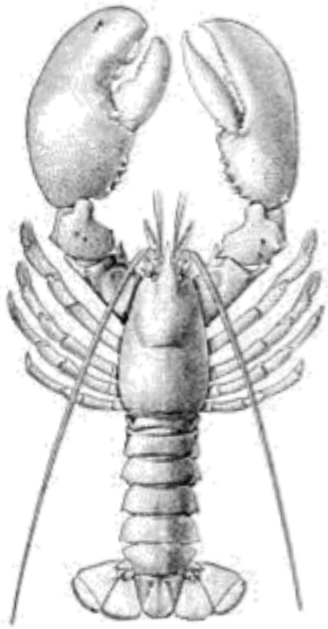
Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2020/002

ASSESSMENT OF LOBSTER (*HOMARUS AMERICANUS*) IN LOBSTER FISHING AREA 33 FOR 2018



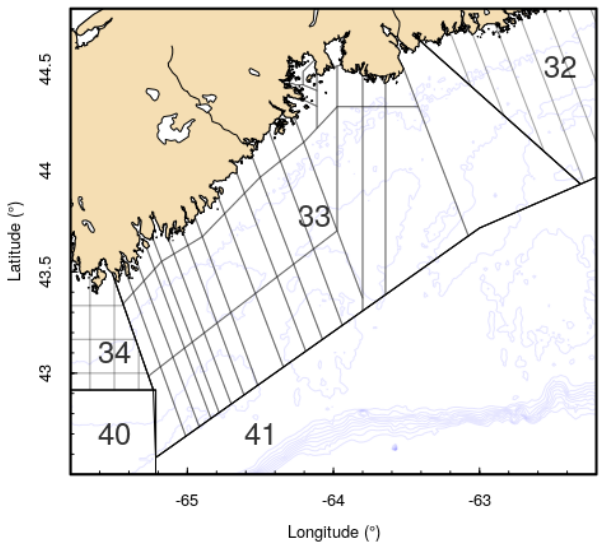


Figure 1. Map of Lobster Fishing Area (LFA) 33.

Context:

Lobsters (Homarus americanus) are found in coastal waters from southern Labrador to Maryland, with some major fisheries in the Canadian Maritimes. Lobster Fishing Area (LFA) 33 covers Cole Harbour to Barrington Bay (Shelburne County) in the south. Although the LFA extends out to 92 km (50 nautical miles), colder water temperatures with increasing depth generally limit fishing to within 15 km of shore in the eastern end of LFA 33 and to within 20 km from shore in the southwest.

The status of the Lobster resources in LFA 33 was last updated in 2017. Fisheries Management has requested updated information on the status of the LFA 27-33 Lobster stocks. A framework meeting was held January 23-24, 2018, to establish the scientific basis for the provision of management advice for this stock. This assessment provides advice only for LFA 33 to align timing of science advice with data availability and the fisheries management cycle.

This Report is from a Science Advisory Process held on October 1, 2018, to assess the status of Lobster stocks in LFA 33. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The landings in Lobster Fishing Area (LFA) 33 for the 2017 – 2018 fishing season were 8,229 mt.
- A spatial representation of Lobster landings by grid cell indicates an increase in landings coming from offshore areas in recent years, especially near the boundary with LFA 40.
- Primary indicators are used to define stock status in relation to the reference points. The primary indicator for describing stock status is the unmodelled commercial catch per unit effort (CPUE). In addition to CPUE from log data, exploitation estimated using the Continuous Change in Ratio (CCIR) method from data collected by the Fishermen and Scientists Research Society (FSRS) is used as an indicator of fishing pressure that is independent of landings reported in the logs.
- The trend in CPUE indicates that a significant increase in the stock biomass has occurred in the last ten years. The 3-year running median value for CPUE for the 2017/2018 season is 1.08 kg per trap haul (TH), which is above the Upper Stock Reference (USR) of 0.28 kg/TH and Limit Reference Point (LRP) of 0.14 kg/TH.
- Since 2013, exploitation has declined to about two-thirds the level of the Removal Reference (RR). The 3-year running median value of CCIR exploitation for the 2017/2018 season is 0.56, which is below the RR of 0.81.
- Secondary indicators represent important time series trends that are tracked individually, but no reference points are defined. The secondary indicators for LFA 33 are landings and total effort (trap hauls), as well as FSRS recruitment trap recruit and legal catch rate series.
- There has been a significant increase in landings over the last ten years that corresponds with an increase in CPUE. There are some annual fluctuations in effort, with a slight increasing trend over time.
- Both FSRS recruit and legal size classes show a gradual increasing trend, which is not as dramatic as the increase in landings and CPUE over the last ten years.
- None of the contextual indicators change our perception of stock status.
- The CPUE index is above the USR, suggesting the current status of LFA 33 is within the Healthy Zone, and exploitation is below the RR.

BACKGROUND

Species Biology

The American Lobster (*Homarus americanus*) is a crustacean species that has been commercially fished since the early 1800s. Nova Scotia Lobsters can take up to 8-10 years to reach a minimum commercial size of 82.5 mm carapace length (CL). Moulting frequency begins to decrease from one moult per year at about 0.45 kg to moulting every 2 or 3 years for Lobsters above 1.4 kg (Aiken and Waddy 1980).

Lobsters mature at varying sizes depending upon local conditions, with climatological factors such as temperature influencing the size at maturity (Cook et al. unpublished report[1]). In Lobster Fishing Areas (LFAs) 27-33, the Size of Maturity (SoM) has been estimated through several studies (reviewed in Tremblay and Reeves 2004; Reeves et al. 2011), with the general consensus that SoM increases from east to west, with LFA 27 having a lower SoM than LFA 33. In LFA 27-32, the minimum legal size is above the SoM indicating a high proportion of the females caught have had the opportunity to breed prior to interception by the fishery. This is in contrast to LFA 33 and other inshore fisheries where the median size in the catch is below SoM and a small proportion of females have had the opportunity to breed.

Very large Lobsters have a much greater relative fecundity and are, thus, an important component to conservation. A key component of past stock assessments was maintaining the high reproductive potential in this area by preserving its size structure dominated by mature animals (Pezzack and Duggan 1989, Pezzack and Duggan 1995).

Fishery

The commercial fishery for American Lobster has been active for over 100 years in LFA 33. This area covers 25,722 km^2 from Halifax to Shelburne County. Though the LFA extends out to 92 km (50 nautical miles), the fishery is primarily prosecuted within 15 km (100 m depth contour) on the eastern end and more recently in offshore areas on the western end (Figure 1). The fishery is effort controlled, with restrictions on the number of licences, number of traps per licence (250), season length, minimum legal size (MLS), and non-retention of berried females (Cook et al. unpublished report[1]; DFO 2011). The fishing season begins on the last Monday in November and goes until May 31. The landings in LFA 33 for the 2017-2018 fishing season were 8,229 mt (Table 1).

