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IN SITU ACOUSTIC OBSERVATIONS OF ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) WITH HIGH RESOLUTION MULTI-BEAM SONAR

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SUMMARY

Initial field studies to investigate the ability/adaptability of a high frequency multi-beam sonar to document, monitor, and quantify bluefin tuna was undertake at several fishing sites (commercial and recreational) off PEI and at a tuna pen in Nova Scotia. The preliminary results of this study clearly illustrate that bluefin tuna can be detected and tracked acoustical within the swath the multi-beam sonar. Some restrictions/limitations were imposed depending upon sea state and water depth. In rough seas the surface layer became too turbulent (air bubble noise) to consistently separate noise from fish like targets. Whereas in shallow water (20-30m) the full detection range of the sonar could not be used due to the acoustic beams intercepting with the bottom. Water depths > 50-60m allowed the full range of the sonar to be utilized uncluttered. Adjustment of the tilt angle of the sonar could be used to optimize observations with a pan and tilt unit if available. In summary the results indicate that there is good potential for the utilization of multi-beam sonar to monitor and quantify bluefin tuna in a broad scale fishery independent survey. Further analysis of the vast amount of data will be conducted this fall and further investigations will be undertaken in summer 2015.

RÉSUMÉ

Des études initiales sur le terrain destinées à étudier la capacité/ l'adaptabilité d'un sonar multifaisceaux à haute intensité de documenter, suivre et quantifier le thon rouge ont été menées dans plusieurs zones de pêche (commerciale et récréative) au large de l'île de Prince Édouard et dans un enclos de thons en Nouvelle-Écosse. Les résultats préliminaires de cette étude montrent clairement que le thon rouge peut être détecté et suivi acoustiquement dans le champ du sonar multifaisceaux. Quelques restrictions/limitations ont été imposées en fonction de l'état de la mer et de la profondeur de l'eau. Par mer agitée, la couche de surface devient trop turbulente (bruit de bulle d'air) pour pouvoir distinguer clairement le bruit des espèces de poissons cibles alors qu'en eau peu profonde (20-30m), le champ de détection complet du sonar ne peut pas être utilisé car les faisceaux acoustiques entrent en contact avec le fond. Les profondeurs de plus de 50-60 m ont permis d'utiliser le champ complet du sonar sans interception. Un ajustement de l'angle d'inclinaison du sonar peut être appliqué afin de tirer le maximum de profit des observations avec module panoramique et d'inclinaison si disponible. En résumé, les résultats indiquent que l'utilisation d'un sonar multifaisceaux offre un potentiel intéressant permettant de suivre et de quantifier le thon rouge dans le cadre d'une étude indépendante sur la pêche à grande échelle. Une analyse plus poussée de la grande quantité de données sera réalisée cet automne et d'autres études seront réalisées au cours de l'été 2015.

RESUMEN

Se llevaron a cabo estudios iniciales de campo para investigar la capacidad/adaptabilidad de un sonar de haces múltiples de alta frecuencia para hacer un seguimiento y cuantificar atún rojo en diversas zonas de pesca (comercial y de recreo) en aguas de PEI y en una granja de atún en Nueva Escocia. Los resultados preliminares del estudio demuestran claramente que el atún rojo puede detectarse y seguirse acústicamente dentro del barrido del sonar multihaz. Se impusieron algunas restricciones/limitaciones dependiendo del estado del mar y de la profundidad del agua. En los mares agitados, la capa superficial estaba demasiado turbulenta (ruido de burbujas de aire) para separar el ruido de los objetivos parecidos a peces. En aguas poco profundas (20-30 m) el rango de detección total del sonar no podría utilizarse debido a

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que los haces acústicos interceptan con el suelo. Profundidades de más de 50-60 m permitían que todo el rango del sonar fuera utilizado despejado. El ajuste del ángulo de inclinación del sonar podría utilizarse para optimizar las observaciones con una unidad de movimientos horizontales y verticales. En resumen, los resultados indican que hay un buen potencial para el uso del sonar multihaces en el seguimiento y cuantificación del atún rojo en una prospección a gran escala independiente de la pesquería. Este otoño se llevarán a cabo más análisis de la gran cantidad de datos y en el verano de 2015 se realizarán más investigaciones.

KEYWORDS

Bluefin tuna, Migrations, Sonar detection, Acoustic equipment

Introduction

Currently western bluefin tuna are assessed using a VPA (Virtual population Analysis) stock assessment model tuned or calibrated primarily with fishery dependent indices of abundance. The indices are based on the catch and effort of commercial bluefin tuna fisheries in specific regions of the North Atlantic. Recently, the SCRS has expressed concern about the representativeness of these indices due to changing fishing patterns and management imposed initiatives for both the eastern and western bluefin tuna stocks. Both the eastern and western fisheries have been subjected to varying degrees of operational changes and management enforced regulations such that indices of abundance developed from the fisheries catch and effort information have come into question. The main concern is even though a number of initiatives to improve the indices have been undertaken, observed trends in the indices may reflect anthropogenic intervention more than an actual change in abundance. Canada provides two, geographically separated, standardized catch series from the rod and reel, tended line and harpoon fisheries for tuning the western bluefin tuna assessment; Gulf of St Lawrence (GSL) and south west Nova Scotia (SWNS). In the GSL, fishing restrictions imposed by the regional fishing associations have affected the period of the year fished. The first year this was implemented an unusually large increase in the GSL index was observed and resulted in the exclusion of the 2010 data point from the series in the 2012 assessment. Another area of inconsistency in the SWNS time series was identified at the 2014 Science and Management working group meeting, whereby effort estimates may be biased due to the targeting of multiple species on bluefin tuna trips.

