuna: Physiology, Ecology and Evolution. Fish Physiology 19. Academic press. San Francisco. 468 pp.

Hanke, A. R., Andrushchenko, I., Neilson, J. D. and C. Whelan. 2013. Indices of stock status from the Canadian bluefin tuna Fishery. Collect. Vol. Sci. Pap. ICCAT, 69(1): 335-377.

Hilborn, R. and C. J. Walters. 1992. Quantitative fisheries stock assessment. Chapman and Hall, London, pp.570.

ICCAT. 2013. International Commission for the Conservation of Atlantic Tunas. Report for biennial period, 2012-13 Part II (2013) - Vol. 2. SCRS 2013-17: 343p.

ICCAT. 2013a. First meeting of the working group of fisheries managers and scientists in support of the western Atlantic bluefin tuna stock assessment. Montreal, Canada, June 26-28, 2013. Report Comm/SCRS 2013- 10:44p.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Bimetrika 52: 225-247.

Krebs, C. J. 1989. Ecological Methodology. Harper & Row Publishers Inc., New York, NY.

National Research Council. 1994. An assessment of Atlantic bluefin tuna. National Academy Press, Washington, D. C. pp. 148.

Pollock, K. H., Nichols, J. D., Brownie, C. and J. E. Hines. 1990. Statistical inferences for capture-recapture experiments. Wild. Monogr. 107: 1-97.

Polacheck, T., Eveso, J. P., Laslett, G. M., Pollock, K. H., and W. S. Hearn. 2006. Integrating catch-at-age and multiyear tagging data: a combined Brownie and Petersen estimation approach in a fishery context. Can. J. Fish. Aquat. Sci. 63: 534-548.

Ricker W. E. Computation and interpretation of biological statistics of fish opulations. 1975 Bull. Fish. Res. Board Can. 191.

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

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52: 249-259.

Stokesbury, K. D. E., Stokesbury, M. J. W., Balazik, M. T., and M. J. Dadswell. In Press. Use of the SAFE index to evaluate the status of a summer aggregation of Atlantic sturgeon in Minas Basin, Canada and the implication of the index for the USA Endangered Species designation of Atlantic and shortnose sturgeons. Reviews in Fisheries Science and Aquaculture, Submitted 23 December 2013.

Stokesbury, M.J.W., Teo, S.L.H., Seitz, A., O'Dor, R. K., and B.A. Block. 2004. Movement of Atlantic bluefin tuna (Thunnus thynnus) as determined by satellite tagging experiments initiated off New England. Canadian Journal of Fisheries and Aquatic Sciences 61: 1976-1987.

Stokesbury, M.J.W., Harvey-Clark, C., Gallant, J., Block, B.A., and R.A. Myers. 2005. Movement and environmental preferences of Greenland sharks (*Somniosus microcephalus*) electronically tagged in the St. Lawrence Estuary, Canada. Marine Biology 148: 159-165.

Stokesbury, M.J.W., Cosgrove, R., Teo, S.L.H., Browne, D., O'Dor, R.K. and B.A. Block. 2007. Movement of Atlantic bluefin tuna from the eastern Atlantic Ocean to the western Atlantic Ocean as determined with pop-up satellite archival tags. Hydrobiologia 582:91-97.

Stokesbury, M.J.W., Dadswell, M.J., Holland, K.N., Jackson, G.D., Bowen, W.D. and R.K. O'Dor. 2009. Tracking diadromous fishes at sea using hybrid acoustic and archival tags. pp. 311-320. In Haro, A. J., K. L. Smith, R. A. Rulifson, C. M. Moffitt, R. J. Klauda, M. J. Dadswell, R. A. Cunjak, J. E. Cooper, K. L. Beal, and T. S. Avery, editors. 2009. Challenges for Diadromous Fishes in a Dynamic Global Environment. American Fisheries Society, Symposium 69, Bethesda, Maryland.

Stokesbury, M.J.S., Neilson, J.D., Susko, E. and S. J. Cooke. 2011. Estimating mortality of Atlantic bluefin tuna (*Thunnus thynnus*) in an experimental recreational catch-and-release fishery. Biological Conservation 144: 2684-2691.

Wilson, S. G., Lawson, G. L., Stokesbury, M. J. W., Spares, A., Boustany, A. M., Neilson, J. D., and B. Block. 2010. Movements of Atlantic bluefin tuna from the Gulf of St. Lawrence, Canada to their spawning ground. ICCAT SCRS/2010/077.

Annex 1. Proposed budgets

1.1 Trolling-Acoustic Proposal Budget

A major source of uncertainty associated with this project is that no funding source has been identified and no funds have been allocated to conduct this, or any other, survey to develop a fishery independent index of abundance for bluefin tuna. The following budget is based on the estimated cost to undertake the survey for both the start-up and subsequent year's. The largest portion of the budget is attributed to vessel costs to conduct the survey. Major cost saving could be achieved through vessel contributions from industry and/or DFO. The proposed survey is budgeted with and without the vessel costs.

Year 1:

Technical support:				
1 field technician (EG 4/5 $80K/year)			$20,000	
1 full time technician (EG 4/5 $80K/year)			$80,000	
Travel:				
Field Costs				$9,000
Consultations (Industry/Scientific)			$7,000	
O&M:				
O&M (equipment, maintenance, material, supplies)		$60,000		
Software upgrades				$10,000
Over-time in field				$5,000
Sub-Total Start-up year	$191,000			
Vessel Charter				
28 days at 8k/day				$224,000
Total Start-up year	$415,000			

Year 2 (and after without inflation):

Technical support:			
1 field technician (EG 4/5 $80K/year)		$20,000	
1 full time technician (EG 4/5 $80K/year)		$80,000	
Travel:			
Field Costs			$9,000
Consultations (Industry/Scientific) 2,000			
O&M:			
O&M (equipment, maintenance, material, supplies)		$10,000	
Software upgrades			$10,000
Over-time in field			$5,000
Vessel Charter			
Sub-Total Start-up year	$136,000		
Vessel Charter			
28 days at 8k/day		$224,000	
Total Start-up year	$360,000		

1.2 Mark-Recapture Proposal Budget

Budget

Category	Number	Cost	Total	Sub Totals
Salaries				
Post-Doc	1	50,400	50,400	
Technician (3 months)	3	7,560	22,680	73,080
Equipment				
Floy Tags	400	4	1,600	
Floy Tag Return Lottery	1	5,000	5,000	
Coded Acoustic Tags (V16)	40	462	18,480	
Vessel Charter	80	700	56,000	81,080
Office Supplies	1	1,000	1,000	1,000
Travel & Accommodations (Field work)				
Mileage	4	2,500	10,000	
Accommodations	4	2,500	10,000	
Food	4	2,500	10,000	
Supervisor (Mileage and accommodation)	1	3,000	3,000	33,000
Consultants				
Program management consulting	15	600	9,000	
Scientific consulting	10	600	6,000	15,000
			Subtotal	203,160
Acadia university Overhead (20%)				40,632
			Grand Total	$243,792 per year

Budget justification

1. Salaries and benefits (Total = $73,080/year)

A. Post doctoral fellow and technicians – Total Amount: $73,080/year
Context: Funds are requested to support one Post-Doc (Mr. Aaron Spares) during each year of the program. The NSERC approved annual salary for a Post-Doc is $45,000 (plus 0.12 benefits) for a total cost of $50,400/year. Also, we will need three technicians for 3 months each ($15/hour, 37.5 hours/week, plus 0.12benefits = $7,560/tech/year; Tech total = $22,680).

Post-Doc and technicians will be responsible for specific focused tasks. They will receive training (some already have) in conventional (Floy) tag deployment on bluefin tuna. They will also receive training in metadata recording, structure and quality. Our researchers will be placed in major tuna landing or access centres in the southern Gulf of St. Lawrence. They will be responsible for deploying conventional tags on tuna. They will also gather recaptured tags from fishers in their area. Generally researchers develop a good relationship with local fishers because they have a project presence in each region to answer questions and provide a point of contact. Their presence will have a very positive impact on the quality of the data acquired. This factor will also greatly increase the rate of tag return. As a side benefit to bluefin tuna research, researchers will be trained in otolith removal, care and storage, as well as tissue removal, storage and data capture. Our researchers placed in the major landing centers will be able to sample bluefin tuna heads and tissue for the Department of Fisheries and Oceans, to assist the otolith analysis now underway (contact: Dr. Alex Hanke, DFO, St. Andrews, NB).

2. Equipment or facility (Total = $81,080/year)

A. Purchase – Total Amount: $20,080 /year

Funds are requested to purchase 400 Floy ™ conventional tags with applicators ($4k). These tags will be deployed on bluefin tuna throughout the study (Total = $1,600).

Funds are requested to purchase 40 V16 coded acoustic tags. (Total cost $18,480). These tags, in conjunction with Ocean Tracking Network receiver lines in place across all opening of the Gulf of St. Lawrence, will provide information on seasonality, emigration and immigration into the Gulf of St. Lawrence. Tags will be programed for 10 years, which will provide a long data set of Atlantic bluefin tuna activity.

B. Charter – Total Amount: $56,000/year

Fishing boat charter will be used to deploy tags. The estimated cost will be $700 per day. We have budgeted for 80 days per year (20 days per major tuna port total = $56,000/year). This will provide coverage of the major areas of tuna distribution and having 4 tag deployment centres over time will address the assumption of the tags being randomly mixed with the population.

C. Tag Return Lottery: $5,000

Conventional tags that are recaptured must be returned in order for the population assessment model to be accurate. The best way to ensure compliance is to have good communication between the science team and fishers. Also, instead of a small reward ($10 or hat per tag return) we will conduct a lottery. For each tag returned that fishing captain gains one chance to win an end of the year lottery for $5,000.

3. Materials and supplies (Total = $1,000/year)

Yearly user fee for operation of ESRI products (ArcGIS Geostatistical Analyst ($45), ArcGIS Tracking Analyst ($45), ArcGIS Spatial Analyst ($45), ArcINFO ($450), and ArcGIS 3D Analyst ($41) = $720/year (HST included). Also, support is required for materials and supplies for students in the program such as printer paper and ink, production of posters for poster presentations, office supplies (Total = $1,000/year)

4. Field work travel – Total = $33,000/year

A. Field work

Tagging of large pelagics will be performed in the southern Gulf of St. Lawrence from 4 locations, Tignish PEI, North Lake PEI, Port Hood, NS, and Ballentyn's Cove / Arasaig NS. Tagging and tag recapture will take place July-September. We estimate mileage costs of $2500/ year per location, accommodation costs of $2500/year per location (for house rental or motel, whichever is the least expensive) and per diem costs of $2500/year per location (Total = $30,000/year). As the project supervisors the total for PI's will travel costs will be similar to each field operation since they must visit the four locations regularly and also make trips to New Brunswick and Quebec (Magdalen Islands) for information dissemination, and tag retrieval ($3,000). Total travel field costs for PI's are $30,000 + $3,000 = $33,000).

5. Consultants

The hiring of a consultant for program management includes interacting with funding partners, and dissemination of information to industry and government groups.
Scientific consultant includes experimental design and statistical assistance to ensure maximum benefit is derived from data on mark and recapture abundance (Total = $16,000/year)

Cash and In- Kind contributions from other sources

In Kind contributions include salaries for scientific team, and some administrative support from the Prince Edward Island Tuna Fishermen's association. Also, the Ocean Tracking Network has invested over $1,000,000 in this region to provide coverage to detect animals carrying acoustic tags that cross the Cabot Strait and Strait of Belle Isle receiver lines.

Cash contributions to the proposed research program are detailed in the table below.

Source	Status	Year 1	Year 2	Year 3
		2014	2015	2016
NSERC DG to MJWS	Secured for year 1-3	20, 000	20,000	20,000
NSERC IRDF	Unsecured	30,000	30,000	30,000
NSERC IUSRA (3)	Unsecured	13,500	13,500	13,500
Total Cash Contribution		63,500	63,500	63,500

Annex II: Research Team

II 1.0 Acoustic Trolling Survey

Dr. Gary D. Melvin is Head of the Pelagic (large and small) unit at the DFO St Andrews Biological Station responsible for research and assessment of Atlantic bluefin tuna. Nationally and internationally he is a recognized expert in fish stock assessment and hydroacoustics. His experience covers many aspects of fisheries, aquaculture, and environmental science as a researcher, scientific advisor, and manager. His current research involves adapting acoustic technology (single, split, and multi-beam) to addressing fisheries issues, monitoring behaviour, evaluating the potential impact of tidal power development and developing collaborative projects with the fishing industry and universities.

