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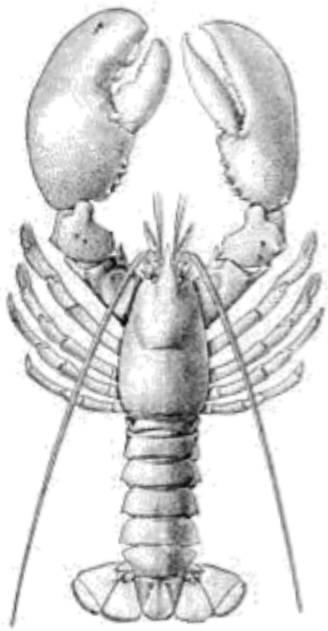
Canadian Science Advisory Secretariat
Maritimes Region **Science Advisory Report 2020/026**

ASSESSMENT OF AMERICAN LOBSTER (HOMARUS AMERICANUS) IN LOBSTER FISHING AREAS 27–32



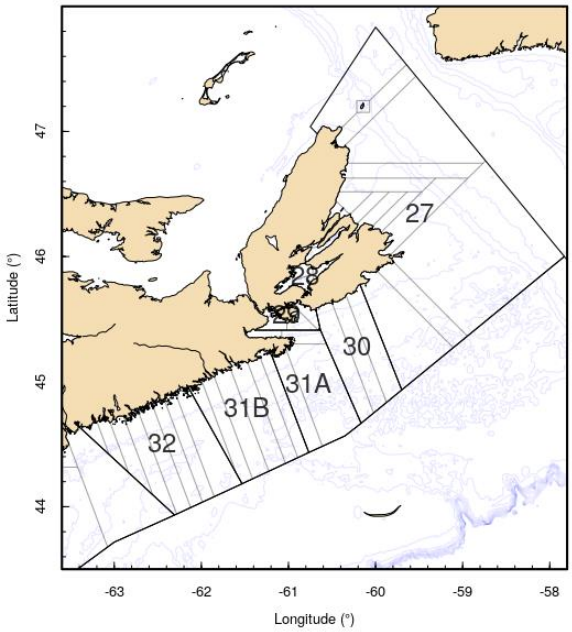


Figure 1. Map of Lobster Fishing Areas 27–32.

Context:

Lobsters (Homarus americanus) are found in coastal waters from southern Labrador to Maryland, with major fisheries in the Canadian Maritimes. Lobster Fishing Areas (LFAs) 27–32 stretch from the northern tip of Cape Breton Island to Hartland Point. Although the LFAs extend out to 92 km (50 nautical miles), colder water temperatures, with increasing depth, generally limit fishing to 5 km off shore in northern Cape Breton and to within 20 km from shore in the south.

The status of the Lobster stocks within LFAs 27–32 was last updated in 2018. A framework meeting was held from January 23–24, 2018, to establish the scientific basis for the provision of management advice for these stocks. This report applies the suite of indicators proposed during the 2018 Framework to assess the stock status up to the end of the 2018 season.

This Science Advisory Report is from the February 11–12, 2019, Stock Assessment for American Lobster in Lobster Fishing Areas 27–32. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Lobster Fishing Areas (LFAs) 27–32 are managed separately and several LFAs have unique conservation measures, which include Minimum Legal Size (MLS), trap limits,

maximum hoop sizes, maximum size or window sizes for landed females, and v-notching.

- A spatial representation of Lobster landings indicates a recent increase in landings in some of the more easterly grids, while landings in other regions have remained more stable.
- Primary indicators are used to define stock status in relation to reference points. The primary indicator for describing stock status is the commercial Catch Per Unit Effort (CPUE). Exploitation, estimated using the Continuous Change in Ratio (CCIR) method, will be used as an indicator of fishing pressure.
- Secondary indicators represent time series trends that are tracked individually, without defined reference points. The secondary indicators are landings and total effort, as well as the recruitment trap sub-legal and legal catch rate series.
- Contextual indicators describe the biological processes that influence production as well as ecosystem and fishery performance.
- The primary indicators show positive signals for all LFAs. The CPUE is at its highest level in the time series for six of the seven LFAs. The primary indicator for exploitation, the CCIR models, are annually variable; however, the 3-year running median indicates exploitation has been relatively stable in all LFAs, where data is available.
- The current status of the lobster stocks within each LFA is within the Healthy Zone and exploitation is below the Removal Reference (RR).
- Within each LFA, contextual indicators support the determination, based on the primary and secondary indicators, that the stock is healthy.
- Within each LFA, the trend in landings is similar to the trend in CPUE as effort has remained fairly consistent in recent years.

LFA 27

- The trend in CPUE indicates that an increase in stock biomass occurred over a period when the MLS increased from 70 mm to 82.5 mm. The 3-year running median for CPUE for the 2018 season is 1.08 kg/trap haul (TH), which is above the Upper Stock Reference (USR, 0.27 kg/TH).
- The 3-year running median of CCIR exploitation for the 2018 season is 0.77, which is below the RR (0.84).
- The trend in the sub-legal size classes is similar to the trend in CPUE, with the largest increases in 2013, 2017, and 2018.

LFA 28

- The CPUE in LFA 28 for 2018 was 0.47 kg/TH, which is higher than the long-term mean of approximately 0.31 kg/TH and similar to the peaks observed in 2013–2015. The 3-year running median value for CPUE for the 2018 season is 0.35 kg/TH, which is above the USR (0.25 kg/TH).
- Despite the deceased effort in 2017 and 2018, landings increased relative to 2016, but remained lower than the highs in 2014 and 2015.

LFA 29

- The 3-year running median value for CPUE for the 2018 season is 1.57 kg/TH, which is above the USR (0.22 kg/TH).
- The 3-year running median value of CCIR exploitation for the 2018 season is 0.71, which is below the RR (0.94).
- The trend in the legal and sub-legal size classes is similar to the trend in CPUE and landings, with an increase from 2003–2009, declines until 2013, and increasing thereafter. In 2018, the estimates of catch rates for both legal and sub-legal lobsters are the highest in the time series.

LFA 30

- The 3-year running median value for CPUE for the 2018 season is 2.78 kg/TH, which is above the USR (0.56 kg/TH).
- The 3-year running median value of CCIR exploitation for the 2018 season is 0.41, which is below the RR (0.77).
- The trend in the legal size classes is similar to the trend in CPUE. While there tends to be fewer sub-legal lobsters captured in recruitment traps, the trend is still consistent with other indicators.

LFA 31A

- The 3-year running median value for CPUE for the 2018 season is 1.20 kg/TH, which is above the USR (0.31 kg/TH).
- The 3-year running median value of CCIR exploitation for the 2018 season is 0.70, which is below the RR (0.89).
- Catches of sub-legal size classes show a trend that is similar to the CPUE, but increases in sub-legal abundance are observed one year before they are observed in the commercial fishery, indicating that in this LFA the recruitment traps are a good indicator of recruitment.