As a result of concerns about the impact of the above and other initiatives, the SCRS has in recent years strongly recommended the development of fishery independent abundance indices for both stocks to complement the existing indices. A number of proposals were presented by Canada, Japan, and the United States at the second meeting of the working group of fisheries managers and scientists in support of western bluefin tuna stock assessment on the development of new fishery independent indices of abundance and improvements to existing indices. The proposals covered a broad spectrum of ideas, approaches and technologies with encouraging potential for improvements and enhancements in the future. As a follow up to the submissions, the proposals will be ranked by the supporting CPC's and considered at the 2014 SCRS meeting. One of Canada's proposals was based on the use of split and multibeam sonar under a scientific survey design to develop a new fishery independent index of abundance for the GSL.

In preparation for the development and implementation of a full scale acoustic survey in the GSL, a field study was implemented during the 2014 fishing season to evaluate the ability of acoustic technology to detect, observe, and quantify bluefin tuna on the fishing grounds and in a sea pen. In addition, information was collected on the hardware orientation (tilt), vertical beam width, and horizontal range for several water depths and sea states. It must be noted that the results presented in this document represent a preliminary summary of findings as the field work was conducted less than one month ago. The data contain far more extensive information than presented in this document. A detailed analysis of the extensive data set will be undertaken during the fall/winter of 2014 and presented to the SCRS in 2015.

Methods

Field studies were undertaken at three PEI tuna fishing areas, McMaster's Bank off North Point (August 25-28, 2014), near North Lake (September 9 and 11, 2014), and Fishermans Bank (September 10, 2014). The confined tuna observations were made on September 4, 2014 around a commercial tuna pen located in Mills Cove on St

Margaret's Bay, Nova Scotia (**Figure 1**). No specific survey design was established for either location as the survey vessel moved in and around the fishing vessel operations to make acoustic observations. A short series of transects were, however, run at two PEI locations that may render a biomass estimate in the detailed analysis. The same acoustic equipment was used at all three locations.

The acoustic equipment consisted of two calibrated Simrad EK 60 split-beam echosounders (120 and 200 kHz, 7degree 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 studies. The 120 kHz transducer was orientated downward and the M3 sonar plus the 200 kHz transducer forward, but at a 7 degree tilt off the horizontal. **Figure 2** illustrates the difference between the multi-beam and the split beam swath verses a single beam angle. Ping rates for the EK systems were set to 1 transmission/receive per second, while the M3 was set at maximum and was range setting dependent (~5pings/sec at 50m). All transducers were pole mounted to the small survey boat (24' Rossbourgh) and suspended approximately 1m below hull depth. The three acoustic systems were connected to a single GPS navigation system with simultaneous data streams. This enabled the synchronization of the difference systems based on position. Initially a pan and tilt unit was to be mounted to the pole and used to fine tune the tilt angle depending upon sea state and water depth. Unfortunately, the pan and tilt unit to adjust the horizontal angle (tilt) of the sonar head and the EK60 transducer (200 kHz) malfunctioned just prior to the field season. Despite efforts to have the system repaired, it was not available for this year's program. A series of wooden wedges were used to change the tilt from 0 to 10 degrees off the horizontal.

Results

Several factors contribute to the ability of acoustic technology to detect targets in the water column and the range of the detection. The first couple of images illustrate how surface noise and water depth can inhibit returns. **Figure 3** illustrates the clarity of the acoustic image when the water depth is sufficient to avoid bottom at a specific range setting. In **Figure 4** the acoustic recordings are taken in shallow water during fairly rough seas (10-15 knots). Here the acoustic beams of the multibeam sonar intercept with the bottom at approximately 35m in a water depth of about 25m with a tilt angle of 7 degrees and a vertical beam angle of 30 degrees. Reducing the vertical beam angle will increase the distance before intercepting the bottom. The figure also illustrates how the surface noise (turbulence) can reduce the observer's ability to detect targets. We have several examples where it is virtually impossible to detect fish like targets near the surface due to wave action. Improvements to the image can be made by adjusting the tilt angle, vertical beam width, and the range setting even in fairly rough seas. Unfortunately tilt angle could only be adjusted mechanically this field season.

Throughout the two weeks of surveying numerous examples of single and double tuna observations were made in the sonar images. **Figures 5 and 6** show the characteristics of tuna for these types of occurrences. The critical factor in determining the type of target is the target strength or the strength of the signal return of the individual fish. Bluefin tuna are generally large in this area and strong reflectors due to the presence of a swim bladder. In these images the tuna stand out among the other targets and can easily be tracked from one ping to another. It was also observed that bluefin tuna appear to travel in packs separated by 5-10m between individuals. **Figure 7** and **Figure 8** clearly shows the wall like distribution of the tuna as they move through the water from ping to ping. In **Figure 8** the single image shows only 7 fish of a 25 fish array, while **Figure 7** displays 4 of a 16 fish array. Individual fish can also be positioned in 3D space for each image, their movement tracked from ping to ping and speed calculated from the time they are first observed to they pass through the acoustic swath.