Dr. Alex Hanke is a Research Scientist in the Population Ecology Section at the St. Andrews Biological Station. He has broad experience as an oceanographer, a fish geneticist and quantitative fisheries ecologist. As part of the Large Pelagics Group, he is concerned with International Governance Strategy issues related to Atlantic bluefin tuna, swordfish and marine turtles. His current research interests include understanding the life cycle and behaviour of the western Atlantic bluefin tuna population, improving the western Atlantic bluefin tuna stock assessment through improved indices of abundance, and examining ocean climate influences on the distribution and abundance of western Atlantic bluefin tuna.

Technical support: Technical support for the acoustic analysis and field operations will be recruited from a pool of qualified technicians/biologists.

II 2.0 Mark-Recapture Study

Dr. Michael Stokesbury is a Canada Research Chair in Ecology of Coastal Environments at Acadia University. He has published many tagging and tracking studies, including migration and behavior research on Atlantic bluefin tuna, Atlantic salmon, Greenland sharks, Atlantic sturgeon. He has also co-authored a paper in *Nature* on Atlantic bluefin Tuna population structure and authored a paper detailing the post-release survival rate for Atlantic bluefin tuna in the Gulf of St. Lawrence.

Mr. Aaron Spares is a doctoral candidate at Dalhousie University and is nearing completion of his thesis. He has authored and co-authored several publications on the open ocean marine migration of Atlantic salmon and Arctic char. Aaron has also worked tagging Atlantic bluefin tuna off North Carolina and Nova Scotia with the Tag-A-Giant Foundation and, most recently, with the PEI Fishermen's Association off Prince Edward Island.

Dr. Steve Cooke is a Canada research Chair in fish ecology and conservation physiology at Carleton University in Ottawa. He has published over 330 articles that focus on understanding the interface between behaviour, physiology, and fitness in wild fish. He is a globally recognized expert in conducting fish tagging experiments and worked with M. Stokesbury to determine the post release mortality for Atlantic bluefin tuna, captured and released in the Gulf of St. Lawrence.

Dr. Kevin Stokesbury is Chair of the Department of Fisheries Oceanography at the University of Massachusetts, Dartmouth, MA, USA. He is responsible for the Fisheries program conducted at SMAST which includes sea scallops, lobsters and groundfish research. His is laboratory and members of the commercial sea scallop industry and the Massachusetts Department of Marine Fisheries have provided critical data that has been used in sea scallop fisheries management plans and the Habitat omnibus.

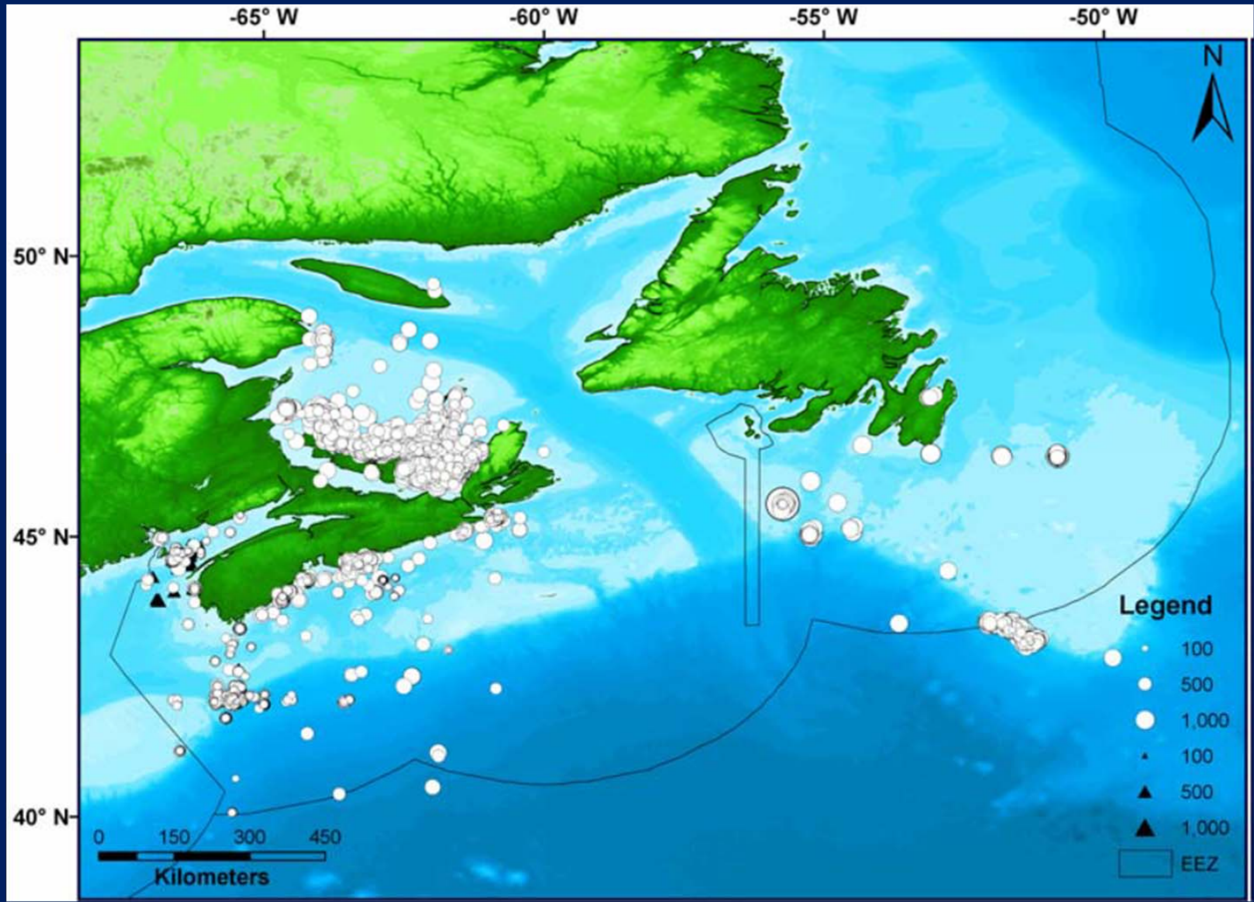
Dr. Michael Dadswell is a Professor of Biology at Acadia University, Wolfville, Nova Scotia. His research focuses on the life history and migratory behavior of fishes. He has published numerous papers and articles on marine migration and population estimates of marine fishes using mark-recapture methods including shortnose sturgeon, Atlantic sturgeon, alewife, American shad, Atlantic salmon and striped bass.
Brunswick and Quebec (Magdalen Islands) for information dissemination, and tag retrieval ($3,000). Total travel field costs for PI’s are $30,000 + $3,000 = $33,000).

Appendix 7

A Mark and Recapture Experiment to Determine the Abundance of Atlantic Bluefin Tuna Present on a Seasonal Basis each Year in the Gulf of St. Lawrence, Canada

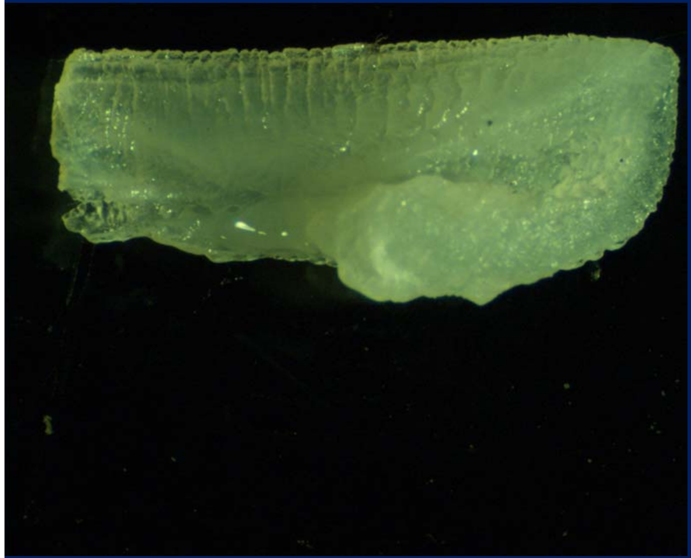
Dr. Michael Stokesbury
Canada Research Chair in the
Ecology of Coastal Environments
Acadia University

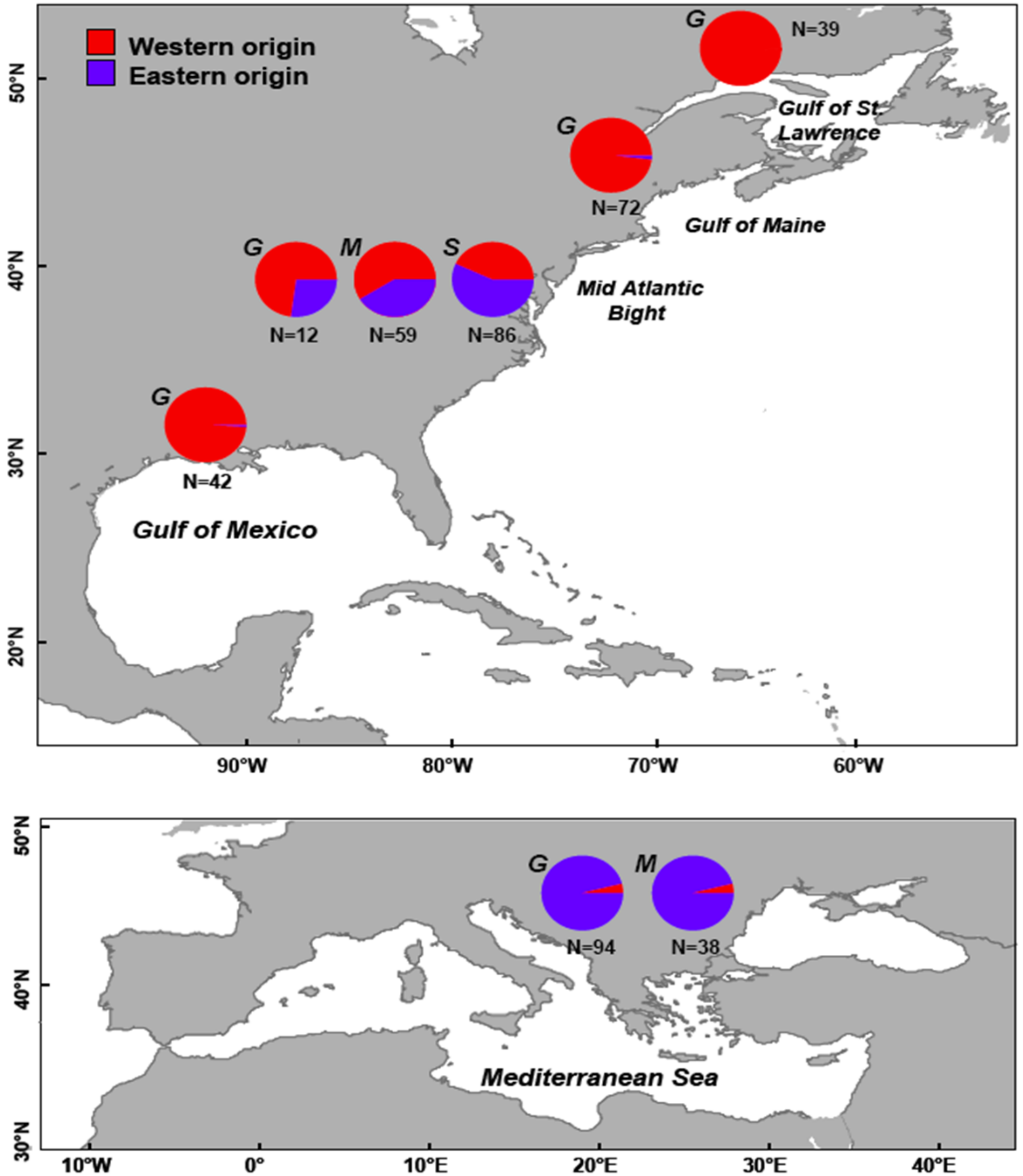
GSL Study Site



Location and landed weight in lbs from logbooks of Atlantic Bluefin Tuna caught by Canadian fishers from 2000-2009. Symbols represent landed weight by gear (white circles = hook and line; black triangles = electric harpoon). Black line is the boundary of the Canadian Exclusive Economic Zone (Figure from DFO 2011).