LFA 31B

- The 3-year running median value for CPUE for the 2018 season is 1.28 kg/TH, which is above the USR (0.32 kg/TH).
- The 3-year running median value of CCIR exploitation for the 2018 season is 0.76, which is below the RR (0.82).
- The trend in the legal and sub-legal size classes is similar to the trend in CPUE and landings.

LFA 32

- The 3-year running median value for CPUE for the 2018 season 0.80 kg/TH, which is above the USR (0.29 kg/TH).
- The 3-year running median value of CCIR exploitation for the 2018 season is 0.74, which is below the RR (0.84).

- The trend in the legal and sub-legal size classes is similar to the trend in CPUE and landings.

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 1 moult per year at approximately 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 (SoM) (Cook et al. 2020). In Lobster Fishing Areas (LFAs) 27–32, the average SoM has been estimated to range from 73–90 mm (Cook et al. 2020; Reeves et al. 2011). The SoM increases from east to west, with LFA 27 having a lower SoM than LFA 32. In LFAs 27–32, the Minimum Legal Size (MLS) is usually above the SoM, indicating a high proportion of females have had the opportunity to breed prior to being caught in the fishery. This is in contrast to other inshore fisheries in the Bay of Fundy and Southwestern Nova Scotia where the median CL in the catch is below SoM, and a smaller proportion of females have had the opportunity to breed.

Very large lobsters have a greater relative fecundity and are thus an important component to conservation. Management planning has looked at maintaining high reproductive potential by preserving a size structure dominated by mature animals, which has been a key component of past stock assessments (Pezzack and Duggan 1989, Pezzack and Duggan 1995).

Fishery

The commercial fishery for American Lobster has been active for over 100 years in LFAs 27–32. These areas cumulatively cover 62,800 km^2 from Cape Breton to Hartland Point, and the fishery occurs primarily within 15 km (shore to 100 m depth contour = 13,600 km^2) from the shore, though the LFAs extend out to 92 km (50 nautical miles) (Figure 1). The fishery is effort controlled, with restrictions on the number of licences, number of traps per license (250 in LFA 28–32 or 275 in LFA 27), MLS (82.5 mm in LFA 27, 30–32 and 84 mm in LFAs 28 and 29), and non-retention of berried females (Cook et al. 2020). The LFAs 27–32 are managed separately and several LFAs have unique conservation measures, which include differences in MLS and trap limits, maximum hoop sizes, maximum size or window sizes for landed females, and v-notching (Table 1). The landings in LFAs 27–32 for the last 5 fishing seasons are presented in Table 2.

Table 1. Lobster Fishing Area (LFA) specific conservation measures and season dates.

LFA	Season	Total No. of licences	Trap Limit[1]	MLS (mm)	Other Measures
27	May 15–July 15	515[2]	275	82.5	N/A
28	April 30–June 30	14	250	84	Max. hoop size - 153 mm
29	April 30–June 30	63	250	84	Max. hoop size - 153 mm
30	May 19–July 20	20	250	82.5	Max. carapace length - 135 mm for females
31A	April 29–June 30	71	250	82.5	Closed window, 114-124 mm for females
31B	April 19–June 20	70	250	82.5	V-notching and release of 110 lb of mature females/licence
32	April 19–June 20	157	250	82.5	V-notching and release of 110 lb of mature females/licence

[1] Trap limit is for category "A" licence holder. Part-time or category "B" licences are allowed 30% and Partnerships 150% the limit of a single full-time licence.
[2]480 licences within Maritimes Region and 35 licences in the Gulf Region
N/A- not applicable

Table 2. Landings (tonnes) for recent fishing seasons in Lobster Fishing Areas (LFAs) 27–32.

Season	LFA 27	LFA 28	LFA 29	LFA 30	LFA 31A	LFA 31B	LFA 32
2014	3844	16	768	455	806	1148	1239
2015	3807	16	722	424	754	1036	1087
2016	3875	9	791	417	724	1069	1289
2017	5444	10	874	577	841	1214	1231
2018[1]	4414	11	983	571	873	1150	966

[1]Not all logs were submitted when this report was produced. The estimated percent of outstanding logs for 2018 as of Feb 1, 2019 are: LFA 27 (23%), LFA 28 (73%), LFA 29 (24%), LFA 30 (5%), LFA 31A (16%), LFA 31B (6%), and LFA32 (19%). Gulf landings are not included.

A spatial representation of Lobster landings by grid cell reported in the commercial logbooks is presented in Figure 2. These maps indicate a recent increase in landings in some of the more easterly grids, while landings in other regions have remained more stable.