Bluefin tuna have long been known to aggregate around commercial fishing operations, especially those targeting prey species such as mackerel and herring. This abundance of easy food while fishers retrieve their nets provides an opportunity to observe tuna. On the early morning of 28 August we were fortunate to be able to move among the herring fleet (20-25 vessels) as they lifted their nets with the acoustic gear active. Every fishing vessel had numerous bluefin tuna lingering around the boat and were picking off herring that dropped from the gillnets as the catch was hauled aboard. **Figure 9** shows a single image of bluefin tuna with approximately 24 fish within a 40m radius of the fishing boat. The tuna can be easily detected and counted by tracking the targets from one ping to the next. It should also be noted that as soon as the fleet finished fishing the tuna dispersed and could no longer be found in the fishing area.

The retaining and grow-out of bluefin tuna in sea pens has been ongoing for decades in St Margaret's Bay. Each year bluefin tuna are captured in traps (mackerel) and transferred to pens for summer feeding. This provides an excellent opportunity test the acoustic equipment with known targets. Several hours were spent ensonifying the sea pen from a variety of directions, ranges and angles to determine the content of the cages. Although the owner believed he had eight tuna in the pen (not really certain) our preliminary acoustic estimate would suggest 9. We were also able to make acoustic length measurements of several of the fish. Unfortunately, the fish will not be harvested for a few weeks. **Figure 10** shows the entire pen with 5 tuna in a single ping. Tracking the individual fish from ping to ping allows the separation of fish as they move in and out of the acoustic swath.

Discussion

The primary objective of this short field experiment was to determine if bluefin tuna could be detected and enumerated using single and multi-beam sonar in preparation for the development of a fishery independent index of abundance. Additional information was collected on specifics regarding the configuration and orientation of the acoustic gear to optimize detections. The data described above represents a preliminary summary of our results and reflects observations from about 5 gigabytes of the 300+ gigabytes collected. The study serves to illustrate the capability of the M3 sonar and suggests it may be a useful tool to monitor the abundance and behaviour of Atlantic bluefin tuna in the wild and under a variety of situations.

During the study estimates were made on the relationship between water depth and detection range. In shallow water (20-30m) the functional range of the sonar anterior to the survey vessel was limited to 35-45m for a tilt angle of 7 degrees. However, once the water depth exceeded 50- 60m the full operational range (>100m) was available for observations. It was also determined that surface noise due wind turbulence (bubbles) could limit the operator’s ability to discern fish from noise. This was especially true when wind speeds exceeded 15knots and in swells >1.5m. Both the bottom detection distance and surface noise could be optimized for observations by slight changes in the tilt angle. During calm seas the tilt angle could set to near horizontal without surface noise problems, yet as the wind increased so did the need to increase the angle off the horizon. Overall we settled on a 7 degree tilt for most observations as adjustments had to be made manually. A pan and tilt unit would have made tilt angle adjustments easy. Another method to improve range due to surface noise and shallow water depths was to adjust the vertical beam width of the swath. In the M3 sonar this is simply a pull down window with options for 3, 7, 15 and 30 degrees. Over the 3 week study we discovered in the shallow water that 7 degrees was the preferred width and in calm seas the 15 degree setting. Three degrees was too narrow and 30 degrees too wide in shallow water. Once the vessel was in deeper water the wider options were available to cover greater vertical distribution.

Vessel size is another consideration when implementing acoustic surveys. The small 24’ boat we used to conduct this study was a bit small for the task in open water and a larger vessel would have been appreciated. One of the difficulties with the acoustic observations was vessel movement and motion where the small boat was constantly pitching and heaving in relatively calm seas. A larger vessel would help to stabilize the sonar, increase detection range and improve acoustic observations.

Integration of the sonar and echosounder data will be undertake in the near future and summarize in a report at the 2015 SCRS meeting.

Summary

The results of this year’s study indicate that there is promising potential for the utilization of multi-beam sonar to monitor and quantify bluefin tuna in a broad scale fishery independent survey. Further analysis of the vast amount of data will be conducted this fall and further field investigations will be undertaken in summer 2015.