Microconstituent Analyses Indicate Origin

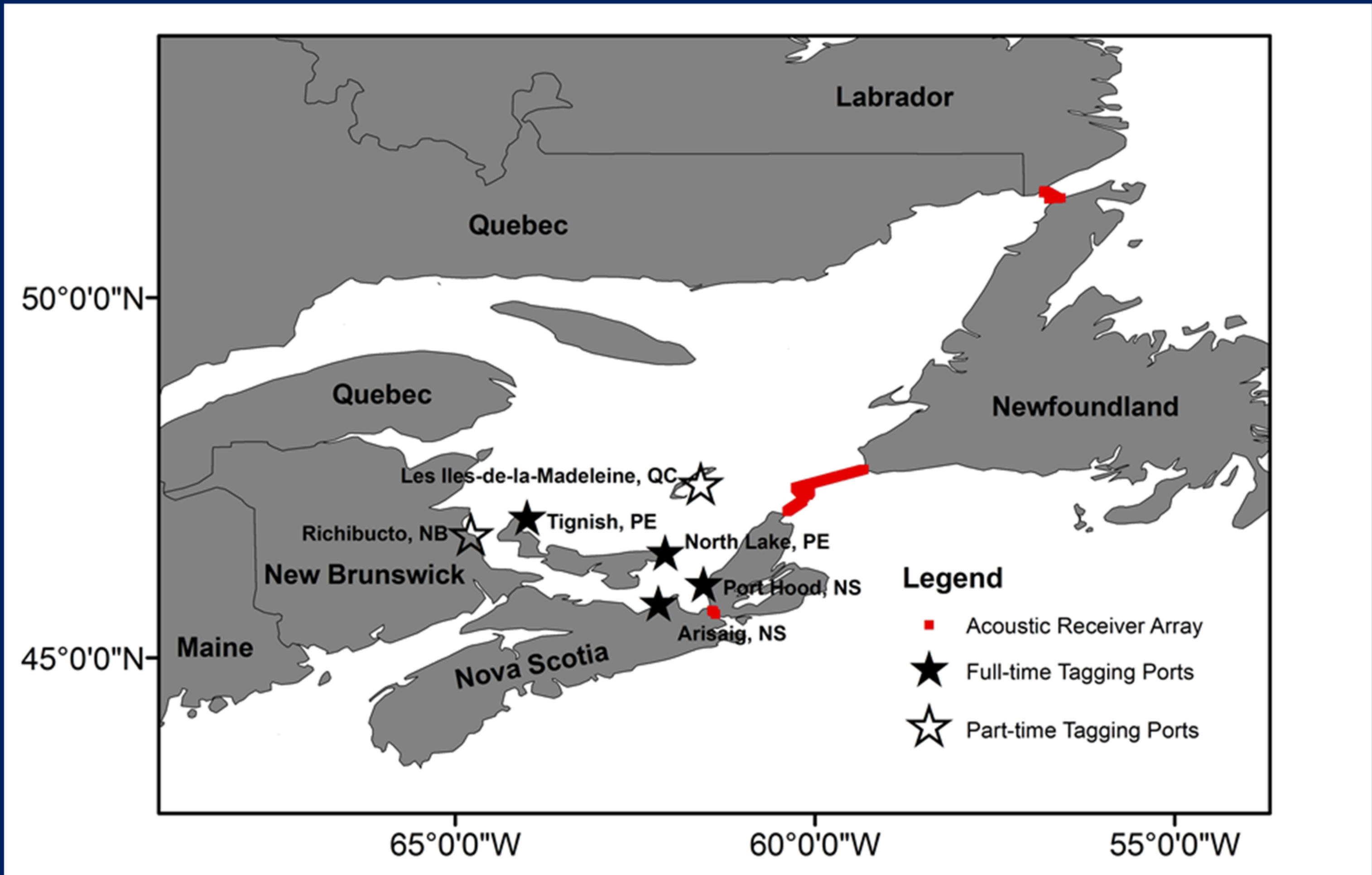




Science

Rooker, Secor, DeMetrio, Schlosser, Neilson & Block, 2008 322:742-744.

Historical archival, acoustic and conventional tagging



Map of the Gulf of St. Lawrence with positions of hydroacoustic receiver lines operated by the Ocean Tracking Network, Dalhousie University, and positions of proposed placement of our Atlantic Bluefin Tuna team for tagging operations in 2014.

Jolly-Seber Mark and Recapture Experimental Design for an open population

Key Assumptions for the accurate and unbiased assessment of abundance.

- 1) every animal has the same probability of capture
- 2) marked animals have the same probability of survival
- 3) marks are not lost or overlooked

Assumptions will be fulfilled as:

- 1) Bluefin Tuna will be fished with non-selective gear, on a broad geographical scale (tagging locations very similar to areas of high commercial catch).
- 2) All marked animals will have the same probability of survival as tags will not affect catchability after the 14 day period used to provide random mixing of tagged fish back into the population.
- 3) We will double tag a portion of the tuna (20%) to obtain an estimate of tag shedding (tag loss) and engage fishers throughout the fishery to ensure high rates of return of tags that have been captured.

Valid Estimate (archival)

- Multiple years of tagging and tag recapture will be required. The number of tagged fish must build up over at least two seasons to provide enough tagged fish and tag returns to create a valid estimate of abundance.

- Based on the recapture of our archival tags in 2010 in relation to the total estimated catch (2/55 = u = 0.036) we suggest a provisional population of ~ 14,000 tuna are now in the Gulf each year, keeping in mind that this is only a portion of the total stock.

- Based on the estimated provisional population we will be required to tag between 200 to 250 tuna a year to obtain a valid estimate that will have either the 25 or 10 % probability of accuracy that is required for management and scientific study, respectively.

Tag and Release

- Commercial and Charter boats involved
- Barbless circle hooks
- Heavy leaders
- Fish brought to surface and tagged over the side while moving forward
- Fish released

Experimental Design (Conventional tags)

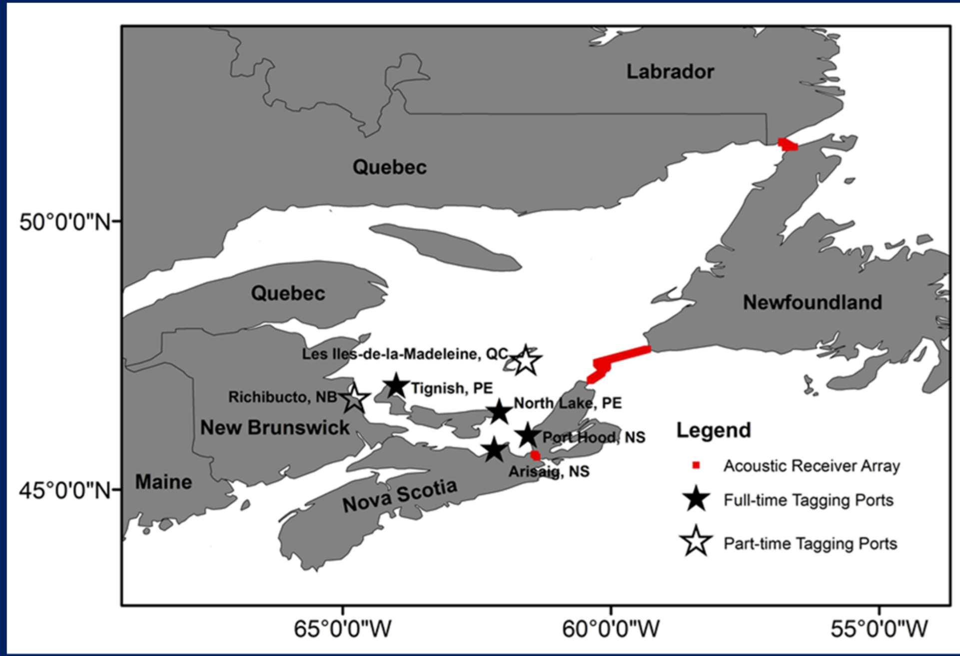
- By tagging Bluefin Tuna captured recreational fishery, as well as the wide spatial distribution provided by tagging with commercial fishers, there is an opportunity to apply conventional tags to large numbers of tuna during the summer and early autumn.

- Researchers will be deployed in four locations during August to November (North Lake and Tignish PEI, Port Hood and Arasaig NS). Opportunistic tagging can occur in other locations i.e., Richibucto, NB, Magdalen Islands PQ.

- Returns of marked animals will occur both through recapture in the charter fishery and through the commercial fisheries that open in the autumn.

Immigration and Emigration (Acoustic Tags)

- 40 bluefin/ year will be tagged with uniquely coded acoustic tags
- OTN has both passages to the GSL gated with hydroacoustic receivers.
- This will determine the ratio of tagged fish returning to the Gulf on a yearly basis
- Immigration rate from historical monthly trends in CPUE through the year compared with estimates of emigration from acoustically tagged fish



Timeline

	2014	2015				2016			
Task	**Oct-Dec**	**Jan-Mar**	**Apr-June**	**July-Sept**	**Oct-Dec**	**Jan-Mar**	**Apr-June**	**July-Sept**	**Oct-Dec**
Experimental Design Refinement	XXX	XXX				XXX			
Hiring of Post-Doc & Techs	XXX		XXX				XXX		
Training of Post-Doc & Techs (sampling)	XXX		XXX				XXX		
Survival Systems Inc. training	XXX		XXX				XXX		
Field training Post-Doc and Techs (tagging)	XXX			XXX				XXX	
Field logistics (accommodation etc.)	XXX	XXX				XXX			
Ordering tagging supplies	XXX	XXX				XXX			
Meetings with fishers & associations	XXX		XXX	XXX			XXX	XXX	
Conventional tagging				XXX	XXX			XXX	XXX
Acoustic tagging				XXX	XXX			XXX	XXX
Tag recapture				XXX	XXX			XXX	XXX
Otolith & Tissue sampling				XXX	XXX			XXX	XXX
Data Analysis		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
OTN line download (OTN Dalhousie)					XXX				XXX
Lottery for tagging trips			XXX				XXX		
Tag prize lottery ($5k)					XXX				XXX
Lottery for tagging trips			XXX				XXX		
First relative abundance estimate					XXX				
Annual Relative abundance estimate					XXX				XXX

Grant chart of activities (2014-2016) for a mark and recapture experiment to estimate relative abundance of Atlantic Bluefin Tuna annually present in the Gulf of St. Lawrence, Canada.

Budget

Category	Cost
Salaries	73,000
Equipment	82,000
Field work travel	33,000
Consultants	15,000
Overhead	41,000
Grand Total	**244,000/year**

Key Collaborators

- PEIFA
- GNSTFA
- DFO
- OTN
- Aaron Spares, Dalhousie U., Canada
- Dr. Steve Cooke, Carleton U., Canada
- Dr. Kevin Stokesbury, U. Mass., USA
- Dr. Mike Dadswell, Acadia U., Canada

NSERC CRSNG

OCEAN TRACKING NETWORK

ACADIA UNIVERSITY

Appendix 8

ADDITIONAL RESEARCH PLAN FOR WESTERN ATLANTIC BLUEFIN TUNA FROM JAPAN FOR 2014 DISCUSSION

(Document submitted by Japan)[3]

Japan proposed a research plan in 2013 in the first meeting of the working group of fisheries managers and scientists in support of the western Atlantic bluefin tuna stock assessment (Itoh 2013). Taking account of the discussion at the meeting as well as articles published in journals recently and relevant information, we propose an alternative research plan for Atlantic bluefin tuna (ABF) to be considered.