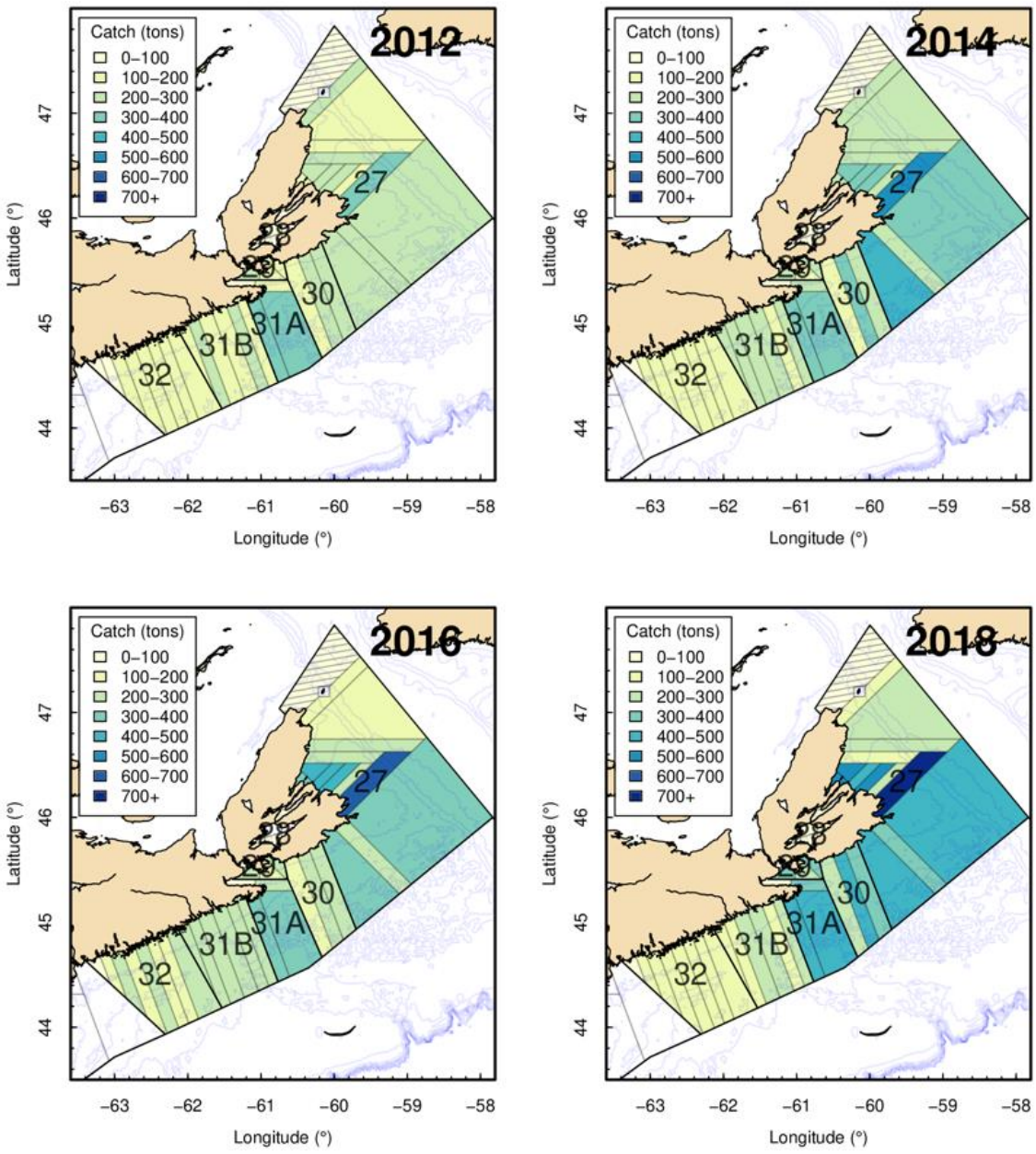


Figure 2. Map of the fishery footprint expressed as the amount of landings in each grid cell of LFAs 27–32 from 2012, 2014, 2016, and 2018 seasons. Landings reported in Gulf Region, which come primarily from grid cell 361 (score lines), are not included.

ASSESSMENT

Stock Status Indicators

This stock assessment applies the methods and primary, secondary and contextual indicators presented at the 2018 Framework Assessment (Cook et al. 2020). 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 LFAs 27–32 Lobster stocks and the ecosystem.

Primary indicators are used to define stock status in relation to reference points defined in Cook et al. (2020). Secondary indicators are those in which time series trends are displayed but do not have 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 establishing indicators for LFAs 27–32 are primarily fishery dependent. Commercial logbooks report information on date, location (grid), effort, and estimated catch. At-sea samples are collected during commercial fishing operations and provide information on lobsters caught, including carapace length, sex, egg presence, egg stage, shell hardness, culls, and v-notches, and the number of traps, location, and depth. The Fishermen and Scientists Research Society (FSRS) are contracted to conduct a recruitment trap project involving volunteer fishermen who record lobsters that are captured in standardized traps that are designed to retain both legal- and sub-legal-sized lobsters.

Primary Indicators

In LFAs 27–32, there are two primary indicators, one for stock status and one for estimating exploitation, which describe the time series trends relative to reference points. The primary indicator for describing stock status is the commercial Catch Per Unit Effort (CPUE). An exploitation index estimated from the Continuous Change in Ratio (CCIR) method is used as an indicator of fishing pressure.

Catch Per Unit Effort

In LFAs 27–32, the time series of commercial catch rates are comprised of two data sources: (1) voluntary logbooks, which began in the 1980s and continued until 2013, and (2) mandatory log books, which have been in place since the mid-2000s and provide a more complete data set to evaluate changes in catch rates (Tremblay et al. 2012). In years where both voluntary and mandatory logbooks 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, these two commercial catch rate series are treated 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 represents both low and high productivity time periods and covers approximately 2 generations; it was used to define reference points 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 the biomass at maximum sustainable yield (B_{MSY}). Following the recommendations of DFO (2009), the USR and LRP were set to 80% and 40% of the B_{MSY} proxy. The 3-year running median is used to compare the commercial catch rates to the USR and LRP. This value will dampen the impact of any anomalous years, which may occur due to factors outside of changes in abundance.

Continuous Change In Ratio

The CCIR method is used as an indicator of fishing pressure. It is based on recruitment trap data and reflects trends in exploitation in the inshore portion of the LFAs, where the majority of the fishery occurs. It provides indices of exploitation by modelling the change in proportion of two monitored 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). This approach does not rely directly on fishery dependant landings data and, thus, the CPUE indicator and CCIR are based on independent time series.

The implicit assumptions of the CCIR over the sampling period include: 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. These assumptions have been tested in previous assessments (Tremblay et al. 2012; Cook et al. 2020) and are considered valid for the data set and regions used in this assessment. The recruitment trap catch data provides information on changes in the pre-exploitable reference group (sub-legal-sized) to the exploitable group (legal-sized), which are needed to estimate exploitation. The Removal Reference (RR) was defined as slightly higher than the maximum modelled CCIR exploitation rate, specifically, the 75th quantile of the posterior distribution. Since 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 assumed that the RR is less than the level of fishing mortality associated with maximum sustainable yield (F_{MSY}).

Secondary Indicators

Secondary indicators represent time series trends that are tracked individually, without defined reference points. The secondary indicators for LFAs 27–32 are landings and total effort, as well as FSRS recruitment trap sub-legal and legal catch rate series.

Landings and Effort

Levels of commercial landings are related to population abundance as fishery controls are input (effort controls) rather than output-based (total allowable catch). There are many factors that can affect this relationship, including 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.

Fishing effort can be used as a proxy for fishing pressure. It is an indicator for fisheries performance as changes in landings can be due to changes in commercial sized biomass or fishing effort or both. Fishing effort, recorded as the number of Trap Hauls (THs), 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; however, this maximum is never met as factors such as weather conditions, seasonally variable catch rates, and fishing partnerships limit the total number of THs. Presently, total fishing effort is calculated from mandatory logbooks, but prior to their widespread adoption effort was calculated from CPUE and total catch.

Recruitment Trap Legal and Sub-legal Catch Rates

The FSRS recruitment trap survey provides the best available information on the abundance of sub-legal-sized lobsters. It is also the only abundance data for LFAs 27–32 that is collected in a

standardized manner. The catches of legal- (≥82.5 mm)[1] and sub-legal-sized (70 mm–82.5 mm) Lobsters were modelled with a Bayesian approach to characterize the credible intervals of the predicted time series that is used as the indicator. The numbers of legal- and sub-legal-sized lobsters were assumed to follow a negative binomial distribution with the log number of traps used as an offset. For sub-legal-sized lobsters, catch rate predictors included temperature, the number of legal-sized lobsters caught, and year as a factor. For legal-sized lobsters, the predictors were temperature, the day of the season, and year as a factor. All of these effects were significant. Bottom temperature is assumed to affect catch rates of all lobsters. Larger lobsters (legal-sized) are assumed to reduce the entrance of smaller lobsters (sub-legal-sized) 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-sized lobsters per trap.