Acknowledgements

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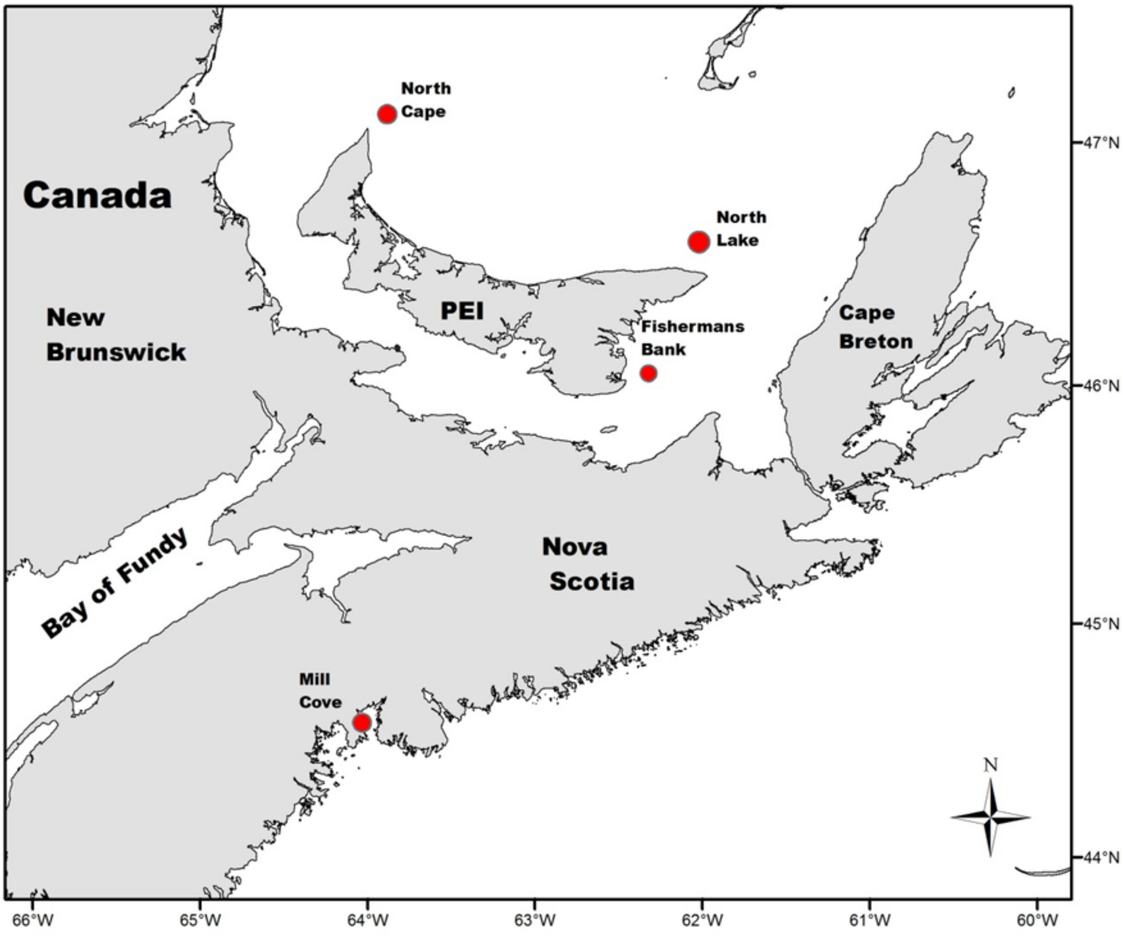

Figure 1. Map illustrating the location of acoustic sampling areas between August 27 and September 12, 2014. Areas around PEI were open water while Mill Cove was the site of a tuna pen in St Margarets Bay, Nova Scotia.

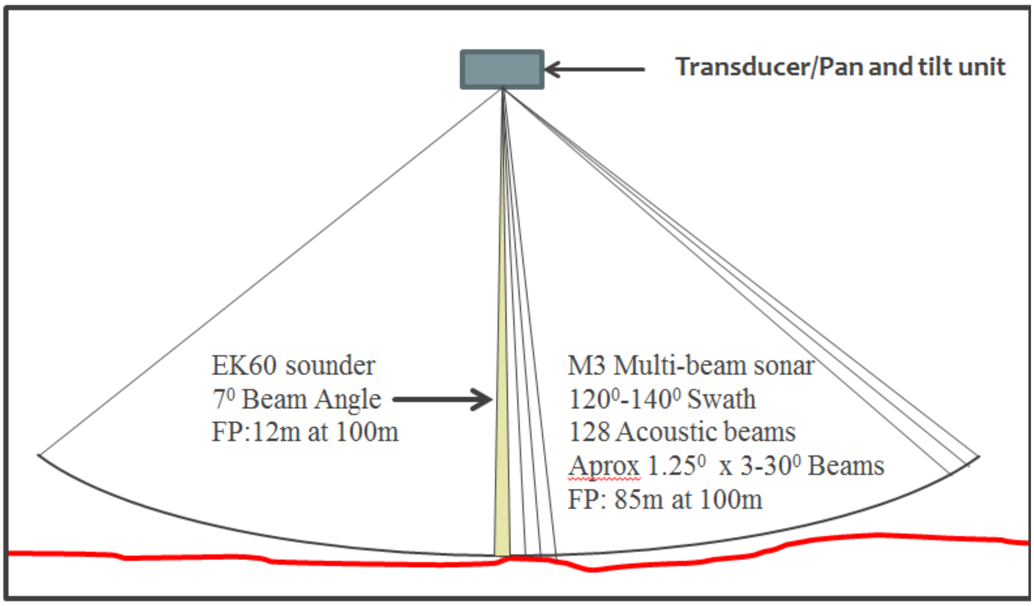

Figure 2. Comparison of the Simrad EK 60 scientific echosounder and Mesotech M3 multi-beam sonar beam pattems and system characteristics.