Golet *et al*. (2013) reported that distribution of large size ABF in the Gulf of Maine has shifted toward east (offshore) in recent years, and therefore United States ABF catch was decreased (**Figure 1**). Vanderlaan *et al*. (2014) pointed out that one of the possible reasons for increasing in CPUE for large size ABF in the Gulf of St Lawrence was the result of distributional shift from the Gulf of Maine to the Gulf of St Lawrence. These suggest that it is dangerous to rely on any stock abundance indices from limited time, area or fishing gear especially in the case of ABF, which is a highly-migrating species whose distribution and migration appear to vary largely in the long term.

In order to resolve these uncertainties, we propose to have research programs that will obtain five fishery indices for ABF in large size (185 cm in curved fork length, 177 cm in straight fork length) in the feeding ground in the northwestern Atlantic. These five indices should be obtained every year with certainty.

- Fisheries indices in the Gulf of St Lawrence in Canada
- Longline CPUE off southwestern Nova Scotia in Canada
- Rod & Reel CPUE in the area in Gulf of Main and Georges Bank in US
- Japanese longline CPUE in the area 40-50N, 45W-55W
- Japanese longline CPUE in the area 40-50N, 55W-70W

For the fisheries indices and relevant researches in Canada and US, we expect proposals from them. For the Japanese longline, many operations have been conducted every year in the area 45W-55W around 40 degree North, however, the number of operations has been small and fluctuated in the western area from it (Kimoto *et al.* 2013) (**Figure 2**). We analyzed Japanese longline logbook data in 21 years (1993-2013) since the present recording form was established. **Figure 3** shows the proportion of the number of years that Japanese longline vessels caught ABF in more than 10 operations by 5-by-5 degree square. In the area west of 55W, the proportions were small as less than 43%. This area is in the middle of the four areas, the main fishing ground for Japanese vessels (around 45W), Gulf of St Lawrence, Nova Scotia and Gulf of Main. It is interesting to obtain the data in this area to know the continuity of ABF distribution among the four areas, as well as the relative proportion of abundance in each area. Obtaining distribution data from this middle area will enable drawing of a whole picture.

Japanese longline vessels are the best candidate for the scientific research. Using commercial vessels has advantages in order to secure consistency in catch ability to compare the index within the area for previous years and neighboring areas.

To have the research, in order to obtain reliable abundance indices, at the same time in practical sense, it would be appropriate to conduct 20 operations per month in November and December by three vessels. The research area will be in the area between 40N and 43N and between 55W and 66W, excluding EEZ. The area may be split into four sub-areas in order to secure a certain number of operations in each of sub-area.

In the logbook record dataset, annual CPUE (N_BFT/1000 hooks) ranged from 0.59 and 9.71 with mean of 3.25 in the area. The total round weight of ABF per operation was 751kg in mean. Expected catch in round weight, if no fish were released, is 3 vessels x 2 months x 20 operations x 0.751 ton = 90.1 tons.

---

[3]Tomoyuki Itoh, National Research Institute of Far Seas Fisheries, Fisheries Research Agency. 5-7-1 Orido, Shimizu, Shizuoka, 424-8633, JAPAN. itou@fra.affrc.go.jp

Note that not all the ABF caught were large fish in the area. In some years or specific areas, a large part of catch was smaller size fish. No detailed size information was available for old years earlier than 2008.

Given large fluctuations among years in catch amount and size, it is quite difficult to predict catch amount and its size composition precisely in advance. If actual catches were much larger than planned, the research must be ended earlier or the fish hooked must be released to keep the mortality less than allowed. The operations and fish caught should be observed on board by the scientific observer, as well as its activity should be monitored by daily reporting.

Since CPUEs in the area are much lower than those in the main fishing ground, commercial longline vessels are not likely to operate in this area as part of their commercial activities. A certain incentive should be considered if they are used or an alternative framework such as using a research vessel should be considered.

Among the five components described above, whether fish we are targeting are independent (stay only in one area) or relating to another area (move between areas) within a couple of months is another key question to be asked. Such distribution dynamics should be investigated by using electronic tags, including archival tags and pop-up satellite tags.

Another question is the origin of fish. While large size fish in the Gulf of Main and Gulf of St Lawrence are found to be western origin, a tentative result from GBYP suggests that fish caught in the Japanese longline fishing ground is a mix of eastern and western fish. In the researches, a sufficient number of otoliths should be collected to answer this question.

References

Golet, W. J., B. Galuardi, A. B. Cooper and M. E. Lutcavage (2013) Changes in the distribution of Atlantic bluefin tuna (*Thunnus thynnus*) in the Gulf of Maine 1979-2005. PLoS ONE 8(9) e75480.

Itoh, T. (2013) Research proposal to improve stock abundance indices for western stock of Atlantic bluefin tuna. SCRS-13-200.

Kimoto, A., Y. Takeuchi and T. Itoh (2013) Updated standardized bluefin tuna CPUE from the Japanese longline fishery in the Atlantic to 2012 fishing year. SCRS/2013/185.

Vanderlaan, A. S. M., A. R. Hanke, J. Chasse and J. D. Neilson (2014) Environmental influences of Atlantic bluefin tuna (*Thunnus thynnus*) catch per unit effort in the southern Gulf of St. Lawrence. Fisheries Oceanography 23: 83-100.

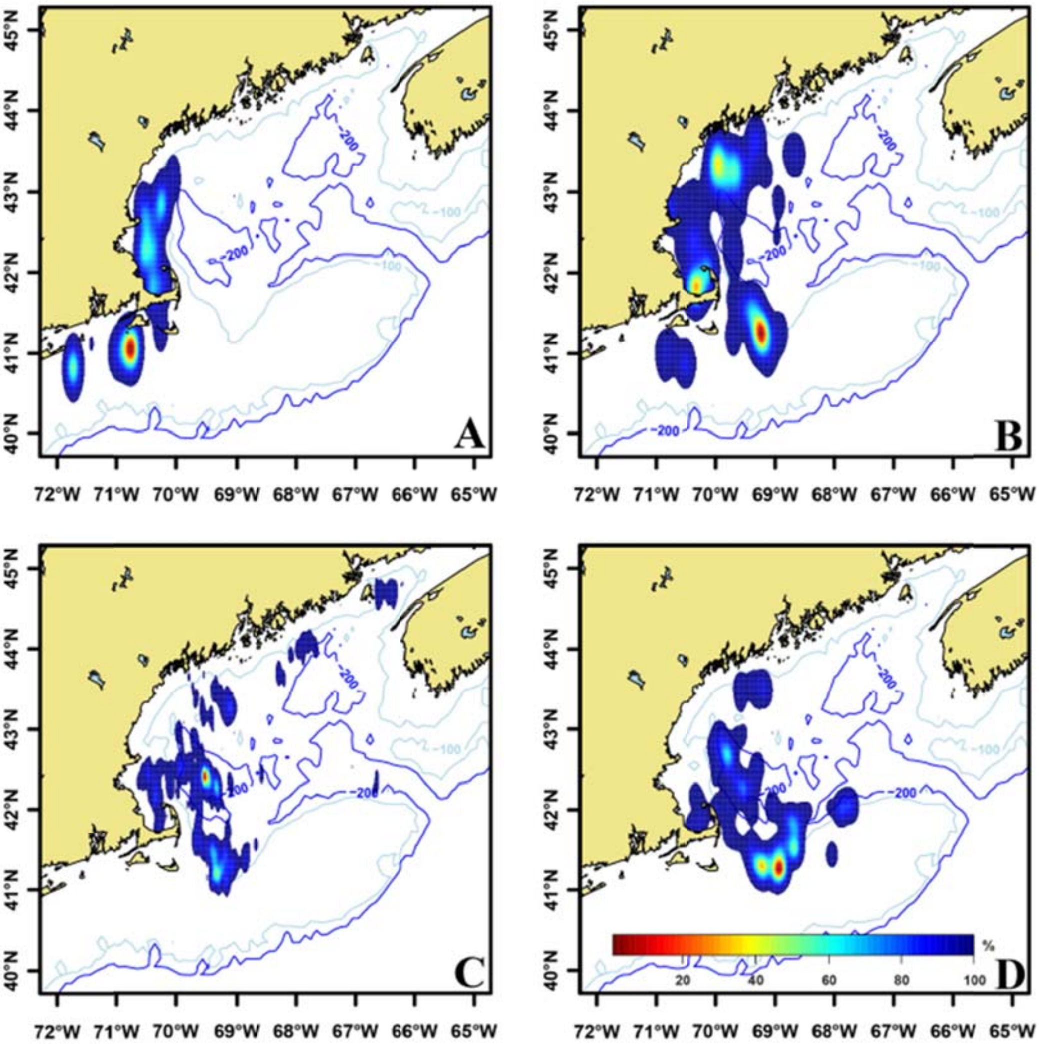


Figure. 1. Distribution of Atlantic bluefin tuna in the Gulf of Maine. Kernel density estimations were constructed based on the number of fish observed in each school over four selected time periods. Density estimations were normalized yielding utilization distributions that displayed probability of occurrence during four time periods, A) 1979-1985, B) 1986-1992, C) 1993-1999, and D) 2000-2005. (Figure 2 of Golet *et al*. 2013).

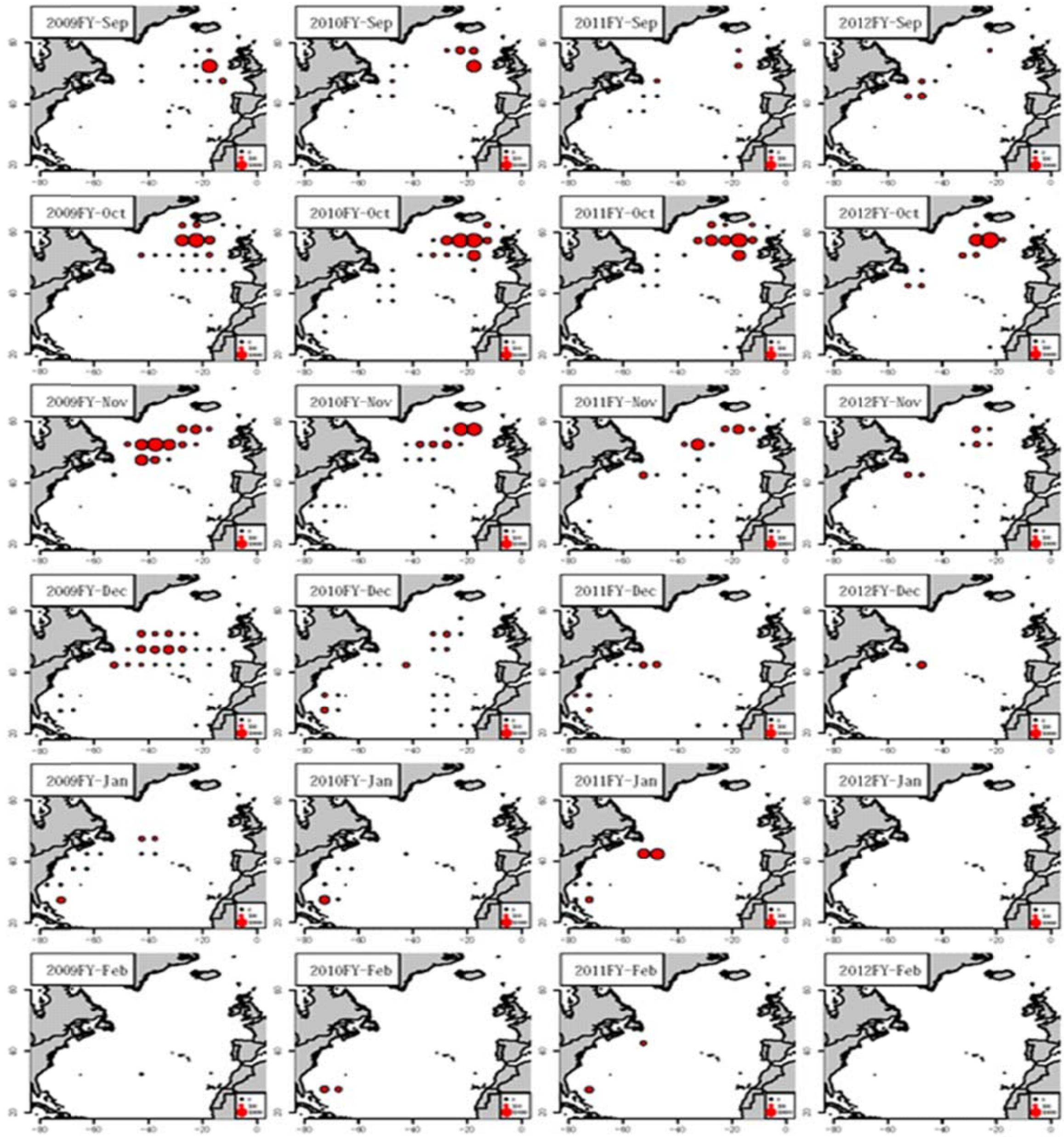


Figure 2. Monthly distributions of accumulative bluefin catch in number by Japanese longliners by 5x5 degree area in the main season (September-February: top to bottom) in the period between 2009 and 2012 Fishing Years (left to right). (from Kimoto *et al.* (2013).