Table 1. Landings and number of licences for recent fishing seasons in LFA 33.

Season	Landings (mt)	Number of Licences
2013-2014	5,839	567
2014-2015	7,071	562
2015-2016	10,024	563
2016-2017	8,019	570
2017-2018	8,229	554

A spatial representation of Lobster landings by grid cell reported in the commercial logbooks is presented in Figure 2. The pattern indicates an increase in landings coming from offshore areas in recent years, especially near the boundary with LFA 40, which is closed to Lobster fishing.

[1] Cook, A.M., Hubley, P.B., Denton, C., and Howse, V. 2018 Framework Assessment of American Lobster (*Homarus americanus*) in LFA 27 - 33. Unpublished report.

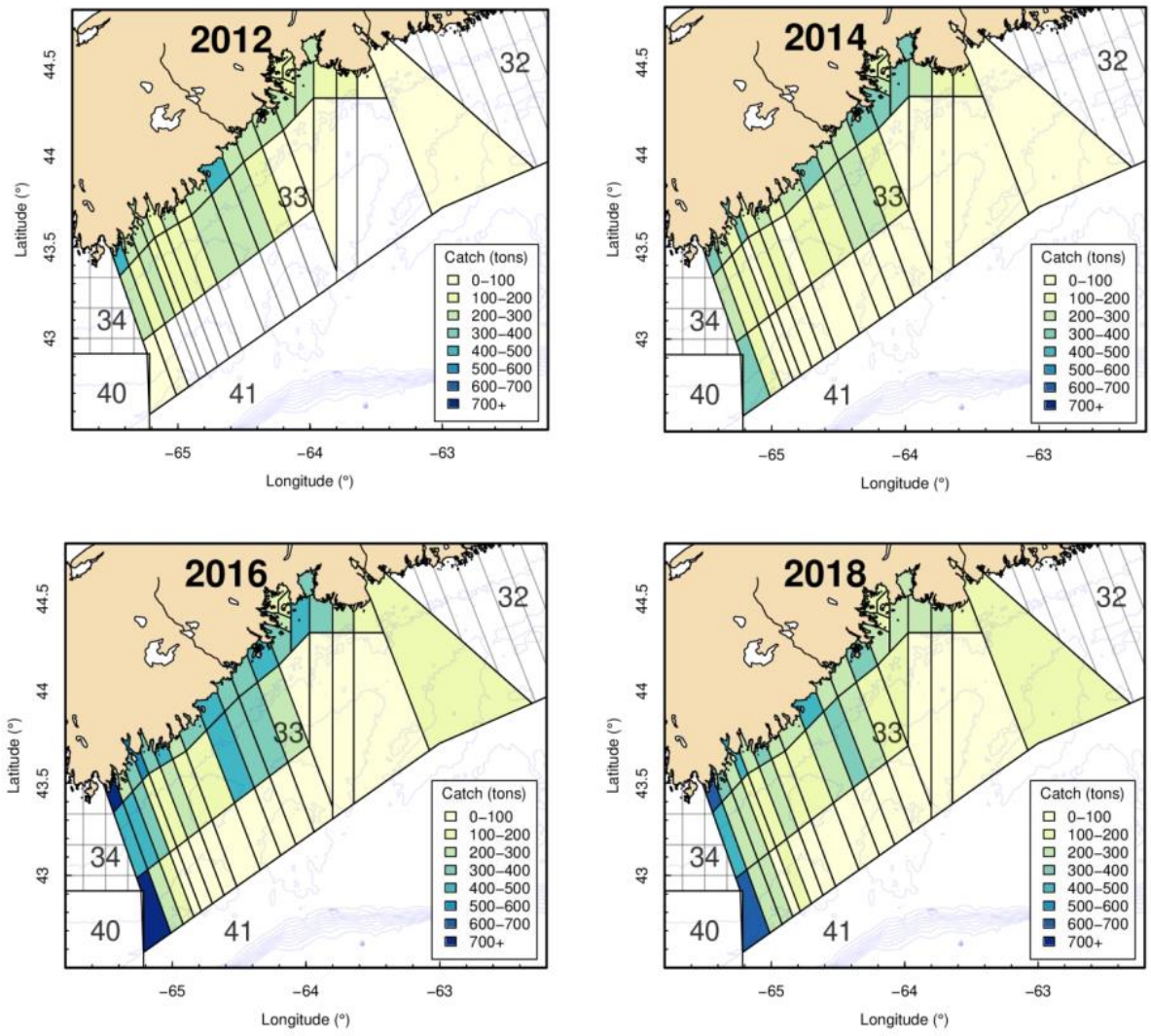


Figure 2. Map of the fishery footprint expressed as the amount of landings in each grid of LFA 33 for selected seasons between 2012-2018.

To date, there has been no analysis of sources of fishing mortality on Lobster within LFA 33 outside the Lobster fishery; however, given the absence of other major fisheries known to have Lobster bycatch in this area, it is not expected to be significant.

ASSESSMENT

Stock Status Indicators

This stock assessment follows the Framework Assessment of 2018 (Cook et al. unpublished report[1]), applying the methods and agreed-upon primary, secondary and contextual indicators from that work. Some indicators used here are directly linked to stock health and status (e.g. abundance), whereas others describe the population characteristics (e.g. size structure) or ecosystem considerations (e.g. temperature). These indicators provide a snapshot of the LFA

33 Lobster stock and ecosystem and are largely derived from fishery-dependent data. Although linkages to productivity may not be obvious, documenting the changes in the stock's characteristics and external factors over time may improve understanding of overall stock health and impact the advice provided to resource managers.

Primary indicators are used to define stock status in relation to the reference points, and secondary indicators are those in which time series trends are displayed but are not associated with reference points. The contextual indicators are displayed as part of a multivariate analysis to show the overall patterns over time.

The data sources available for constructing indicators for LFA 33 are mainly fishery-dependent. Commercial logbooks report information on date, location (grid), effort, and estimated catch. At-sea samples are collected during normal commercial fishing operations and provide information on bycatch and Lobster caught, including carapace size, sex, egg presence and stage; shell hardness; occurrence of culls and v-notches; and the number of traps, location and depth. The Fishermen and Scientist Research Society (FSRS) are contracted to conduct a recruitment trap project involving volunteer fishermen who keep track of Lobsters that are captured in standardized traps.