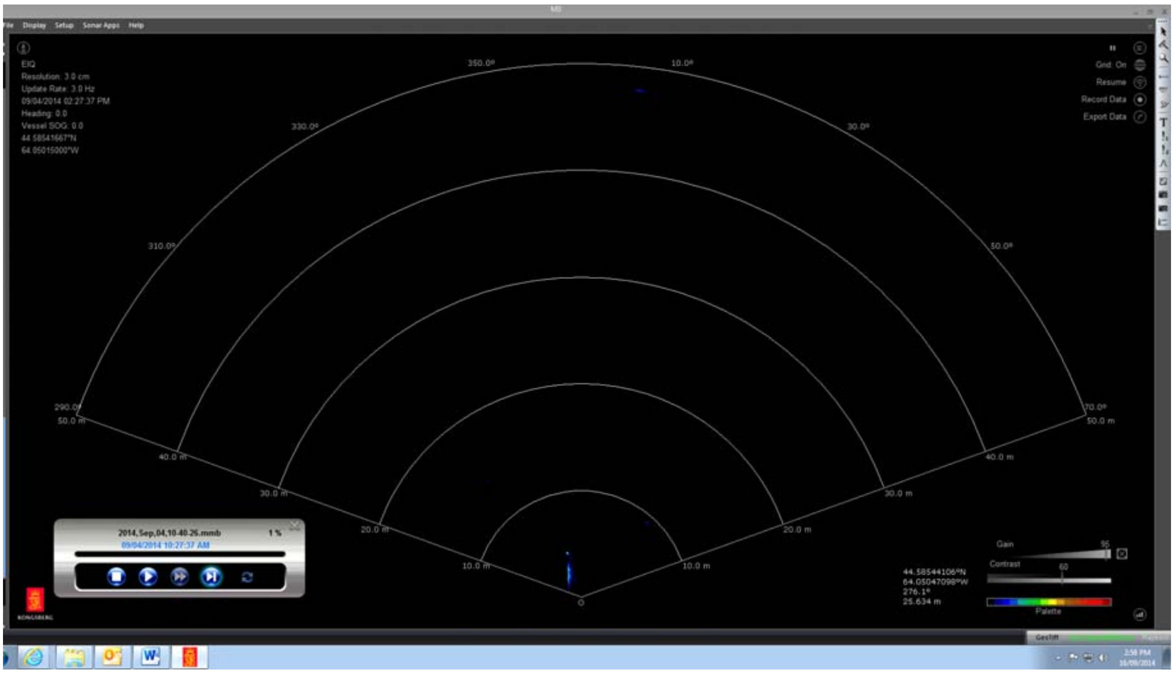

Figure 3. M3 sonar immage at 50m range setting in 60m of water during very calm seas recorded at Mill Cove.

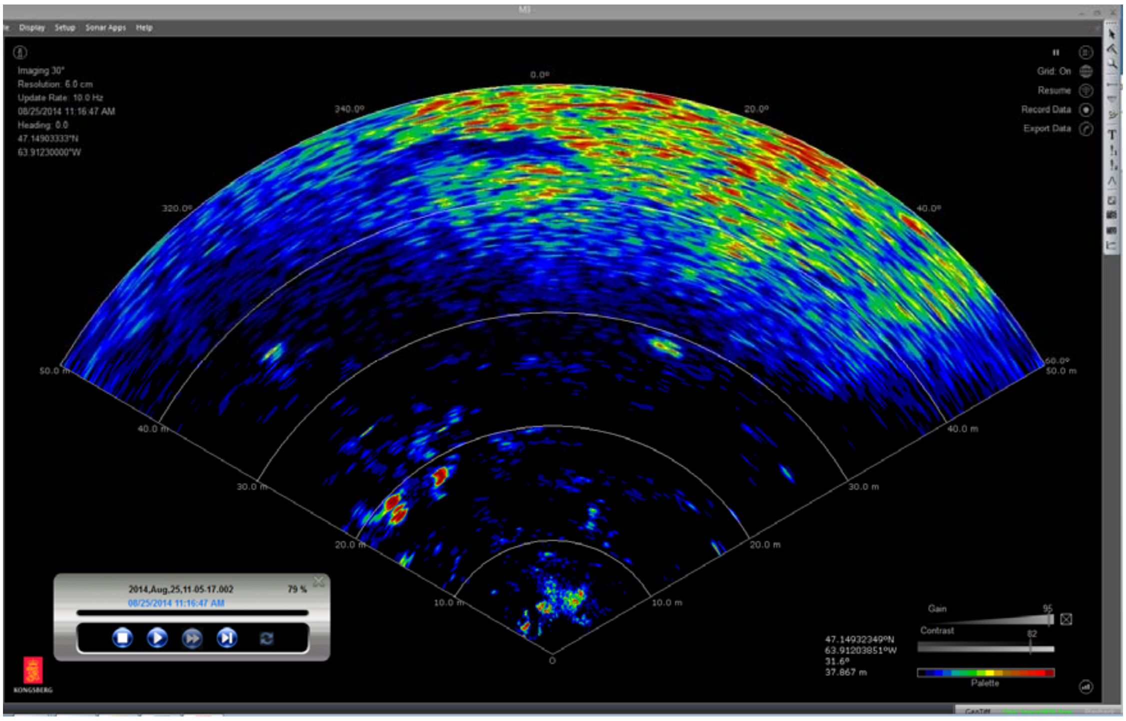

Figure 4. M3 sonar image at 50m range setting and a 30 degree verticle beam in 24 m of water, wave action associated with 15 knot winds. The region between 30 and 50 m is where the acoustic beams intercept with bottom. No fish targets were descernable in this image.