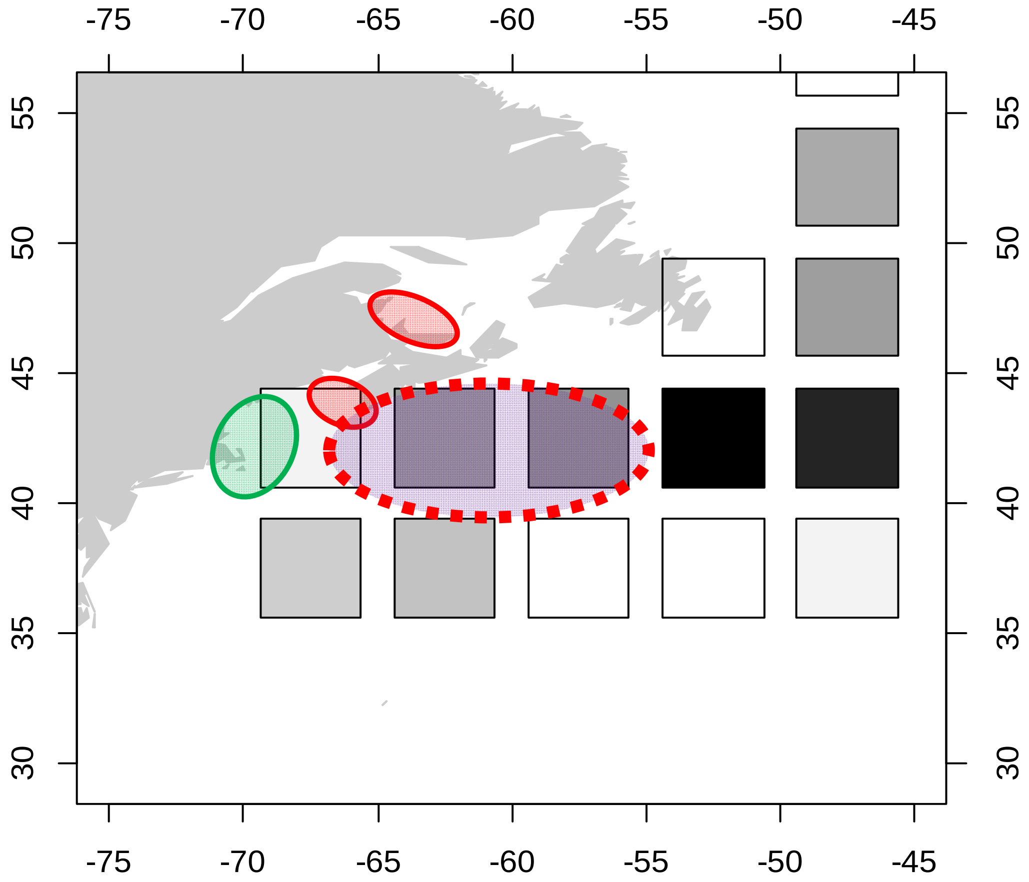


Figure 3. Proportion of years which Japanese longline vessels caught BFT in more than 10 operations in a 5x5 cell among 21 years from 1993 to 2013 in the northeastern Atlantic Ocean from Japanese longline logbook data. Dark squares are higher proportion. The oval enclosed by red dots is the proposed area for Japanese longline research. Ovals in red area are the research areas for Canadian fishery in Gulf of St Lawrence and southwest of Nova Scotia. An oval in green is the research area for US Rod and Reel area in the south of Gulf of Main.

Appendix 9

July 12, 2014

A Perspective on Bluefin Tuna Stock Status:

A case for the ~~lowly~~ Surplus Production Model

By AR Hanke

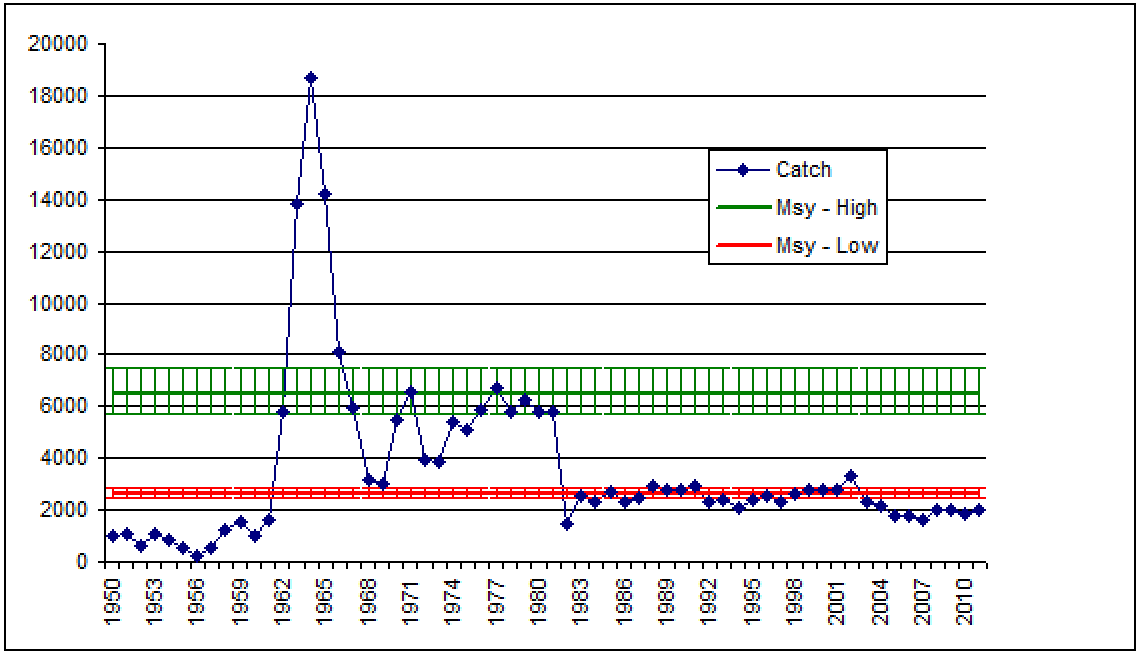
Concept:
"wherever possible, multiple options should be used"

On the plus side
- Minimal data requirements
- Stock and dynamics can be described in terms of biomass
- Can lead to the conclusion that the data provide no information

Caution
- Biomass can be either recruitment or growth
- If no contrast in effort over biomass levels, model confuses high growth and low biomass with low growth and high biomass
- Catch rate not sensitive to changes in biomass

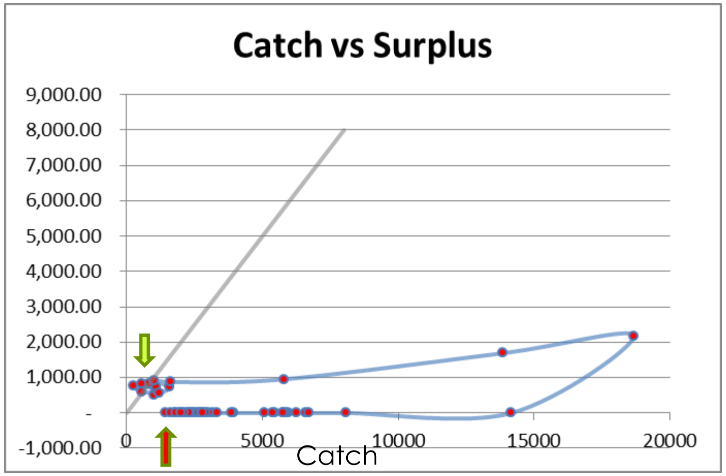
BFT Catch Relative to MSY

"I wouldn't walk over a bridge if it was called VPA!"

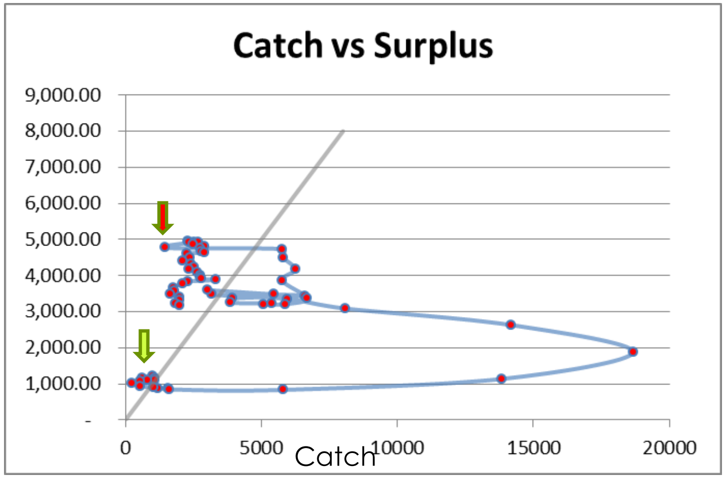


Sustainable Removals:

Low Recruitment



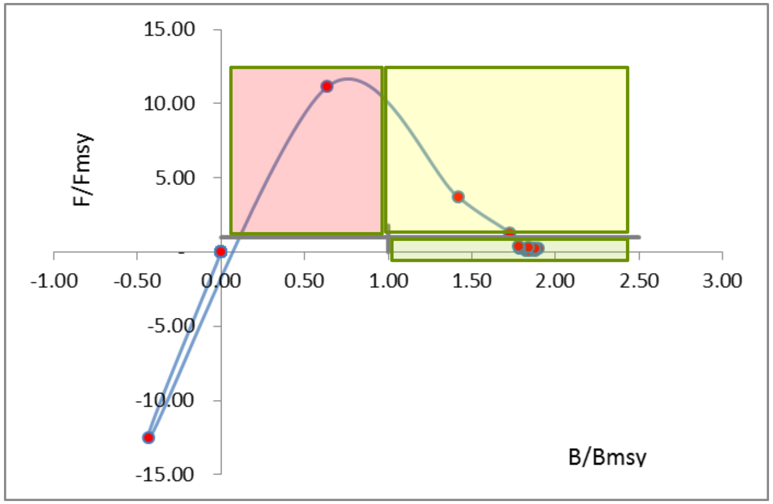
High Recruitment



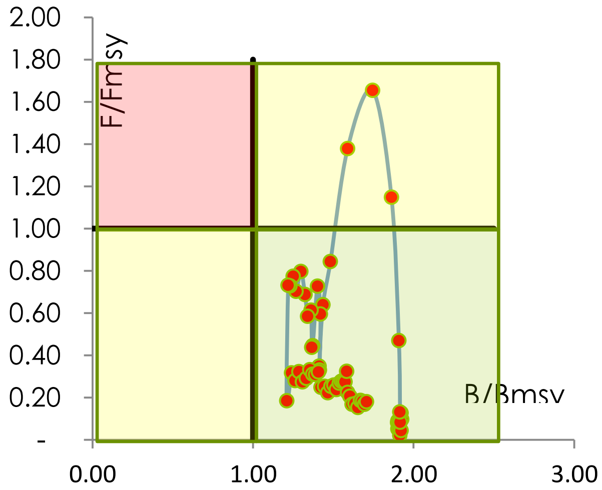
Phase Plots:

Relative Biomass vs Relative F

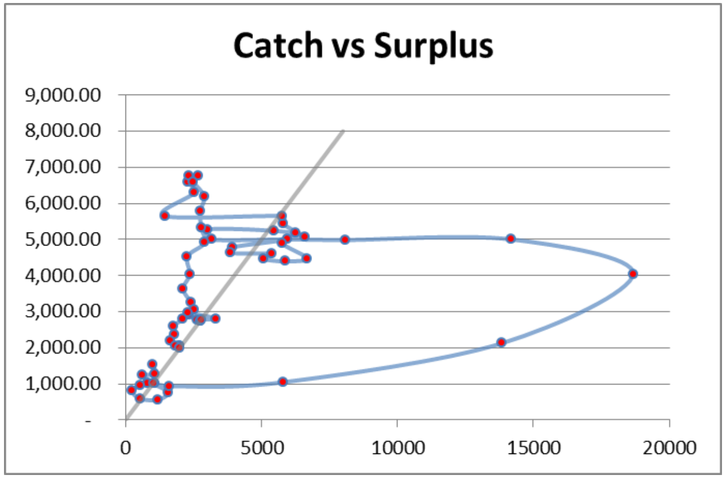
Low Recruitment

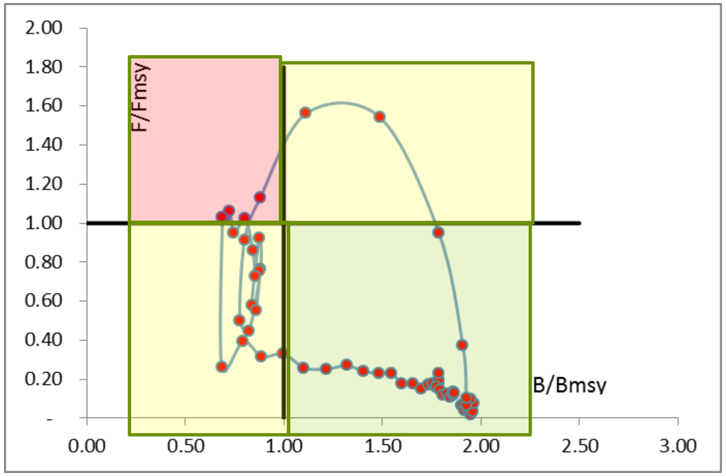


High Recruitment



An Alternative Reality:





Potential Areas of Study

"it is far better to know that the information one has is not informative than to follow model results blindly"

- Stock status: VPA vs SPM
- What is reasonable:
  - Conditions for equivalence
- Stability of model and outputs (hindcasting)

Conclusion:

"simple production models should often be used in stock assessments based on catch/effort data, even when more realistic and structurally correct models are available to the analyst"

- Useful tool when limited information is available or extra information is of dubious quality
- Simple model, more cautious interpretations
- Provide insights into relative performance of the stock through time

Conclusion (cont'd)

- Useful in risk assessments
- Have developed to a point where "*even if more information is available and more complex and realistic models can be implemented, it would be sensible to implement a simpler model if only to act as a contrast*".

The End

Hind Casting:

"wherever possible, multiple options should be used"

- Hind casting trials that compare assessment results for different series of years speak to the stability of the model and outputs.

1970 to 2013 vs 1970 to 2012

or

1970 to 2010 vs 1971 to 2013

Data problems:

Lack of contrast

- Need high F's to observe r at low biomass
- Need low F's to detect K and any density-
- dependent changes in recruitment, growth,
- or mortality at high biomass

Changes in catchability

- Variation in gear, electronics, knowledge, fish distributions
- Violates CPUE = qB

Assumptions

- abundance index (CPUE) is proportional to true abundance (Biomass)
- instantaneous reaction of stock
- symmetric parabola
- need large range of efforts (high and low)
- stock is self-contained
- any loss is mortality
- no interspecific interactions
- the environment is constant
- fishing is density-independent

Advantages (check)

- calculate MSY and Fopt without catchability
- requires only catch and effort data
- don't need to know size or age structure
- inexpensive

Disadvantages

- does not incorporate environmental factors
- excludes trophic linkages
- assumes stock has stabilized at current rate of fishing
- doesn't tell us much about the mechanisms affecting the population dynamics

http://people.uncw.edu/scharff/courses/458/Lecture%2011%20-%20surplus%20production%20models.pdf

- VPA and surplus production models are based on a fairly simplistic view of fish population dynamics. In reality the processes governing fish population size are much more complex. Furthermore, these two methods suffer from specific peculiarities and limitations. VPA models assume that fish cohorts are well defined whereas in reality cohorts are mixed and difficult to distinguish. Closely related to this problem, VPA's are heavily dependent on the ability to age fish, which is problematic.
- VPAs also work best for long-lived species, and tend to be more reliable for estimating historic rather than recent population sizes. Surplus production models, on the other hand, are heavily dependent on the assumption of proportionality between CPUE and resource biomass. Although this assumption may be reasonable for non-shoaling species such as hake or cod, it is clearly invalid for small shoaling species like anchovy and pilchard caught by purse-seine gear. As a result both VPAs and surplus production models are unsuited to the management of small shoaling species.

http://www.olrac.com/index.php?option=com_content&view=article&id=133:surplus-production-models-the-black-box-approach-to-the-estimation-of-fish-stock-size-and-productivity&catid=58:knowledge-base&Itemid=161

Are Age-Structured Models Appropriate for Catch-Effort Data?

- The implication of these findings is that simple production models should often be used in stock assessments based on catch/effort data, even when more realistic and structurally correct models are available to the analyst; the best choice depends on how much contrast has occurred in the historical effort and catch per unit effort data, rather than on prior knowledge about which model structure is biologically more realistic.

Canadian Journal of Fisheries and Aquatic Sciences, 1985, 42(6): 1066-1072, 10.1139/f85-132

Performance of production models on simulated data

Comparing the two models side by side, a general result was
that the simple surplus production model did as well as, if not better than, the age structured production model in estimating B/Bmsy, F/Fmsy, and typically outperformed the age structured model in estimating MSY.

http://www.sefsc.noaa.gov/sedar/download/S9RW01%20Productionmodelsimulation.pdf?id=DOCUMENT

Improvement of Management Indices

Gary Melvin
Department of Fisheries and Oceans
Canada

Introduction

- The Main purpose of this presentation is:
  - to promote a better understanding between Science and Managers, and
  - to stimulate discussion and debate on the management/science interactions
- Each field of expertize has its own language and understanding of what is being stated.
- Would like to provide 3 examples of what might be considered misconceptions or uncertainty
  - Subtle indication for manager consideration
  - Real uncertainty – high/low recruitment scenarios
  - Inaccurate assumptions - Potential improvement

Subtle indicator or Indications

- Within the stock assessment world there is an obligation to report specific values following a standardized protocols (e.g., biomass estimate and probabilities).
- Most cases Management will take these outputs and use them in a typical manner to provide their recommendations on catch levels and other aspects
- There are cases where Science has concerns or uncertainties as to whether or not these outputs (theoretically valid) are reflective of the stock status (garbage in, garbage out).

Subtle Indicators (Cont)

- Where this concern or uncertainty occurs Science will usually put caveats or qualifiers on their advise to Management.
- It is here that Management must take heed in this subtle indicator of uncertainty, and incorporate it into their advice.
- Recent Case in point is the last eastern BFT assessment.

Eastern BFT Assessment

- Unquantified uncertainties are coming from various sources
- Poor quality of fisheries information. SCRS acknowledges there are considerable data (Catch/effort) limitations for the eastern stock up to 2007. (insufficient before 1990’s and even worse up to early 2000’s).
- All CPUE indices have been strongly affected by recent management measures making it difficult to track changes in abundance.

Eastern BFT (Cont)

- Lack of knowledge on key biological/ecological process (natural mortality, population structure, productivity, recruitment dynamics, impact of environmental changes, selectivity patterns, etc).
- The Kobe Matrices provides a mechanism to account for uncertainty in the estimates for the information as provided, however, it cannot integrate many important sources of uncertainty.

Eastern BFT cont

- Result: Even though all CPUE indices are showing an increasing trend, given the multitude and magnitude of the unquantified uncertainties the SCRS cannot provide robust advice to support a substantial change in TAC.
- Important that Management take these subtle indicators from Science that all is not well into their recommendations.
- In other words Management should not take all numbers literally when multiple serious qualifiers are provided by Science.

Real Uncertainty – High/Low Recruitment

- Important to separate stock assessment/ biomass estimates from projections.
- Last Stock assessment (2012) for wBFT shows a gradual increase in SSB since about 2008
- Current Projections based on Beverton Holt (high) and two-line (low) recruitment scenarios for western BFT essentially provide no advice to Management.
- The dilemma dates back to 1982 with the introduction of VPA with 2 options:
    - Constant recruitment – allowed fishing to continue
    - SSB/R relationships – suggested no fishing

Real Uncertainty cont

- In 1993 as part of a separate recovery plans for East and west BFT, two recruitment options proposed SSB/R relationship or geometric mean 1983-1992.
- 1996 Methods working group explored Beverton-Holt and “two line” models, however projections based only on the latter.
- Beyond 1996 both recruitment scenarios were used for projections.

Real Uncertainty cont

- Report of 2000 assessment describes the alternative SSB/R relationships and their relationship to established rebuilding targets.
- First time relationships referred to as the high and low recruitment scenarios.
- Interestingly, both recruitment scenarios give at least a 50% probability of rebuilding to the 1975 biomass by 2018.

Divergent advice:

- Unfortunately, over time there has been a divergence in the projections from each model such that
  - the Beverton-Holt relationship no longer permits fishing nor a recovery by 2018, whereas
  - the “two line” relationship fishing can occur and a recovery by 2018
- Workshop in Washington DC (2012) to review the available data and relationship between SSB/R and to come to a consensus.

Workshop Summary

- Workshop made "No" recommendation for one model over the other, although little support for the two-line model.
- Advice was to keep fishing mortality low and rebuild SSB to 30,000mt (possibly a decade).
- No consideration was given to errors in estimating SSB and R in the VPA
- Bottomline Science/management still stuck with two equally plausible scenarios.

Overview High Low Recruitment

- From a Science perspective this has been ongoing for a couple decades and is a bit embarrassing that it hasn't been resolved.
- From a management perspective Science is not providing any advice on future stock status or targets based on projections.
- On the one hand (low) every thing is well and the fishery is operating at about BMSY, while on the other (high) targets can not be reached even by closing the fishery.

Overview High Low Recruitment

- Overall the two extremes essentially tell managers nothing on how to reach their targets.
- Alternatives approaches to estimate recruitment used in other fisheries must be explored (e.g., geometric mean of time period or fixed recruitment).
- Important to acknowledge that the wBFT stock is low relative to the 1970's, but slowly rebuilding since about 2008.

Inaccurate assumptions – Potential for improvement

- The SCRS has been expressing concern regarding fishery dependent indices of abundance (CPUE) used in BFT stock assessment due to changing fishing patterns and management initiatives.
- Basic assumption of any index of abundance is that factors affecting the index remain relatively constant over time, thus observed changes in the index are reflective of changes in abundance.
- The impact of deviations from this assumption can range no significant effect to inaccurate representation of trends in biomass (random noise) .