Contextual Indicators

Contextual indicators describe the biological processes that influence production as well as ecosystem and fishery performance, and include berried female indices, new recruit indices, size based indices (maximum and median CL), idealized reproductive potential, biomass recruits, proportion of new recruits, proportion mature, and bottom temperature. Contextual indicators were assessed using a multivariate analysis that shows patterns and changes over time. 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). There were no trend analyses conducted as part of this multivariate analysis; this exercise is largely a visualization tool.

Lobster Fishing Area 27

Catch Per Unit Effort

The trend in CPUE indicates that a large increase in stock biomass occurred in the last six years (Figure 3). The CPUE time series had been increasing steadily since 1997, when it was near the LRP. In 2002, the CPUE surpassed the USR and continued to rise steadily until 2013, where it increased substantially and is currently more than triple the USR. The increase in catch rates occurred over a period where the MLS was steadily increased from 70 mm to 82.5 mm. The 3-year running median for CPUE for the 2018 season is 1.08 kg/TH, which is above the USR (0.27 kg/TH) and LRP (0.14 kg/TH).

[1] In LFAs 28 and 29, the minimum legal size for lobsters is 84 mm.

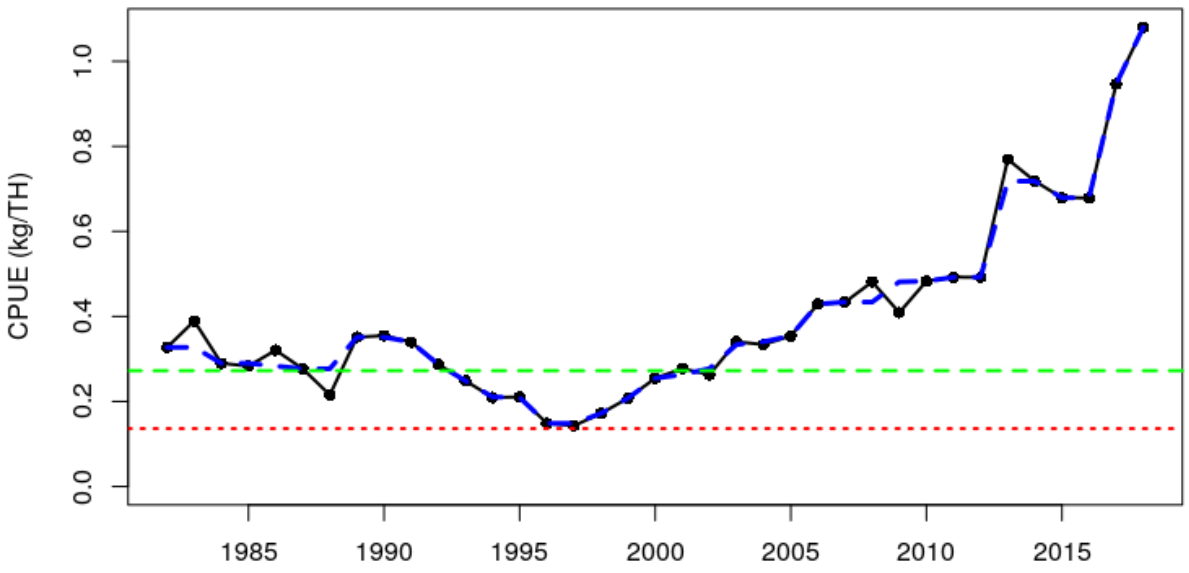


Figure 3. Time series of commercial catch rates (black line) for LFA 27, along with the 3-year running median (dashed blue line). The horizontal lines represent the upper stock (dashed green line) and limit reference point (dotted red line).

Continuous Change In Ratio

The time series of exploitation estimates is shown in Figure 4. Exploitation estimates were stable for most of the time series, just below the Removal Reference (RR). Two years (2011 and 2012) saw a slight decrease in exploitation to 0.70 but it has since increased and remained stable at approximately 0.77. The 3-year running median value of CCIR exploitation for the 2018 season is 0.77, which is below the RR (0.84).

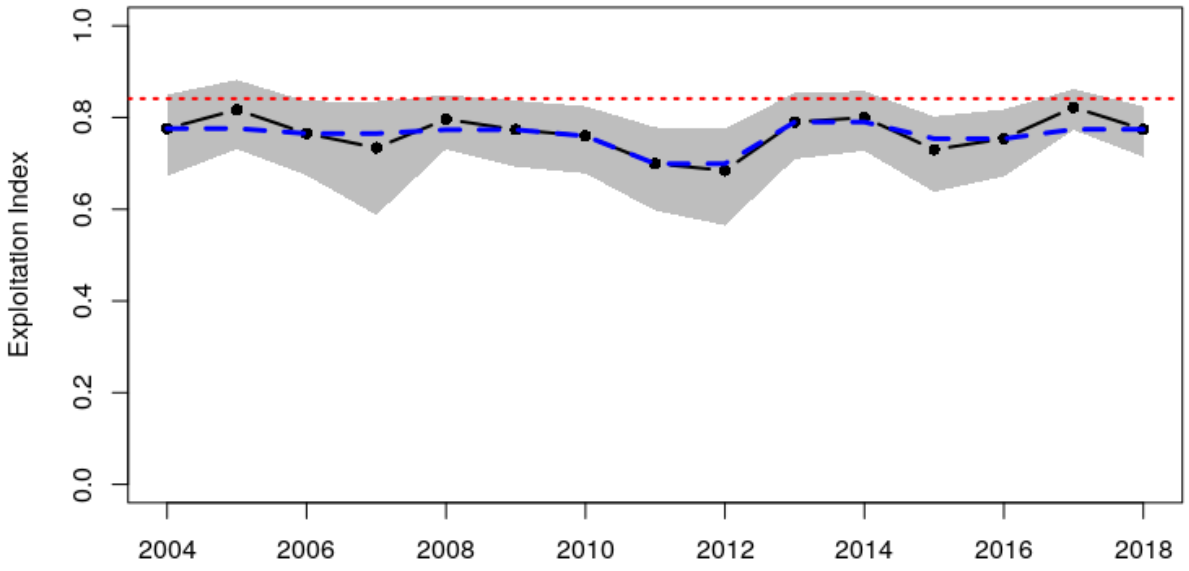


Figure 4. Time series of CCIR exploitation estimates (black line) for LFA 27, with 95% credible intervals (grey shading), three-year running median (dashed blue line), and the removal reference (dotted red line).

Landings and Effort

Generally, the trend in landings is similar to the trend in the primary indicator CPUE, as effort has remained consistent since the early 2000s (Figure 5). Landings from 2013–2016 were high and similar to a previous peak in 1990. Landings in 2017 were the highest on record at 5,444 t. Landings and effort data for 2018 are incomplete due to outstanding logbooks (23%) but will increase to levels that are (at a minimum) the second highest on record.