Primary Indicators

Primary indicators are the focus for defining stock status, by describing the time series trends relative to reference points. The primary indicator for describing stock status is the unmodelled commercial Catch Per Unit Effort (CPUE). Exploitation estimated using the Continuous Change in Ratio (CCIR) method from FSRS data is used as the primary indicator of fishing pressure that is independent of landings reported in the logs.

Catch Per Unit Effort

The time series of commercial catch rates is made up of two data sources. The first was the voluntary log books, which began in the 1980s and continued until 2013 in LFA 33. Mandatory logs have been in place in LFA 33 since the mid-2000s and provide a more complete data set with which to evaluate changes in catch rates (Tremblay et al. 2012). In years where both voluntary and mandatory logs were available, the magnitude and trends over time were similar (Tremblay et al. 2013), so both logbook types were included together. In the current analysis, we will treat these two commercial catch rates series as a single continuous time series beginning in 1990 when there was increased participation in the voluntary logbook program.

The combined catch rate data series from 1990-2016 was used to define the Upper Stock Reference (USR) and Limit Reference Point (LRP). This period was chosen as it represents both low and high productivity time periods and covers approximately 2 generations, as was used in the previous framework (Tremblay et al. 2013) and in the Quebec Region LFAs (Gendron and Savard 2012). The median of this time series was used as the proxy for Biomass at Maximum Sustainable Yield (B_{MSY}), 0.35 kg/trap haul (TH). Following the recommendations of DFO (2009), the USR and LRP were set to 80% and 40% of the B_{MSY} proxy. The value is used to compare the commercial catch rates to the USR and LRP is the 3-year running median, as this dampens the impact of any anomalous years which may occur due to factors outside of changes in abundance.

The trend in CPUE indicates that a significant increase in the stock biomass has occurred in the last ten years (Figure 3). For most of the time series, CPUE has fluctuated just above the USR, substantially increasing after 2008 to the point that it is currently more than triple the USR. The

3-year running median value for CPUE for the 2017/2018 season is 1.08 kg/TH, which is above the USR (0.28 kg/TH) and LRP (0.14 kg/TH).

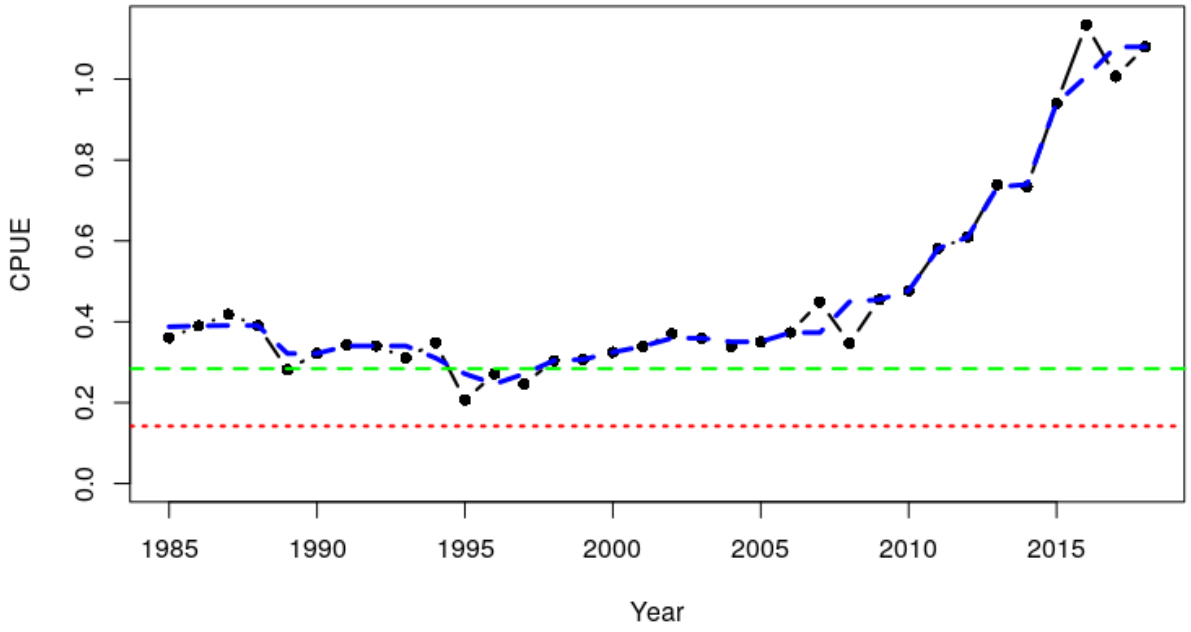


Figure 3. Time series of commercial catch rates (black), three-year running median (dashed blue) with upper stock (horizontal dashed green line) and limit reference (horizontal dotted red line) points.

Continuous Change in Ratio Exploitation Estimates

The Continuous Change in Ratio (CCIR) method is used as an indicator of fishing pressure. It is based on FSRS data and so reflects trends in exploitation in the inshore portion of the LFA, where the majority of the fishery occurs.

CCIR methods provide estimates of population parameters based on the changes in observed proportions of components within the population. Estimating exploitation using CCIR relies on defining and monitoring two (or more) components of the population, consisting of a reference (non-exploited) component and an exploited component. The premise of this method is the proportion of reference individuals within the population will increase with the cumulative removals from the exploitable component (Claytor and Allard 2003). The strength of this approach is that it does not rely directly on fishery dependant landings data and so the CPUE indicator and CCIR are based on independent time series.

The implicit assumptions of the CCIR include that, over the sampling period, 1) the population is closed, 2) the ratio of catchability of the two components is constant, 3) the ratio of the catchability of the monitoring traps and the commercial traps is constant, and 4) the monitoring effort is directly proportional to harvesting effort. The FSRS recruitment trap catch data provides the information on the changes in the pre-exploitable reference group (sub-legal size) relative to the exploitable group (legal size) needed to estimate exploitation. The Removal Reference (RR) was defined as the 75th quantile of the posterior distribution of the maximum modeled CCIR exploitation rate. Given that the regional Lobster stocks are currently in a highly productive state and population growth has not decreased under the range of estimated exploitation, it is

reasonable to assume the RR is less than the fishing mortality corresponding to maximum sustainable yield, F_{MSY}.

The time series of exploitation estimates is shown in Figure 4. For the first half of this time series, exploitation estimates were fairly high, just below the RR. Since 2013, exploitation has declined to about two-thirds of the level of the RR. In the last two years exploitation has increased but the running median remains near two-thirds of the RR. The 3-year running median value of CCIR exploitation for the 2017/2018 season is 0.56, which is below the RR (0.81).