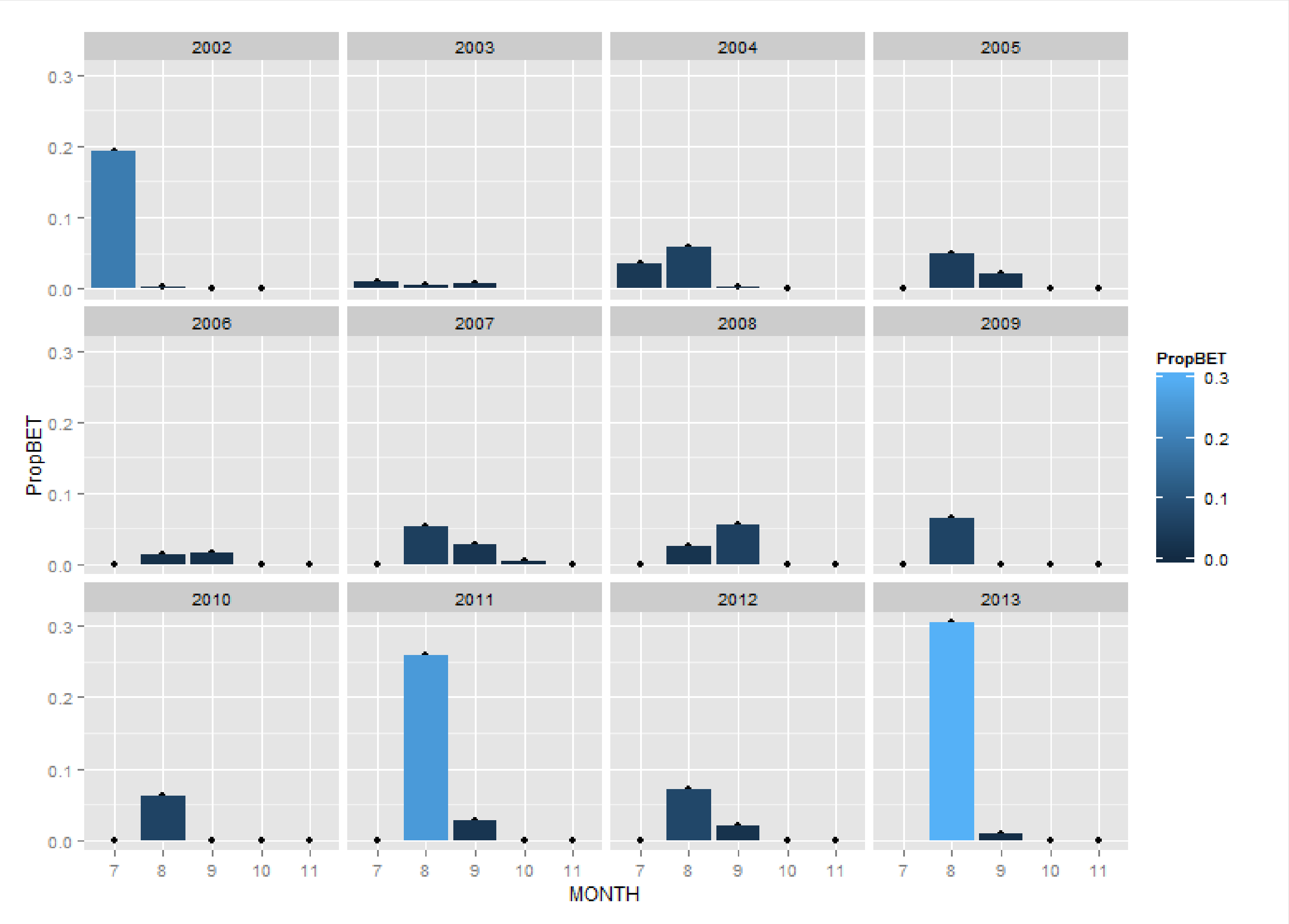
Canadian Example

- The TL/HL CPUE index of abundance for BFT from SWNS is based on the number tuna caught per 100 hours of fishing standardized for several factors (month, gear, year, etc).
- Effort (hours fishing) is determined from the log books identified as targeting BFT under the general assumption the all effort for the trip has been directed at fishing for bluefin tuna.
- While in the past this may have been true, in the last 10 years or more the fishery has been targeting other tuna species such as big eye for part of the fishing trip.
- This change in fishing practice is variable from year to year and the reduction in effort directed for BFT is not accounted for in the SWNS BFT index of abundance.

Big Eye Tuna

- The practice is to hail out as BFT then to spend some unknown portion of time directing for Big Eye before targeting BFT.
- Anecdotal information suggests that for a 5 day trip up to 4 days may be directed at species other that BFT due to the low quota and or market.
- The result is that effort may be over estimated substantially, thereby reducing the index of abundance. (in above 80%).
- The amount of targeting for other species also varies by month and year.

Proportion of BFT trips where the catch of BET exceed BFT by month and year. Effort directed at BET should not be attributed to BFT.



Multi-Species Fishing trips:

- Multi-species fishing trips can introduce a bias depending upon the effort directed at the species.
- Total trip effort will result is an over-estimate of effort and an underestimate of CPUE.
- As with the Big Eye example, the amount of time will and has varied by month and year.
- Logbooks need to be sufficiently detailed so that effort can be apportioned into it species components.
- For some fisheries sufficient detail may already exist in the original logbooks to address this issue.

Summary

- Management needs to take into the consideration the subtle indicators associated with advice from Science.
- Outstanding long term issues such as the high/low recruitment scenario projections must be resolved or overcome (alternative approaches)as they provide no advice to management and generally enhance confusion and uncertainty around the advice.
- Indices of abundance should be examined to determine if fishing patterns have changed or management initiatives have impacted the index and corrected where possible.

Appendix 11

COVERAGE OF FISHERY DATA FOR THE WESTERN STOCK OF ATLANTIC BLUEFIN TUNA IN ICCAT

(Document submitted by Japan[4])

Coverage of catch & effort data and size data to the total catch of western stock of Atlantic bluefin tuna w
Coverage of catch & effort data and size data to the total catch of western stock of Atlantic bluefin tuna was calculated based on ICCAT database for major fisheries. It included USA (longline in the Gulf of Mexico (GOM), longline other than GOM and rod & reel fishery), Japan (longline only), Canada (combined various fisheries) and Mexico (longline in GOM).

Although ICCAT database is a systematic one, it is not easy to fully understand its various types of code and items. It is desirable to double-check the results of this working paper.

Materials and methods

The data files used were as follows:

- Total catch in weight: Task 1. File used was t1nc_20131210.xlsx
- Catch & Effort: Task2_ce. File used was t2ce_20131210.mdb
- Size: Task2_sze. File used was t2sz_20131210.mdb

Data were subtracted as follows:

USA longline in GOM

- Total catch in weight: Species="BFT" & Stock="ATW" & Flag="U.S.A." & Area=”GOFM” & GearGrp=”LL”. It included dead discards.
- Catch&Effort: QuadID=4 & Lon>=45 & FlagCode="USA & GearGrpCode=”LL” & Lat >= 15 & Lat <= 35 & Lon >= 81 & Lon <= 100
- Size: Flag="U.S.A." & GearGrpCod=”LL” & SampAreaCod="BF60"

USA longline other than GOM

- Total catch in weight: Species="BFT" & Stock="ATW" & Flag="U.S.A." & Area≠”GOFM” & GearGrp=”LL”. It included dead discards.
- Catch&Effort: QuadID=4 & Lon>=45 & FlagCode="USA & GearGrpCode=”LL” & Lat > 30 & Lon <= 80
- Size: Flag="U.S.A." & GearGrpCod=”LL” & SampAreaCod=(BF51, BF52W, BF55, BF56W, BF61, BF67W, BF63, BF64W, BF66W)

USA の Rod & Reel

- Total catch in weight: Species="BFT" & Stock="ATW" & Flag="U.S.A." & GearGrp=”RR”. It included dead discards.
- Catch&Effort: QuadID=4 & Lon>=45 & FlagCode="USA & GearGrpCode=”RR”
- Size: Flag="U.S.A." & GearGrpCod=”RR” & SampAreaCod=(BF51, BF52W, BF55, BF56W, BF60, BF61, BF67W, BF63, BF64W, BF66W)

Japan longline

- Total catch in weight: Species="BFT" & Stock="ATW" & Flag="Japan" & GearGrp=”LL”
- Catch&Effort： QuadID=4 & Lon>=45 & FlagCode="JPN & GearGrpCode=”LL”
- Size: Flag="Japan" & GearGrpCod=”LL” & SampAreaCod=(BF51, BF52W, BF55, BF56W, BF60, BF61, BF67W, BF63, BF64W, BF66W)

[4] Tomoyuki Itoh, National Research Institute of Far Seas Fisheries, Fishery Research Agency, Japan.

Canada

- Total catch in weight: Species="BFT" & Stock="ATW" & Flag="Canada"
- Catch&Effort: QuadID=4 & Lon>=45 & FlagCode="CAN
- Size: Flag="Canada" & SampAreaCod=(BF51, BF52W, BF55, BF56W, BF60, BF61, BF67W, BF63, BF64W, BF66W)

Mexico longline in GOM

- Total catch in weight: Species="BFT" & Stock="ATW" & Flag="Mexico" & GearGrp="LL" & Area=="GOFM"
- Catch&Effort: QuadID=4 & Lon>=45 & FlagCode="MEX" & GearGrpCode="LL" & Lat >= 15 & Lat <= 35 & Lon >= 81 & Lon <= 100
- Size: Flag="Mexico" & GearGrpCod="LL" & SampAreaCod=BF60

Coverage in the catch & effort was derived as N_BFT in Task2_ce / total catch in number.

Coverage in the size was derived as the sum of numbers Task2_sz for "siz" (data records which actually measured fish) / total catch in number.

Because Task1 data does not include the total catch in number, the total catch in number was not clear in some cases. The total catch in number used here was the sum of catch-at-size for USA fisheries based on suggestion from Dr. Craig Brown. That for Japanese longline was the sum of the number in catch & effort. For Canada, catch in weight was used for the coverage of catch & effort and catch-at-size for the total of size coverage. For Mexico, catch in weight was used for the coverage of catch & effort.

Results

Data in a period from 1990 to 2012 were used. Details in each of six fisheries were shown in **Table 1**.

Coverage in catch & effort was summarized in **Table 2**. US data for rod & reel in 2011 and 2012 were not included in the dataset used. The coverage has been high for Japanese longline, Canadian fishery and Mexican longline in GOM. That of US rod & reel had been low as 5.8-11.0% in 2007-2010. That of US longline in GOM has been about 80% since 2006.

Coverage in size measurement was summarized in **Table 3**. For ICCAT database, both the number of fish whose size measured and the estimated catch-at-size which raised to total catch should be reported. Such reporting was incomplete for the number of fish whose size measured for US in 2011 and 2012, and for Japan in 2012.

The coverage in size has been high for Canadian fishery. That of US was low as 5-32% in 2008-2010.

The size coverage in old years of Japanese longline had been quite low as 0-7% up to 2007. It increased from 16% in 2008 to 51% in 2010. This increase was because of inclusion of the scientific observer data. In addition, body weights of all the individual Atlantic bluefin tuna caught were decided to be reported from Japanese vessel in 2008. Almost 100% size data coverage has been attained since 2008. Although Japan has not yet submit the data of the individual weight to ICCAT as "siz" records in Task2_sz, the catch-at-size data submitted ("cas" records in Task2_sz) were made from this data.

Table 1. Data coverage of bluefin tuna catch.

Table 1.1 USA longline in GOM.

Source YearC	Task_1 Total catch	Task2_CE N_BFT	Task2_CE W_BFT	Task2_Size Num (size measured)	Task2_Size Num (catch-at-size)	Percent CE	Percent size
unit	Ton	Number	kg	Number	Number	%	%
1990	153	207	0	71	0		
1991	184	360	0	111	0		
1992	112	161	0	73	0		
1993	54	88	0	0	0		
1994	52	63	0	0	0		
1995	35	63	0	0	0		
1996	36	71	0	79	0		
1997	24	55	0	0	0		
1998	18	35	0	0	0		
1999	48	119	0	0	0		
2000	43	472	0	85	0		
2001	20	205	0	36	0		
2002	33	0	0	102	0		
2003	54	361	0	186	0		
2004	151	516	0	93	232	222%	40%
2005	118	314	0	78	0		
2006	88	148	0	0	367	40%	0%
2007	81	302	0	23	344	88%	7%
2008	112	354	0	22	469	76%	5%
2009	112	345	0	69	454	76%	15%
2010	56	201	0	37	219	92%	17%
2011	13	33	0	0	51	65%	
2012	105	345	0	0	422	82%	

Table 1.2 USA longline other than GOM.