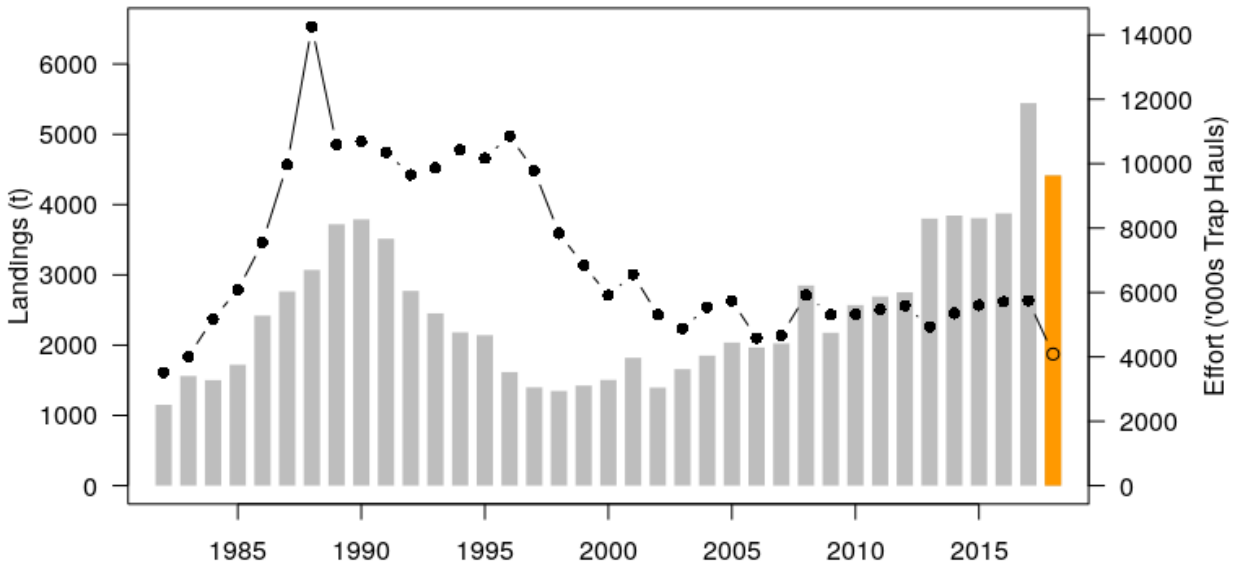


Figure 5. Time series of landings in tonnes (bars), and effort (sold line with points) for LFA 27. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

The results from the FSRS recruitment trap models, showing the median number of sub-legal and legal size lobsters per trap including the 95% credible intervals, are presented in Figure 6. The trend in the sub-legal size classes is similar to the trend in CPUE with the largest increases in 2013, 2017, and 2018. The location of recruitment traps spatially overlaps with fishing activity close to shore, where most of the fishery occurs. Catches of legal size lobsters are less variable over time and show an increase in 2018.

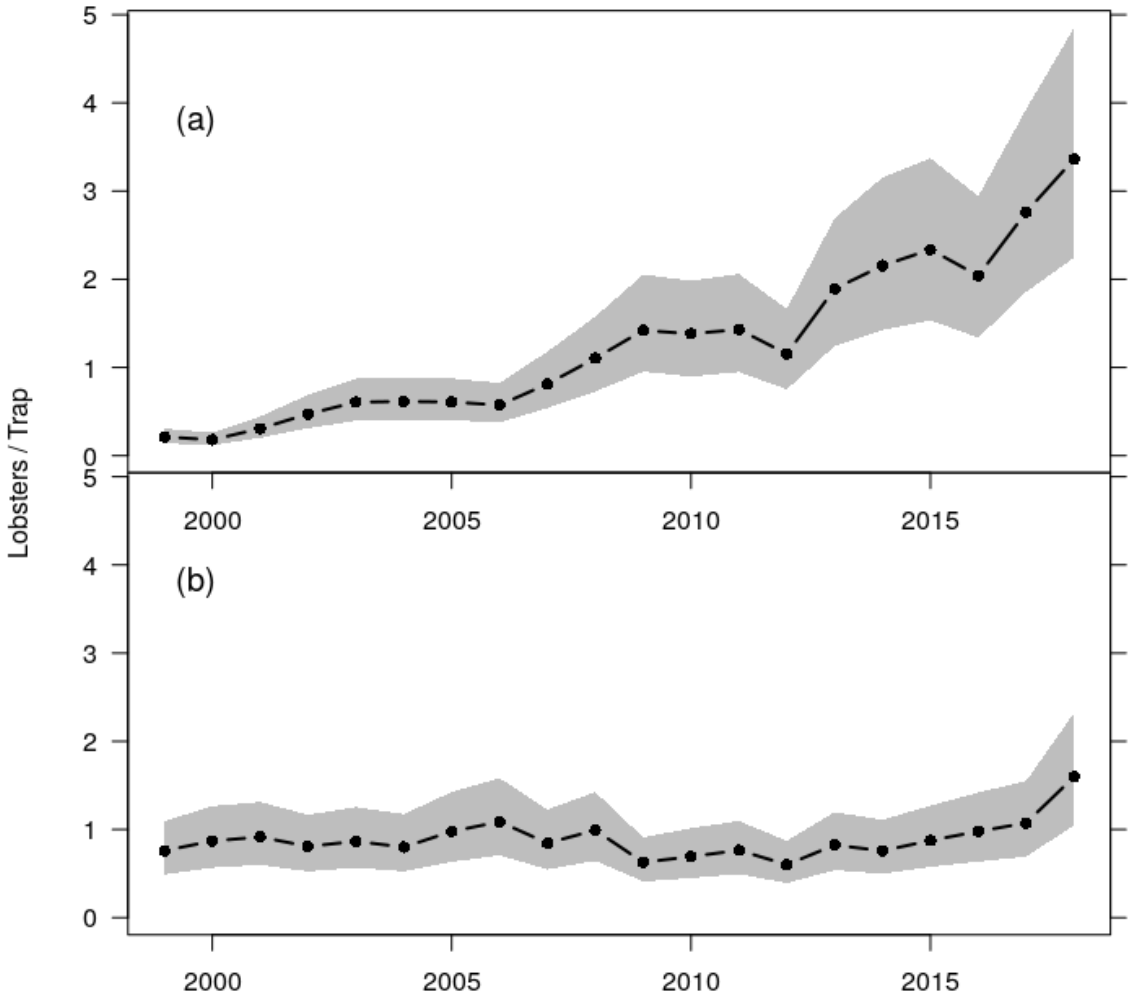


Figure 6. Time series of FSRS recruitment trap catch rates (black line), with 95% credible intervals (grey shading) from modelled results for (a) sub-legal (70 mm to <82.5 mm) and (b) legal (≥82.5 mm) sized lobsters in LFA 27.