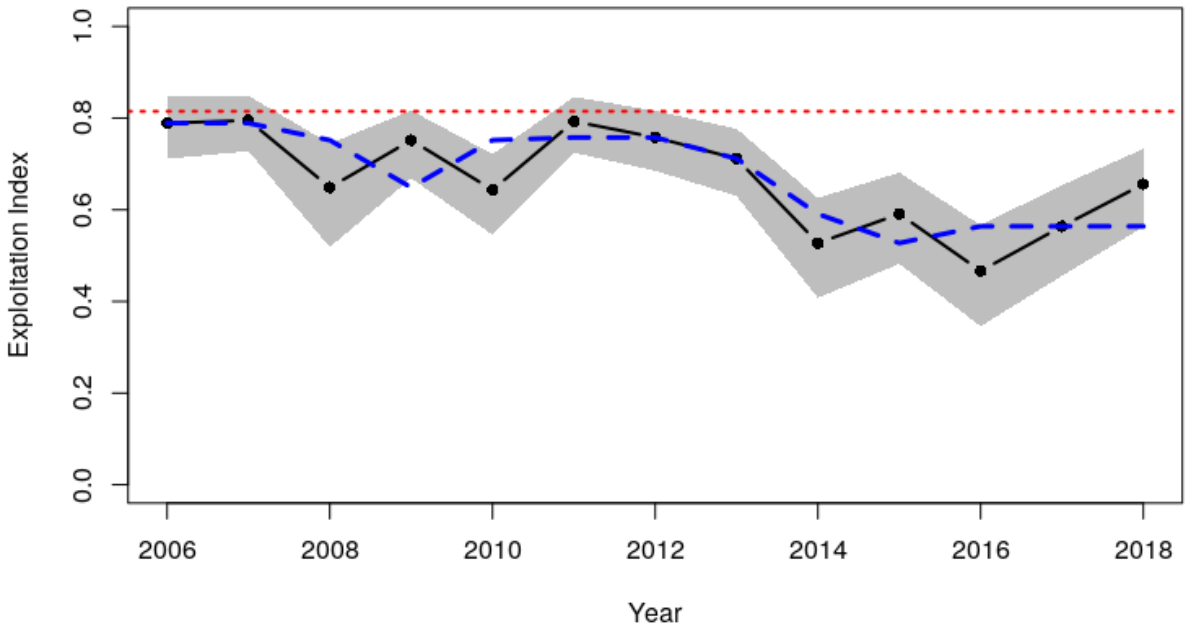


Figure 4. Time series of CCIR exploitation estimates (black long dash) with 95% credible intervals (grey shading), three year running median (short blue dash), and the removal reference (dotted red line).

Secondary Indicators

Secondary indicators represent important time series trends which that are tracked individually, but no reference points are defined. The secondary indicators for LFA 33 are landings and total effort (trap hauls), as well as FSRS recruitment trap legal and sub-legal catch rate series.

Landings and Effort

Levels of commercial landings are related to population abundance, as fishery controls are input-based (effort controls) rather than output-based (e.g. total allowable catch). Changes in levels of fishing effort, catchability (including the effects of environment, gear efficiency), Lobster size distribution, and the spatial overlap between distribution of Lobster and effort will impact landings, thereby weakening the relationship with abundance.

Fishing effort can be used as a proxy for fishing pressure. It is an important indicator for fisheries performance, as increases in landings may be due to increases in commercial sized biomass, or increased fishing effort, or both. Fishing effort, number of trap hauls, in the Lobster fishery is controlled by fishing season length, trap limits and limited number of fishing licenses. Consequently, there is a maximum fishing effort that can be deployed. This maximum is never

met as factors such as weather conditions, seasonally variable catch rates, and fishing partnerships all limit the total number of trap hauls.

Generally, the trend in landings is similar to the trend in the primary indicator, CPUE, as effort has remained fairly consistent over the time series (Figure 5). There has been a significant increase in landings over the last ten years that corresponds with an increase in CPUE. There are some annual fluctuations in effort, with a slight increasing trend over time.

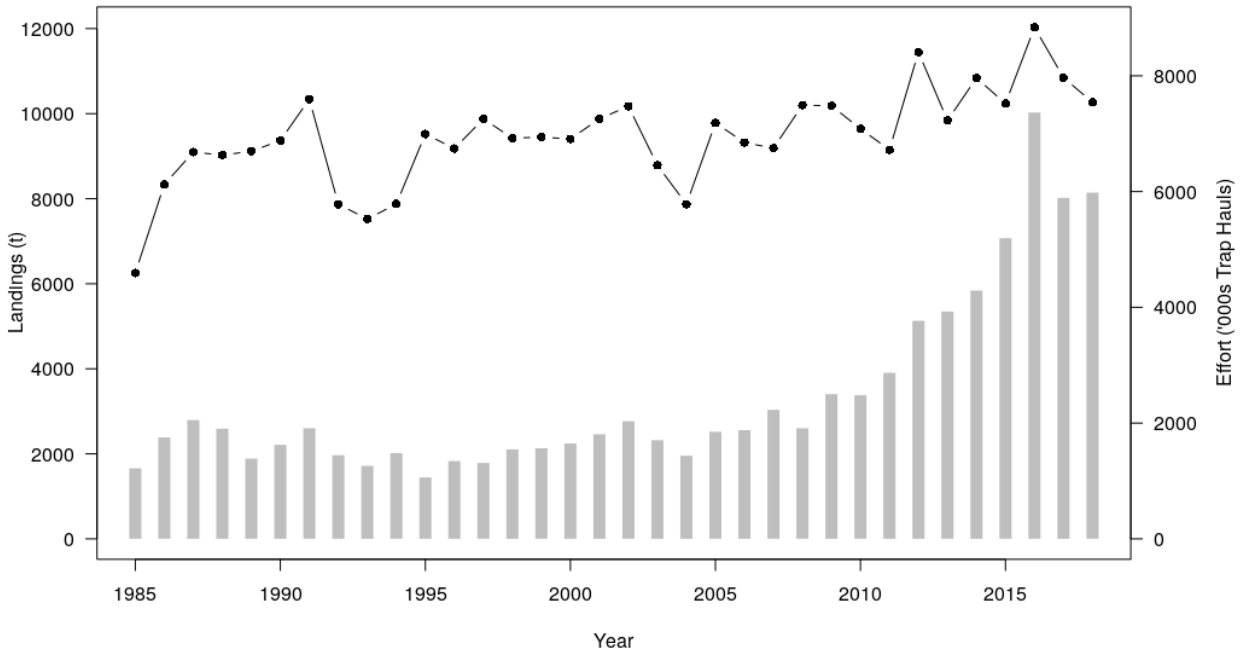


Figure 5. Time series of landings (bars), and effort (sold line with points).