Source YearC	Task_1 Total catch	Task2_CE N_BFT	Task2_CE W_BFT	Task2_Size Num (size measured)	Task2_Size Num (catch-at-size)	Percent CE	Percent size
unit	Ton	Number	kg	Number	Number	%	%
1990	122	57	0	48	0		
1991	121	83	0	20	0		
1992	235	127	0	59	0		
1993	123	176	0	151	0		
1994	133	128	0	176	0		
1995	176	87	0	204	0		
1996	199	61	0	101	0		
1997	167	80	0	148	0		
1998	138	117	0	163	0		
1999	174	86	0	171	0		
2000	199	428	0	79	0		
2001	110	278	0	58	0		
2002	191	0	0	167	0		
2003	246	649	0	224	0		
2004	124	928	0	163	232	400%	70%
2005	93	785	0	103	0		
2006	116	901	0	0	906	100%	0%
2007	92	1,336	0	100	928	144%	11%
2008	121	1,349	0	149	841	160%	18%
2009	223	1,393	0	340	1,431	97%	24%
2010	183	1,471	0	228	1,518	97%	15%
2011	228	878	0	0	1,184	74%	
2012	187	416	0	0	1,124	37%	

Table 1.3 USA Rod & Reel.

Source YearC	Task_1 Total catch	Task2_CE N_BFT	Task2_CE W_BFT	Task2_Size Num (size measured)	Task2_Size Num (catch-at-size)	Percent CE	Percent size
unit	Ton	Number	kg	Number	Number	%	%
1990	752	4,057	0	1,781	0		
1991	696	6,374	0	1,126	0		
1992	324	812	0	1,181	1,455	55.8%	81%
1993	540	703	0	1,712	0		
1994	462	360	0	1,716	0		
1995	844	479	0	1,760	0		
1996	840	0	0	3,094	0		
1997	931	1,976	0	3,787	0		
1998	777	1,395	0	2,466	0		
1999	760	656	0	2,898	0		
2000	683	413	0	2,424	0		
2001	1,244	1,038	0	7,464	1,363	76.2%	548%
2002	1,523	2,163	0	5,639	0		
2003	991	2,929	0	3,480	0		
2004	716	6,596	0	4,853	0		
2005	425	9,123	0	1,218	0		
2006	376	7,029	0	129	6,146	114.4%	2%
2007	634	1,022	0	817	15,069	6.8%	5%
2008	658	655	0	1,757	11,302	5.8%	16%
2009	860	1,239	0	2,760	11,561	10.7%	24%
2010	682	829	0	2,398	7,569	11.0%	32%
2011							
2012							

Table 1.4 Japan longline.

Source YearC	Task_1 Total catch	Task2_CE N_BFT	Task2_CE W_BFT	Task2_Size Num (size measured)	Task2_Size Num (catch-at-size)	Percent CE (N_CE)	Percent size (N_CE)
unit	Ton	Number	kg	Number	Number	%	%
1990	550	6,760	0	684	0	*100%*	10.1%
1991	688	7,238	0	783	0	*100%*	10.8%
1992	512	4,470	0	1,180	0	*100%*	26.4%
1993	581	6,059	0	1,357	0	*100%*	22.4%
1994	427	6,329	0	1,352	0	*100%*	21.4%
1995	387	5,181	0	25	0	*100%*	0.5%
1996	436	4,277	0	954	0	*100%*	22.3%
1997	330	3,232	0	86	0	*100%*	2.7%
1998	691	6,690	0	93	0	*100%*	1.4%
1999	365	4,258	0	154	0	*100%*	3.6%
2000	492	5,195	0	8	0	*100%*	0.2%
2001	506	3,282	0	0	0	*100%*	0.0%
2002	575	5,163	0	11	4,054	*100%*	0.2%
2003	57	759	0	14	744	*100%*	1.8%
2004	470	4,072	0	84	6,023	*100%*	2.1%
2005	265	8,415	0	498	4,160	*100%*	5.9%
2006	376	9,289	0	365	6,113	*100%*	3.9%
2007	277	7,757	0	548	6,679	*100%*	7.1%
2008	492	5,312	0	847	3,196	*100%*	15.9%
2009	162	1,080	0	406	1,079	*100%*	37.6%
2010	353	2,091	0	644	2,088	*100%*	30.8%
2011	578	4,890	0	2,513	4,886	*100%*	51.4%
2012	289	4,099	0	0	1,803	*100%*	0.0%

Table 1.5 Canada.

Source YearC	Task_1 Total catch	Task2_CE N_BFT	Task2_CE W_BFT	Task2_Size Num (size measured)	Task2_Size Num (catch-at-size)	Percent CE (weight)	Percent size
unit	Ton	Number	kg	Number	Number	%	%
1990	438	0	437,400	2,169	2,169	100%	100%
1991	485	0	484,600	2,129	2,129	100%	100%
1992	443	0	413,500	1,782	1,782	93%	100%
1993	459	0	458,700	0	0	100%	
1994	392	0	391,800	1,514	1,514	100%	100%
1995	576	0	576,000	0	0	100%	
1996	597	0	598,100	0	0	100%	
1997	509	0	504,400	1,899	1,899	99%	100%
1998	611	0	596,300	2,345	2,345	98%	100%
1999	587	0	227,800	7	7	39%	
2000	595	0	548,188	47	47	92%	
2001	537	0	523,683	2,168	2,168	98%	100%
2002	641	0	608,683	2,473	2,473	95%	100%
2003	571	0	556,614	5,201	5,201	98%	100%
2004	552	0	536,925	5,115	5,115	97%	100%
2005	600	0	599,526	6,456	6,456	100%	100%
2006	735	0	732,871	8,616	8,616	100%	100%
2007	491	0	490,918	4,808	4,808	100%	100%
2008	576	0	570,769	7,125	7,125	99%	100%
2009	533	0	530,187	6,231	6,231	99%	100%
2010	530	0	504,397	4,134	4,134	95%	100%
2011	510	0	474,082	4,260	4,260	93%	100%
2012	493	0	472,925	4,016	4,016	96%	100%

Table 1.6 Mexico longline in GOM.

Source YearC	Task_1 Total catch	Task2_CE N_BFT	Task2_CE W_BFT	Task2_Size Num (size measured)	Task2_Size Num (catch-at-size)	Percent CE (weight)	Percent size
unit	Ton	Number	kg	Number	Number	%	%
1994	4	15	9,700	14	0	243%	
1995	0	0	0	16	0		
1996	19	59	18,600	57	0	100%	
1997	2	0	2,300	3	0	115%	
1998	8	0	7,800	14	0	98%	
1999	14	0	14,800	16	0	106%	
2000	29	0	35,900	120	0	125%	
2001	10	46	0	41	4		
2002	12	50	0	47	0		
2003	22	0	22,153	71	0	100%	
2004	9	0	9,028	40	0	100%	
2005	10	0	10,137	46	0	100%	
2006	14	0	14,115	60	0	100%	
2007	7	0	7,100	27	26	100%	
2008	7	0	7,167	30	0	100%	
2009	10	0	9,904	35	0	100%	
2010	14	0	14,058	58	0	100%	
2011	14	0	13,501	55	0	99%	
2012	52	0	50,617	200	0	98%	

Table 2. Summary table of coverage in the number of bluefin tuna caught for catch & effort data.

	US.GOM	US.LL	US.RR	Jpn.LL	Canada	MEX.GOM
1990				*100%*	100%	
1991				*100%*	100%	
1992			55.8%	*100%*	93%	
1993				*100%*	100%	
1994				*100%*	100%	243%
1995				*100%*	100%	0%
1996				*100%*	100%	100%
1997				*100%*	99%	115%
1998				*100%*	98%	98%
1999				*100%*	39%	106%
2000				*100%*	92%	125%
2001			76.2%	*100%*	98%	0%
2002				*100%*	95%	0%
2003				*100%*	98%	100%
2004	222%	400%		*100%*	97%	100%
2005	0%	0%		*100%*	100%	100%
2006	40%	100%	114.4%	*100%*	100%	100%
2007	88%	144%	6.8%	*100%*	100%	100%
2008	76%	160%	5.8%	*100%*	99%	100%
2009	76%	97%	10.7%	*100%*	99%	100%
2010	92%	97%	11.0%	*100%*	95%	100%
2011	65%	74%		*100%*	93%	99%
2012	82%	37%		*100%*	96%	98%

Note that coverage of Jpn_LL was defined to be to the total catch in catch & effort so that it became 100%.

Table 3. Summary table of coverage in the number of bluefin tuna caught for size data.

	US.GOM	US.LL	US.RR	Jpn.LL	Canada	MEX.GOM
1990				10%	100%	
1991				11%	100%	
1992			81%	26%	100%	
1993				22%		
1994				21%	100%	
1995				0%		
1996				22%		
1997				3%	100%	
1998				1%	100%	
1999				4%		
2000				0%		
2001			548%	0%	100%	
2002				0%	100%	
2003				2%	100%	
2004	40%	70%		2%	100%	
2005				6%	100%	
2006	0%	0%	2%	4%	100%	
2007	7%	11%	5%	7%	100%	
2008	5%	18%	16%	16%	100%	
2009	15%	24%	24%	38%	100%	
2010	17%	15%	32%	31%	100%	
2011				51%	100%	
2012					100%	

Appendix 12

PROPOSED CONCLUSIONS OF AGENDA ITEM 7 FROM THE SECOND MEETING OF THE WORKING GROUP OF FISHERIES MANAGERS AND SCIENTISTS IN SUPPORT OF THE WBFT STOCK ASSESSMENT

Provided that it does not interfere with the current work program of the SCRS deriving from previous decisions of the SCRS and the Commission, the WG requests the SCRS to:

1) Consider the proposal from Canada to employ the surplus production model in association with the update of stock assessment in 2014.

2) As part of the 2014 update assessment of western Atlantic bluefin tuna, provide guidance on a range of fish size management measures for western Atlantic bluefin tuna and their impact on yield per recruit and spawner per recruit considerations. The SCRS should also comment on the effect of fish size management measures on their ability to monitor stock status.

3) Provide to the 2014 Commission meeting for its consideration:

   - A range of potential interim target reference points based on levels expressed in the percentage of currently estimated spawning stock biomass taking into account relevant factors including, but not limited to, the estimated speed of increase of the spawning stock biomass, levels of recent recruitment, and the level corresponding to a biomass enabling the SCRS to determine if there is an applicable recruitment scenario for the western Atlantic bluefin tuna stock.
   - A Strategy Matrix to achieve these interim target reference points;
   - A limit reference point, taking into account the historically lowest level of spawning stock biomass; and
   - A Strategy Matrix to avoid dropping below the interim limit reference point.

4) Review the current stock abundance indices for WBFT at the data preparatory meeting scheduled early in 2015 where access to original catch and effort data before aggregating should be allowed to all the participating CPC scientists under the confidentiality requirements.

Appendix 13

JOINT STATEMENT BY THE OBSERVERS FROM PEW CHARITABLE TRUSTS, ECOLOGY ACTION CENTRE, DAVID SUZUKI FOUNDATION AND THE OCEAN FOUNDATION

Thank you, Chairs. The Pew Charitable Trusts, Ecology Action Centre, David Suzuki Foundation, and The Ocean Foundation appreciate this Working Group's efforts to improve the western bluefin stock assessment. We support the development of new fishery-independent indices and collaboration to improve current indices. We also strongly support the movement toward reference point-based management using harvest control rules, and note that the SCRS has already established a work plan to develop HCR options informed by Management Strategy Evaluation (MSE).

ICCAT is 15 years into the 20 year rebuilding plan, and the last stock assessment indicated that the stock is at just 36% of the already-depleted 1970 level. With five years remaining in the rebuilding plan, we appreciate the desire to move quickly toward an improved model and better management approach. However, any rash decisions regarding which models to use or circumventing the SCRS in this attempt to move things forward would be a step backward for the Commission and does not constitute responsible management.

As we understand it, these science-managers meetings are intended to provide an opportunity for a fruitful dialogue between scientists and managers to better understand each other and work together to improve the assessment and management. However, in order for the Commission to maintain its credibility and adhere to science-based management, there needs to be a clear firewall between management and the scientific advice. We find parts of yesterday's discussions concerning in that they proposed to blur the lines of responsibility between scientists and managers. In that regard, we support those changes reflected in document "*Proposed Conclusions of Agenda Item 7 from the Second Meeting of the Working Group of Fisheries Managers and Scientists in Support of the WBFT Stock Assessment*" (**Appendix 12**) that help to ensure that this Working Group's recommendations are not overly prescriptive and do not infringe on the independence and creativity of the SCRS.