Contextual Indicators

The first two principal component axes describe 31% and 18% of the variance in the 23 indicators used in this analysis. The trend in component 1 increased through the 1990s, then steadily declined since 2000 (Figure 7). Indicators of biomass, landings, abundance, commercial catch rates, FSRS sub-legal, legal, and short catch rates, and reproductive potential have all increased and comprise the decreasing trends in component 1 (Figure 7). Effort, which was high in the 1990s, was largely responsible for the increasing trend in component 1 during that time. Additionally, the proportion of berried females was low in the mid-1990s, when MLS was 70 mm. Since the increase in MLS in 2015 to 82.5 mm, the proportion of berried females remains high, which is an indicator of overall reproductive potential. These contextual indicators support the determination, based on the primary and secondary indicators, that the stock is healthy.

Incremental increases in MLS within LFA 27, from 70 mm in 1997 to 82.5 mm in 2015 (Cook et al. 2020), corresponded with an increase in the median and maximum size, the reproductive potential (both direct and indirect), and the overall abundance. Although current landings are

similar to the highs in the late 1980s, fewer lobsters are being removed per year and lobsters in LFA 27 are producing more eggs, which should make the population more resilient to environmental and anthropogenic disturbances.

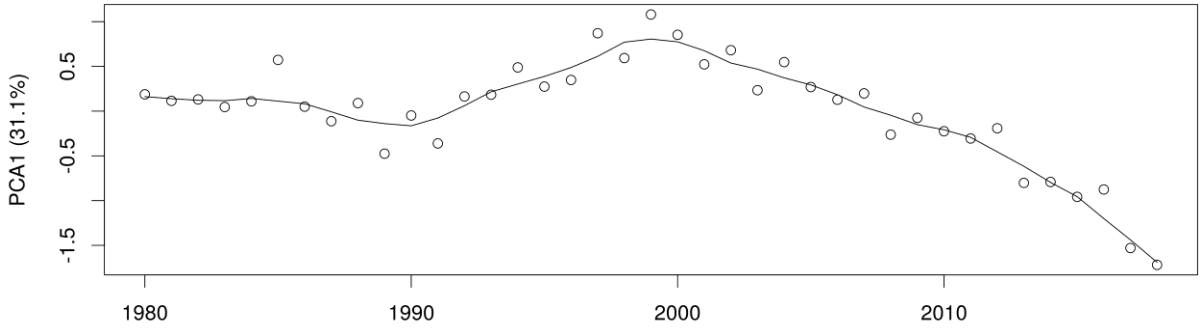


Figure 7. Time series of the first principal component of a multivariate ordination of indicators representing the lobster stock and fishery in LFA 27.The solid line represents a loess smooth.

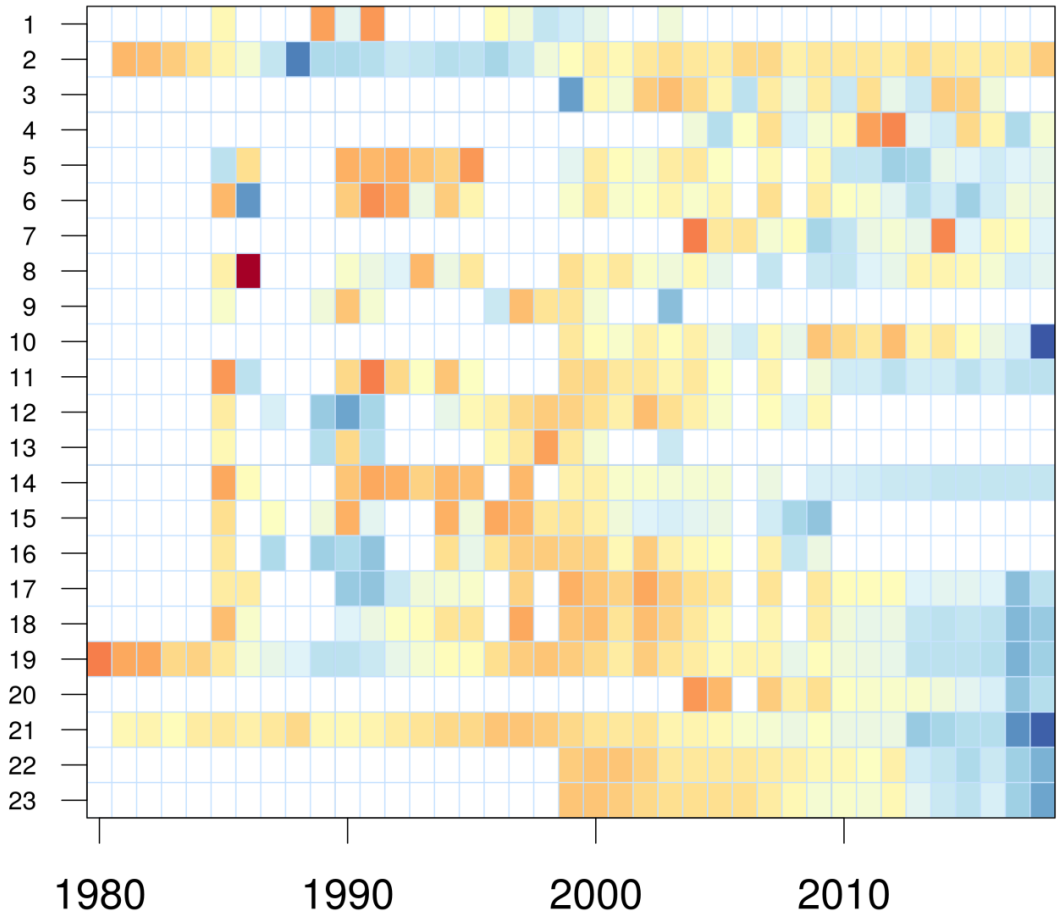


Figure 8. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 27. See Table 3 for description of variables. The blue blocks indicate levels above the mean, the red blocks indicate levels below the mean, and the yellow blocks indicate levels near the mean. White blocks indicate <20 observations were available for that indicator and time period.

Table 3. Description of biological and ecosystem indicators associated with LFA 27 ranked by loading in Principal Component Analysis (PCA)1.