FSRS Recruitment Trap Legal and Sub-legal Catch Rates

The FSRS recruitment trap survey provides the best information on the abundance of under-sized Lobsters. It is also the only data on abundance for LFA 33 that is collected in a standardized manner. The catches of legal (≥82.5 mm) and sub-legal size (70-82.5 mm) were modelled with a Bayesian approach in order to characterize the credible intervals of the predicted time series used as the indicator. The numbers of legal and sub-legal size Lobsters were assumed to follow a negative binomial distribution with the log number of traps used as an offset. For sub-legal size classes, the predictors included temperature, the number of legal-size Lobsters caught, and year. For legal-sized Lobsters, the predictors were temperature, the day of the season, and year. All of these effects were significant. Temperature is assumed to affect catch rates of all Lobsters, while larger Lobsters (legal size) are assumed to reduce entrance of smaller Lobsters (sub-legals) into traps. The resultant models were used to predict the number of Lobsters (for each size class) per trap for each year at a common temperature, date, and number of legal Lobsters per trap.

The results from the FSRS recruitment trap models showing the median number of legal and sub-legal size Lobsters per trap with their 95% credible intervals are presented in Figure 6. Both legal and sub-legal size classes show a gradual increasing trend, which is not as dramatic as the increase in landings and CPUE over the last ten years. It is important to note, however, that

FSRS recruitment traps are mainly located close to shore, where smaller Lobsters are more often present, and do not cover the whole range where Lobster are fished in LFA 33.

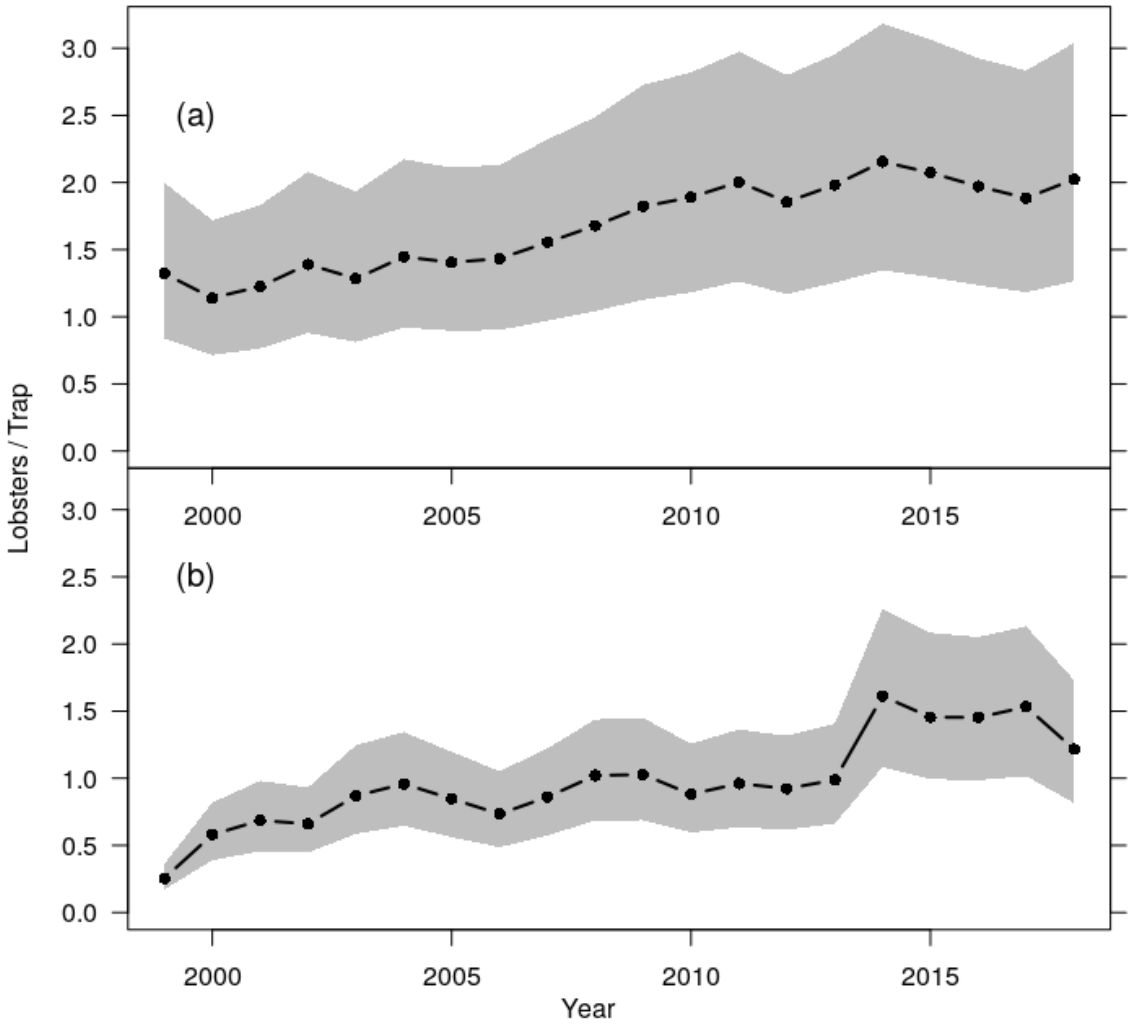


Figure 6. Time series of FSRS recruitment trap catch rates (black), with 95% credible intervals (grey shading) from modelled results for (a) legal (≥82.5 mm) sized and (b) sub-legal (70 mm to 82.5 mm) Lobsters.

Contextual Indicators

The contextual indicators that are provided describe not only the biological processes that influence production but ecosystem and fishery performance indicators as well. They include: berried female indices, new recruit indices, size based indices (maximum CL, median CL), idealized reproductive potential, biomass of recruits, proportion of new recruits, proportion mature, and bottom temperature. Contextual indicators were assessed using a multivariate analysis that shows patterns and how they change over time (Figures 7 and 8). Indicators described throughout this section were made directly comparable through statistical standardization (z-scores) after log transformations to normalize the appropriate indicators (e.g. abundance or biomass) and evaluated with a principal component analysis (PCA). A description of the indicators presented in Figure 7 is provided in the appendix.

The first two principal component axes describe 27% and 12% of the variance in the 24 indicators used in this analysis. The trend in component 1 increased through the mid-late 1980s, declined and stayed stable between 1995 until 2005, when it began to increase and currently remains high (Figure 7). Indicators of biomass, landings, abundance, commercial catch rates, FSRS recruitment, legal and sub-legal, and short (<70 mm CL) catch rates, and reproductive potential comprise the increasing trends in component 1 (Figure 8), while exploitation estimated through CCIR has declined. In recent years, the proportion of mature Lobster in the landings and the maximum size have also declined. None of these contextual indicators change our perception of stock status.