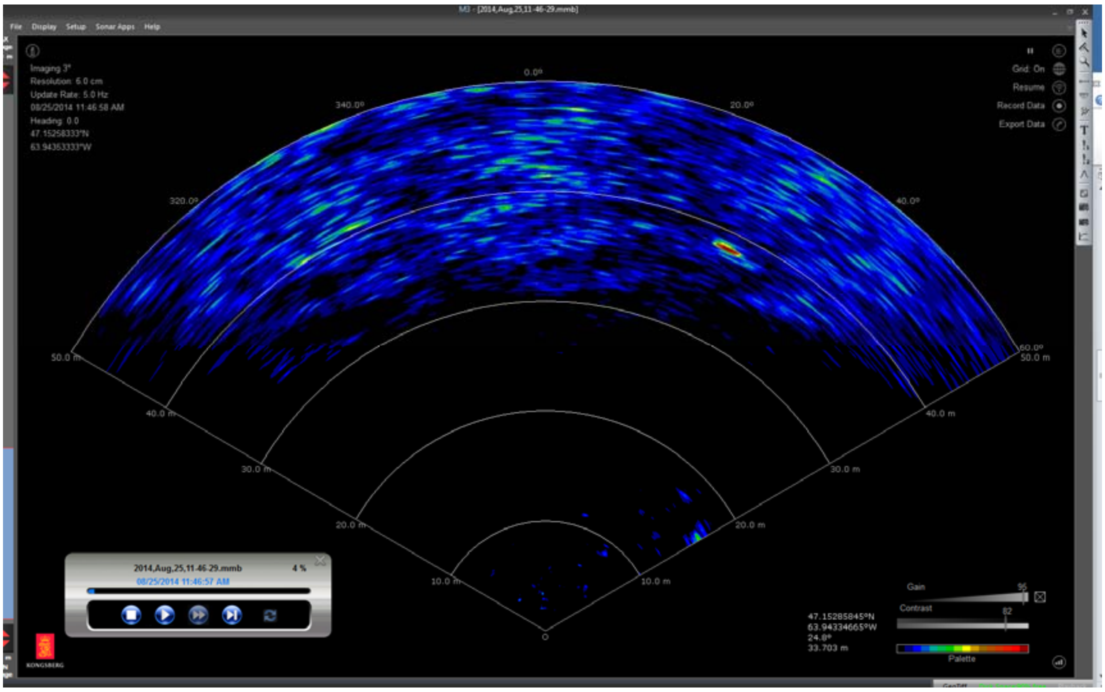

Figure 5. M3 sonar image of a single tuna located about 39m forward of the sonar head on McMasters Bank. The strong signal from the individual tuna far exceeds the angular reflection of the bottom this 7 degree vertical beam width observation.

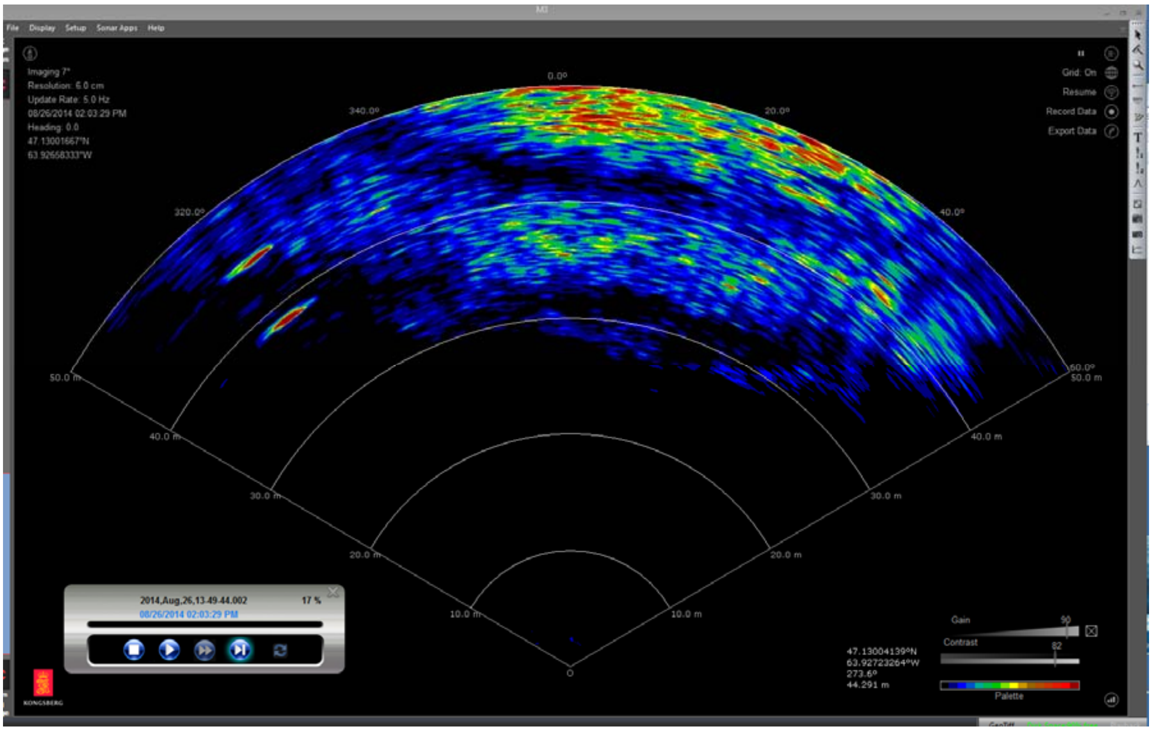

Figure 6. M3 sonar image of 2 bluefin tuna approaching the survey vessel as it moves forward of North Cape PEI.