Rank	Variable	PCA1	PCA2	Description
1	Port.Prop.NewRec	0.56	0.86	The proportion of newly recruited lobsters (MLS:MLS+11mm) in the port samples
2	Effort	0.28	-0.73	Total effort (trap hauls)
3	Temperature	0.24	0.24	Bottom temperature (˚C)
4	Exploitation CCIR	-0.15	-0.31	Continuous change in ratio exploitation rate
5	At.Sea.Prop.Berried	-0.27	0.79	The proportion of berried lobsters from the at-sea samples
6	At.Sea.Max.CL	-0.29	0.82	The maximum (upper 95% CI) size of lobster observed in an at-sea sample
7	FSRS.Rec.Prop.Berried	-0.29	0.18	The proportion of berried females from FSRS recruitment trap samples
8	At.Sea.Prop.NewRec	-0.34	-0.17	The proportion of newly recruited lobsters (MLS:MLS+11mm) in the at-sea samples
9	Port.Max.CL	-0.49	0.11	The maximum (upper 95% CI) size of lobsters observed in port samples
10	FSRS.Legal.CPUE	-0.57	-0.24	Catch rates of lobsters (>82.5 mm) from FSRS recruitment traps
11	At.Sea.Median.CL	-0.59	0.79	The median carapace length of at-sea sampled lobsters
12	Port.Landed.Abund	-0.6	-0.79	The total number of legal size lobsters landed in the fishery using the size frequency information from port samples
13	Port.Median.CL	-0.62	-0.42	Median carapace length from port samples
14	At.Sea.Prop.Mature	-0.64	0.81	The proportion of lobster samples that were mature from at-sea samples
15	Port.Prop.Mature	-0.69	0.29	The proportion of lobster samples that were mature from port samples
16	Port.Reprod.Pot	-0.71	-0.68	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from port samples
17	At.Sea.Landed.Abund.	-0.74	-0.45	The total number of legal size lobsters landed in the fishery using the size frequency information from the at-sea samples
18	At.Sea.Reprod.Pot	-0.89	-0.02	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from at-sea samples
19	Landings.Wt	-0.9	-0.25	Landings (in T)
20	BiomassRecruits	-0.93	0.25	Biomass of recruits estimated from total landings and exploitation rates of new recruits (CCIR)
21	CPUE	-0.94	0.17	Commercial catch rates
22	FSRS.Shorts.CPUE	-1.08	0.11	Catch rates of lobsters (<82.5 mm) from FSRS recruitment traps
23	FSRS.Sub-legal.CPUE	-1.11	0.11	Catch rates of lobsters (70–82.5 mm) from FSRS recruitment traps

Lobster Fishing Area 28

Catch Per Unit Effort

For 2018, the CPUE in LFA 28 was 0.47 kg/TH, which is higher than the long-term median of 0.31 kg/TH but similar to the peaks observed in 2013–2015 (Figure 9). The 3-year running median value for CPUE for the 2018 season is 0.35 kg/TH, which is above the USR (0.25 kg/TH) and LRP (0.12 kg/TH). Effort data was not available from 1996–2007.

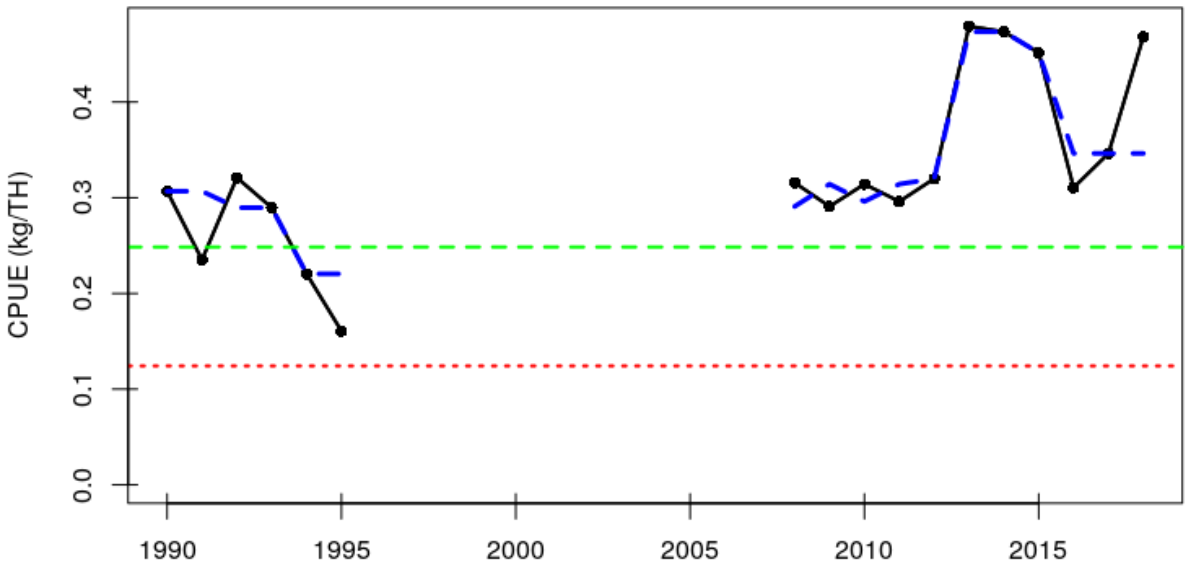


Figure 9. Time series of commercial catch rates (black line) for LFA 28, along with the 3-year running median (blue dashed line). The horizontal lines represent the upper stock (dashed green line) and limit reference (dotted red line) points.

Continuous Change In Ratio Exploitation Estimates

With little to no participation in the FSRS recruitment trap program, there was insufficient data to estimate exploitation rates within LFA 28 (Cook et al. 2020).

Landings and Effort

Effort has marginally declined in recent years while landings have fluctuated (Figure 10). Despite the deceased effort in 2017 and 2018, landings increased relative to 2016, but remained lower than the highs in 2014 and 2015.

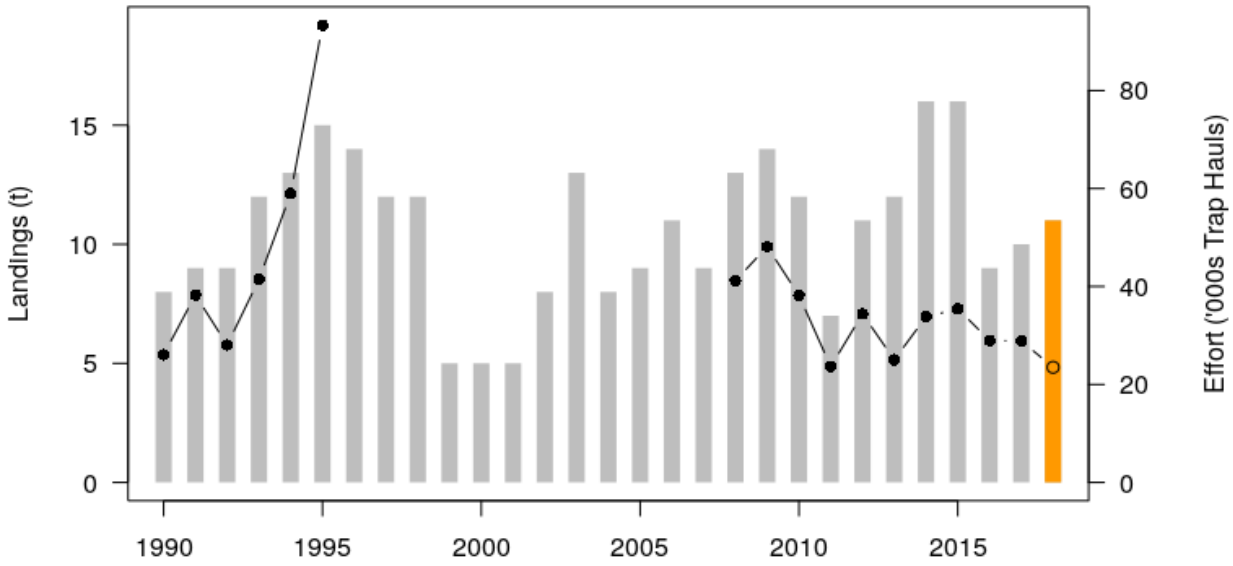


Figure 10. Time series of landings (bars) and effort (sold line with points) for LFA 28. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

With little to no participation in the FSRS recruitment trap program in LFA 28, there was insufficient data to estimate legal and sub-legal catch rates from recruitment traps.