Conservation measures implemented in LFA 33 included the increase in MLS from 81 to 82.5 mm in 1998, with the increase in productivity beginning to occur in approximately 2005, as a result of increased recruitment during that time.

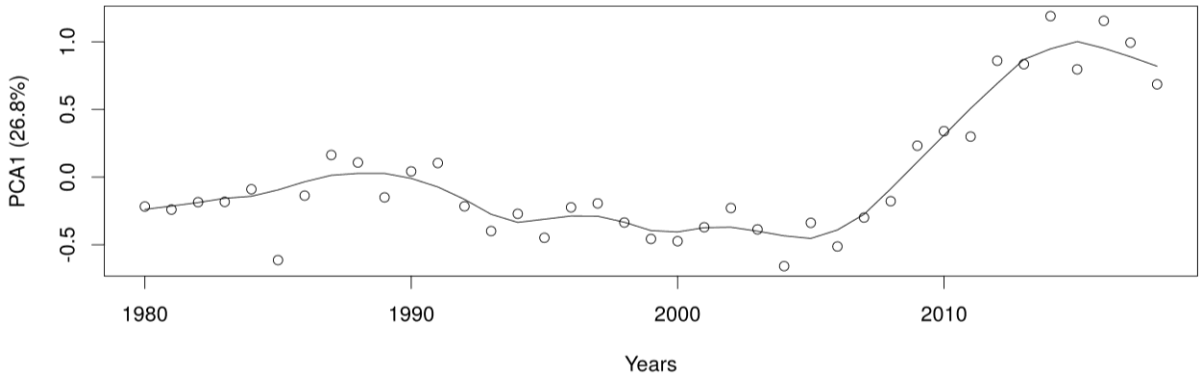


Figure 7. Time series of the first principal component of a multivariate ordination of indicators representing the Lobster stock and fishery in LFA 33. Solid line represents a loess smooth.

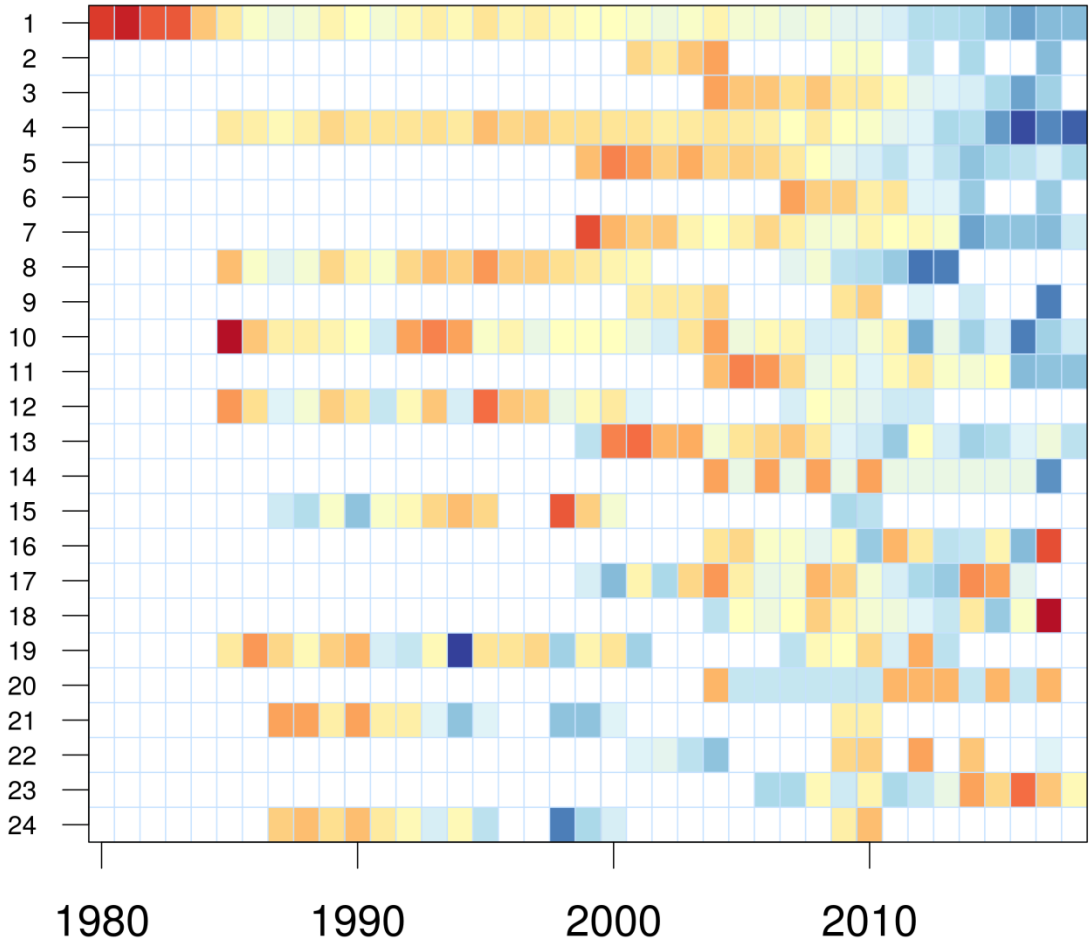


Figure 8. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 33 (see Table 2 for description of variables). Blue indicates levels above the mean, whereas red indicates levels below the mean and yellow indicates levels near the mean. White blocks indicate <20 observations were available for that indicator and time period.

Table 2. Description of biological and ecosystem indicators associated with LFA 33 ranked by loading in PCA 1.

Rank	Variable	PCA1	PCA2	Description
1	Landings Wt	1.02	-0.14	Landings (in metric tonnes)
2	At Sea Landed Abund	1	0.25	The total numbers of legal sized Lobsters landed in the fishery using the size frequency information from the at sea samples
3	FSRS Comm Landed Abund	0.99	0.29	The total numbers of legal sized Lobsters landed in the fishery using the size frequency information from the FSRS recruitment trap samples
4	CPUE	0.98	-0.17	Commercial catch rates