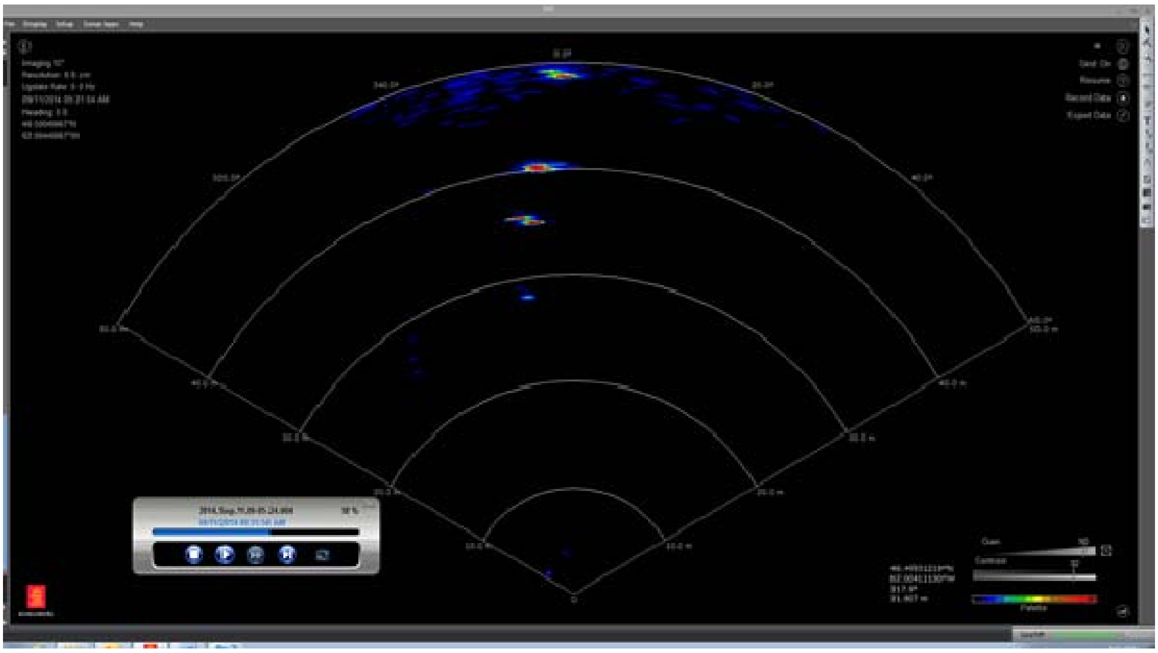

Figure 7. The M3 sonar image illustrates a series of bluefin tuna traveling across in front of the transducer. Here 4 in a line of 14 tuna are observed as the survey vessel passes over the area.

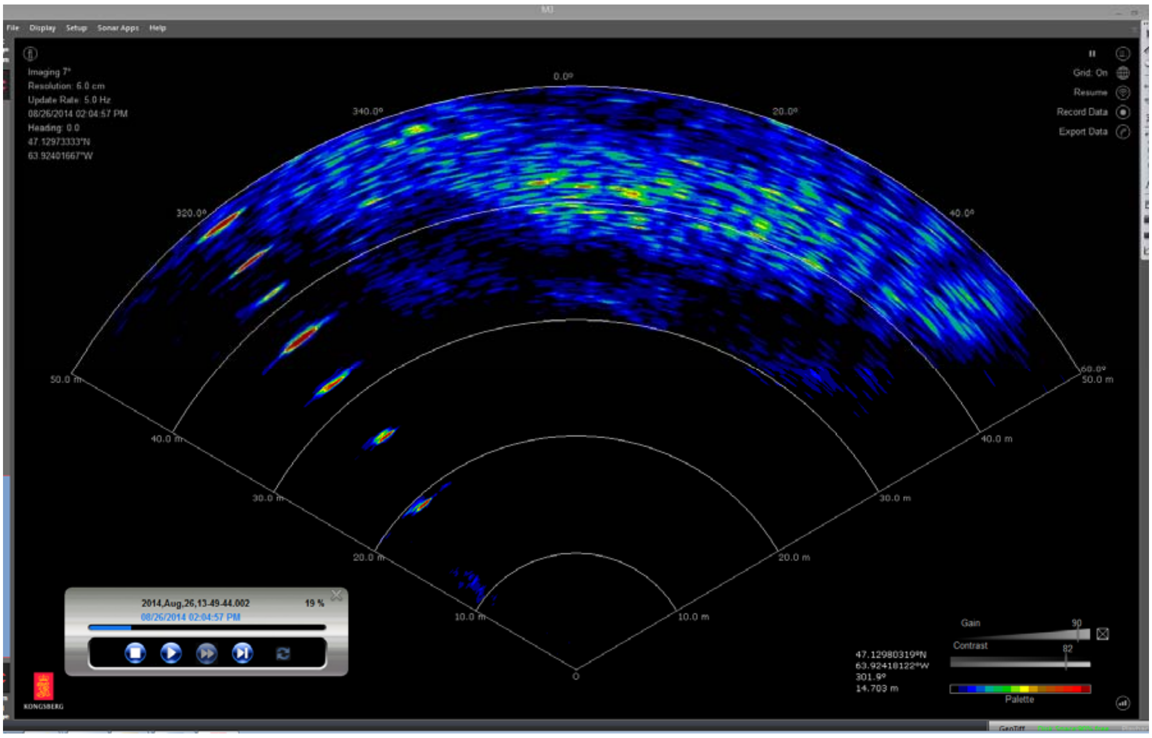

Figure 8. The M3 sonar image illustrates a series of bluefin tuna traveling across in front of the transducer. Here 7 in a line of 21 tuna are observed as the survey vessel passes over the area.