Rank	Variable	PCA1	PCA2	Description
5	FSRS Sub-legal CPUE	0.93	0.01	Catch rates of sub-legal sized Lobsters from FSRS recruitment traps
6	BiomassRecruits	0.91	0.15	Biomass of new recruits to the fishery estimated from total landings and exploitation rates of new recruits (CCIR)
7	FSRS Legal CPUE	0.9	-0.22	Catch rates of legal sized Lobsters from FSRS recruitment traps
8	Port Landed Abund	0.87	-0.11	The total numbers of legal sized Lobsters landed in the fishery using the size frequency information from port samples
9	At Sea Reprod Pot	0.81	-0.75	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives and length frequency information from at sea samples
10	Effort	0.73	-0.01	Total effort (trap hauls)
11	FSRS Rec Prop Berried	0.69	0.37	The proportion of berried females from FSRS recruitment trap samples
12	Port Reprod Pot	0.62	-0.09	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives and length frequency information from port samples
13	FSRS Shorts CPUE	0.59	0.13	Catch rates of short sized Lobsters from FSRS recruitment traps (<70 mm CL)
14	FSRS Comm Median CL	0.59	-0.72	Median carapace length from FSRS commercial trap samples
15	Port Prop New Rec	0.16	-1.15	The proportion of Lobsters that are newly recruited (MLS:MLS+11 mm) in the port samples
16	FSRS Comm Prop Berried	0.04	0.85	The proportion of berried females from FSRS commercial trap samples
17	Temperature	-0.03	0.11	Bottom temperature from FSRS traps
18	FSRS Comm Prop New Rec	-0.16	0.63	The proportion of Lobsters that are newly recruited (MLS:MLS+11 mm) in the FSRS recruitment trap samples
19	Port Prop Mature	-0.23	-0.19	The proportion of Lobster samples there were mature from port samples
20	FSRS Comm Max CL	-0.3	0.31	Maximum (upper 95% CL) size of Lobsters observed in FSRS commercial trap samples
21	Port Median CL	-0.39	0.17	Median carapace length from port samples
22	At Sea Prop Mature	-0.46	-0.59	The proportion of Lobster samples there were mature from at sea samples
23	Exploitation CCIR	-0.64	-0.38	Continuous change in ratio exploitation rate
24	Port Max CL	-0.69	-0.8	Maximum (upper 95% CI) size of Lobsters observed in port samples

Ecosystem Considerations

Long-term increases in water temperature have been noted in other areas, which have likely resulted in increased moult frequency and growth rates (McMahan et al. 2016). Increased growth rates would allow for more rapid transition through the sensitive early life stages and perhaps increase survival rates and hence productivity. Increases in survival and productivity of Lobster stocks also likely occurred as many of the predatory groundfish stocks decreased in abundance during the 1980s through to the 1990s and remain at low levels (e.g. Atlantic cod, Mohn and Rowe 2012; Bundy et al. 2017). The decrease in groundfish stocks would reduce the predation pressure on small Lobster allowing for greater survival through early life stages, improved recruitment, and overall Lobster production, as has been suggested elsewhere (Boudreau and Worm 2010). More research on the impacts of climate change on Lobster in this area would be required to provide greater insight into this complex relationship.

There is currently no new information to inform estimates of bycatch of non-target species in this fishery.

Assessment Frequency and Interim Updates

It was agreed that the Lobster stock in LFA 33 would be assessed every five years, with interim Science Response reports conducted annually. The Science Response report will include updates to the primary and secondary indicators, and the status of the primary indicator in relation to the reference points. A framework or assessment can be triggered in an update year. An earlier stock assessment could be triggered if the stock status approached the Cautious Zone, or in response to an unforeseen change in stock characteristics that would significantly impact the understanding of stock status. A framework would be triggered if the current approach does not provide the required information to characterize the stock.

Sources of Uncertainty

In Lobster, catch rates are known to be influenced by environmental conditions (wind, temperature, moult stage, and reproductive state). Additionally, time series of catch rates can be influenced by either hyperstability or hyperdepletion, whereby catch rates change slower (or faster) than abundance changes (Hilborn and Walters 1992).

CONCLUSIONS AND ADVICE

The primary indicators show strong positive signals for this stock. The stock status indicator, CPUE, has increased dramatically in the last ten years. The primary indicator for exploitation, the CCIR models from the FSRS data, indicates a reduction of exploitation in the inshore areas where this data is available. It should be noted that fishing effort has moved to more offshore areas that were not previously heavily exploited and are not monitored for exploitation.

The conservation measures implemented in other LFAs since the late 1990s and early 2000s, including increasing MLS, protecting window-sized Lobster, returning large females, and v-notching programs, have increased reproductive potential and productivity in respective LFAs. The impacts of some conservation measures can be detected in some of the biological indicator trends (Cook et al. unpublished report[1]). These conservation measures protect the reproductive components of the stock and buffer the impacts of years with suboptimal environmental conditions for lobster production.

Precautionary approach reference points that were proposed at the January 2018 Framework Review are illustrated in Figure 9. The phase plot shows the relationship between commercial

catch rates and CCIR exploitation rate in relation to the reference points USR, LRP, and RR. The trend shows increasing catch rates and decreasing exploitation in recent years. The CPUE index is above the USR, suggesting the current status of LFA 33 is within the Healthy Zone, and exploitation is below the RR.

The removal reference is to be adjusted depending on the stock's abundance and its location in the three stock status zones. In the Cautious Zone, the adjustment of the removal reference does not have to follow a linear relationship, but a progressive reduction in removals is required.

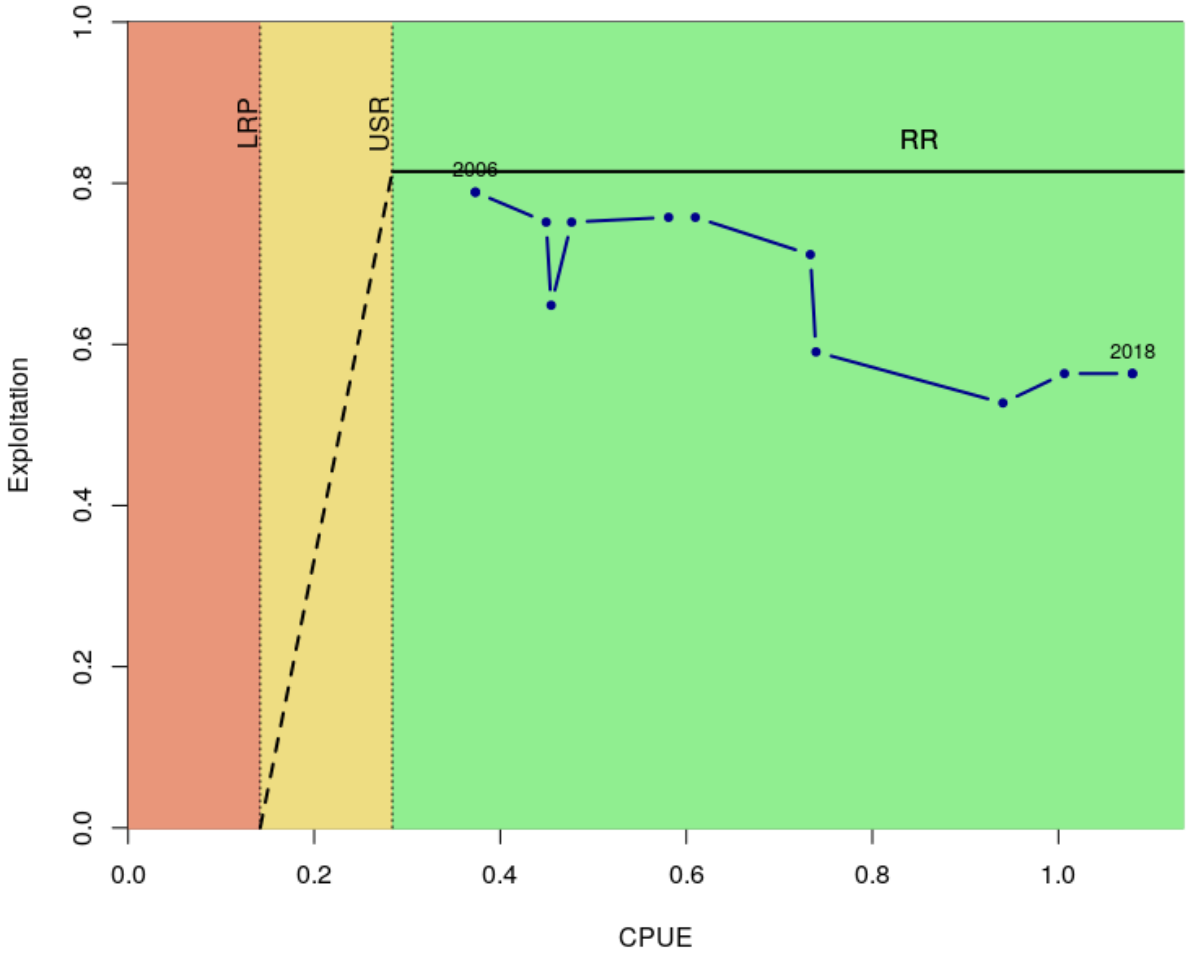


Figure 9. Phase plot using the-three year running median of CPUE and three-year running median of CCIR exploitation index compared against the proposed upper stock and limit reference points based on commercial catch rates. The removal reference is the 75th quantile break of the posterior distribution for the maximum exploitation index.

LIST OF MEETING PARTICIPANTS

Cassista-Da Ros, Manon	DFO Maritimes / Population Ecology Division
Cook, Adam	DFO Maritimes / Population Ecology Division
Ford, Jennifer	DFO Maritimes / Centre for Science Advice
Gray, Paddy	LFA 33 / Halifax West Commercial Fisherman's Assn.
Hubley, Brad	DFO Maritimes / Population Ecology Division
Irvine, Fonya	DFO Maritimes / Population Ecology Division
Kavanagh, Sana	Confederacy of Mainland Mi'kmaq
Lowe, Jonathan	Nova Scotia Dept. Fisheries & Aquaculture
McIntyre, Tara	DFO Maritimes / Population Ecology Division
Mitchell, Vanessa	Maritime Aboriginal Peoples Council
Quigley, Sara	DFO Maritimes / Resource Management
Spinney, Ashton	LFA 34 Advisory Committee
Worcester, Tana	DFO Maritimes / Centre for Science Advice

SOURCES OF INFORMATION

This Science Advisory Report is from the October 1, 2018, LFA 33 Lobster Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Aiken, D.E., and Waddy, S.L., 1980. Maturity and reproduction in the American Lobster. Can J. Fish. Aquat. Sci. 932:60–71.

Boudreau, S.A., and Worm, B. 2010. Top-down control of Lobster in the Gulf of Maine: insights from local ecological knowledge and research surveys. Mar Ecol. Prog. Ser. 403: 181-191.

Bundy A, Gomez, C., and Cook AM. 2017. Guidance Framework for the Selection and Evaluation of Ecological Indicators. Can. Tech. Rep. Fish. Aquat. Sci. 3232.

Claytor, R., and Allard, J. 2003. Change-in-ratio-Estimates of Lobster Exploitation Rate Using Sampling Concurrent with Fishing. Can. J. Fish. Aquat. Sci. 60(10): 1190-1203.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2011. Inshore Lobster Integrated Fishery Management Plan (Summary): Lobster Fishing Areas 27 -38 Scotia-Fundy Sector-Maritimes Region. http://waves-vagues.dfo-mpo.gc.ca/Library/40429064.pdf.

Gendron, L. and Savard, G. 2012. Lobster stock status in the coastal waters of Quebec (LFAs 15 to 22) in 2011 and determination of reference points for the implementation of a precautionary approach in the Magdalen Islands (LFA 22). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/010.

Hilborn, R. and Walters, C.J.1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall. New York. 570 p.

McMahan M.D., Cowan D.F., Chen Y., Sherwood G.D., and Grabowski J.H. 2016. Growth of juvenile American Lobster *Homarus americanus* in a changing environment. Mar. Ecol. Prog. Ser. Vol. 557: 177-187.

Mohn, R.K., and Rowe, S. 2012. Recovery Potential Assessment for the Laurentian South Designatable Unit of Atlantic Cod (*Gadus morhua*): The Eastern Scotian Shelf Cod Stock (NAFO Div. 4VsW). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/138.

Pezzack, D.S., and Duggan, D.R. 1989. Female size-maturity relationships for offshore Lobsters (*Homarus americanus*). Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 89/66: 9.

Pezzack, D.S., and Duggan, D.R. 1995. Offshore Lobster (*Homarus americanus*) trap-caught size frequencies and population size structure. ICES Mar. Sci. Symp. 199: 129-138.

Reeves, A., J. Choi, and J. Tremblay. 2011. Lobster size at maturity estimates in eastern Cape Breton, Nova Scotia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/079.

Tremblay, M.J., and Reeves, A. 2004. Eastern Cape Breton Lobster (LFAs 27-30): stock status and biological effects of the increase in minimum legal size. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/021.

Tremblay, M.J., Pezzak, D.S., and Gaudette, J. 2012. Development of reference points for inshore Lobster in the Maritimes region (LFAs 27-38). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/028.

Tremblay, M.J., Pezzack, D.S., Gaudette, J., Denton, C., Cassista- Da Ros, M. and Allard J.. 2013. Assessment of Lobster (*Homarus americanus*) off southwest Nova Scotia and in the Bay of Fundy (Lobster Fishing Areas 34-38). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/78.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Telephone: 902-426-7070
E-Mail: MaritimesRAP.XMAR@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2020. Assessment of Lobster (*Homarus americanus*) in Lobster Fishing Area 33 for 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/002.

Aussi disponible en français :

MPO. 2020. Évaluation du homard (Homarus americanus) dans la zone de pêche au homard 33 pour 2018. Secr. can. de consult. sci. du MPO, Avis sci. 2020/002.