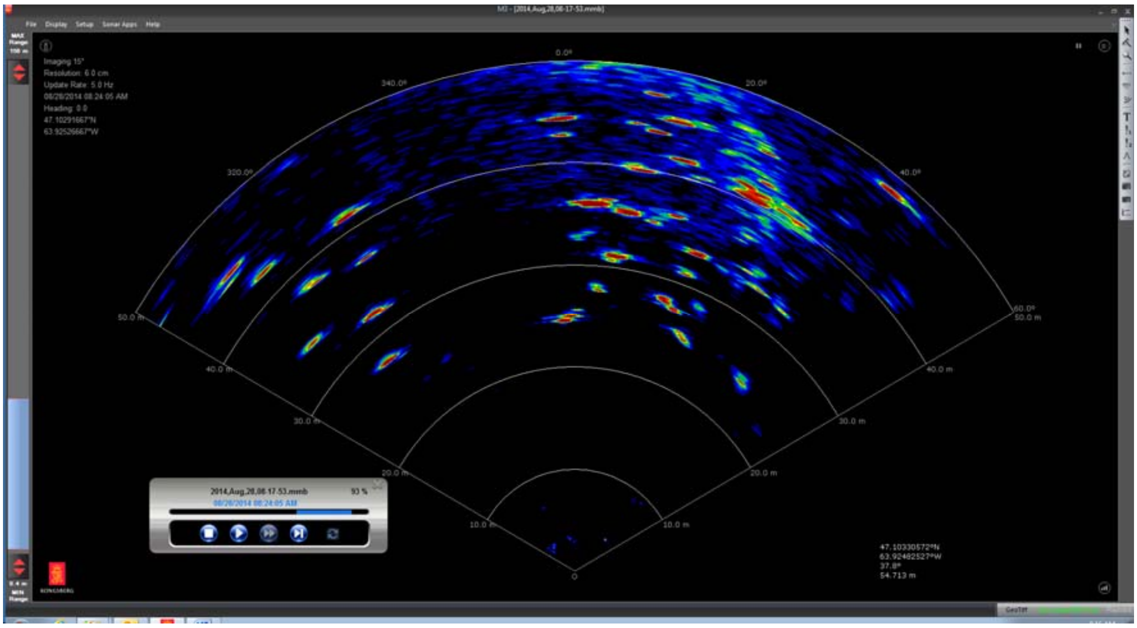

Figure 9. Aggregation of bluefin tuna near a commercial herring gillnetter while hailing its gear. Multiple bluefin tuna are observed in this single ping image.

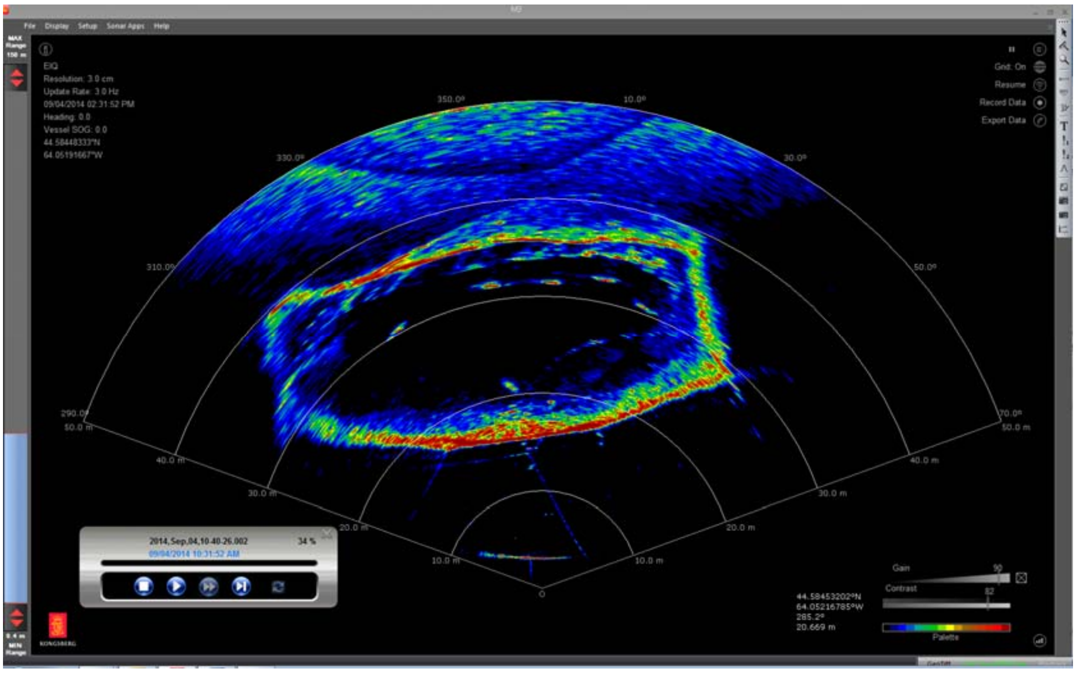

Figure 10. Image of bluefin tuna in the Mill Cove pen in St Margarets Bay, Nova Scotia, September 4, 2014. Owner estimates a total of 8 fish in the pen.