Contextual Indicators

There were insufficient data to conduct an analysis of contextual indicators for LFA 28.

Lobster Fishing Area 29

Catch Per Unit Effort

The trend in CPUE for LFA 29 increased between 2002–2009, from 0.32 to 1.37 kg/TH, then declined to approximately 1.00 kg/TH from 2011–2016, and has increased in the last two years to the highest in the time series at 1.57 kg/TH (Figure 11). The 3-year running median value for CPUE for the 2018 season is 1.57 kg/TH, which is above the USR (0.22 kg/TH) and LRP (0.11 kg/TH).

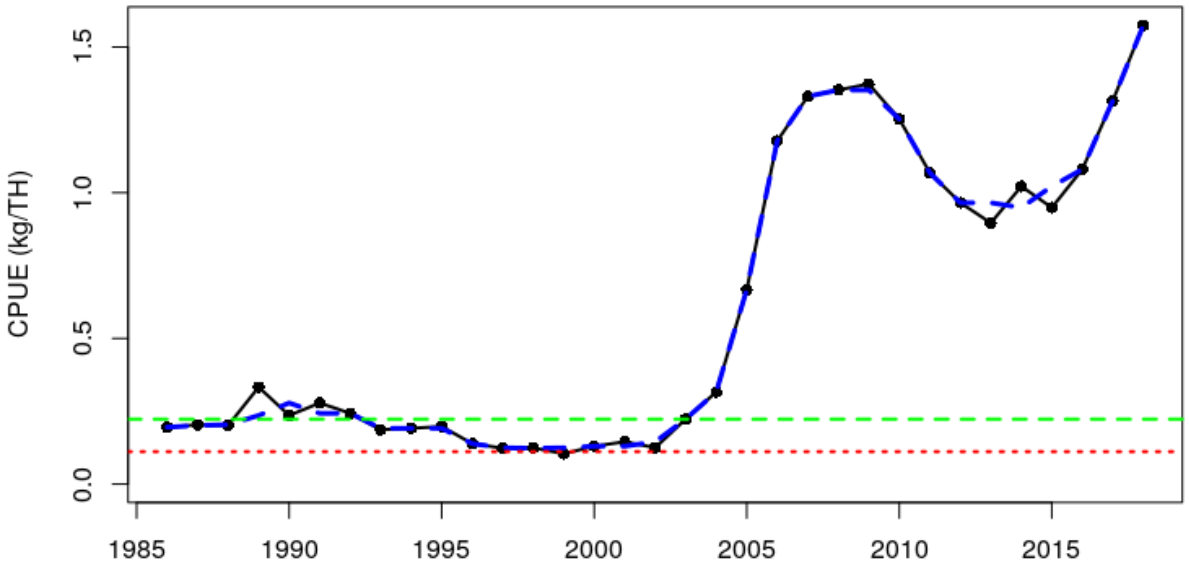


Figure 11. Time series of commercial catch rates (black line) for LFA 29, along with the three-year running median (dashed blue line). The horizontal lines represent the upper stock reference point (dashed green line) and limit reference point (dotted red line).

Continuous Change In Ratio

The time series of exploitation estimates for LFA 29 is shown in Figure 12. Exploitation estimates for LFA 29 fluctuate throughout the time series, ranging from a high of 0.79 at the beginning of the time series to a low of 0.49 between 2009–2012. Currently, the 3-year running median value of CCIR exploitation for the 2018 season is 0.71, which is below the RR (0.94).

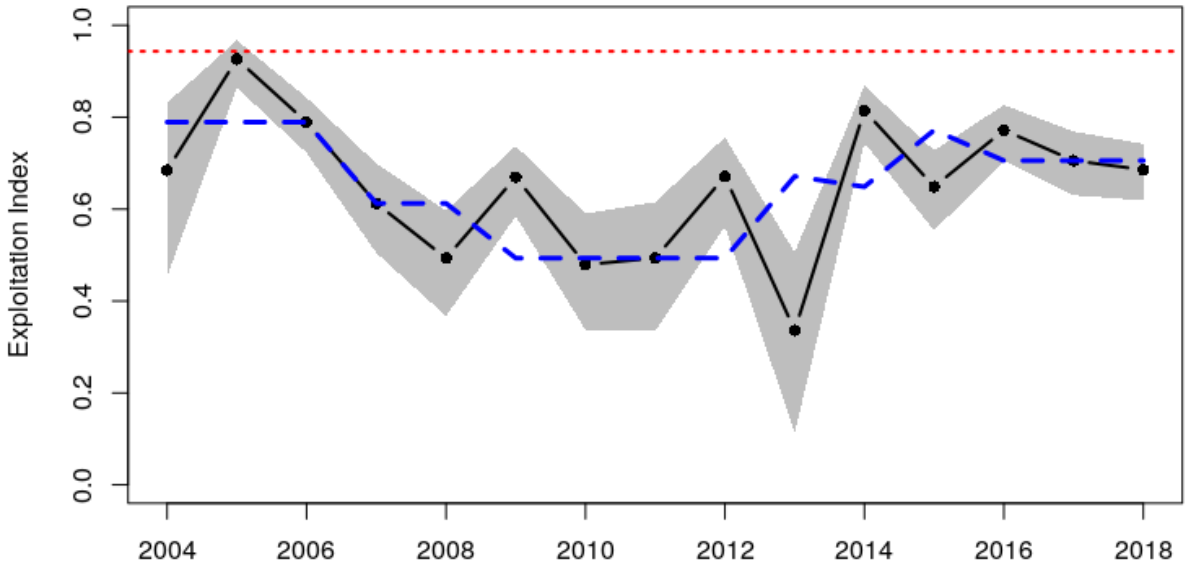


Figure 12. Time series of CCIR exploitation estimates (black line) for LFA 29, with 95% credible intervals (grey shading), three-year running median (dashed blue line), and the removal reference (dotted red line).

Landings and Effort

Generally, the trend in landings is similar to the trend in the primary indicator CPUE, with increases between 2003–2009, declines until 2013, and increases thereafter (Figure 13). There had been an increase in effort from 1997 to 2008 after a decrease that occurred from the highest levels of effort observed in 1987.

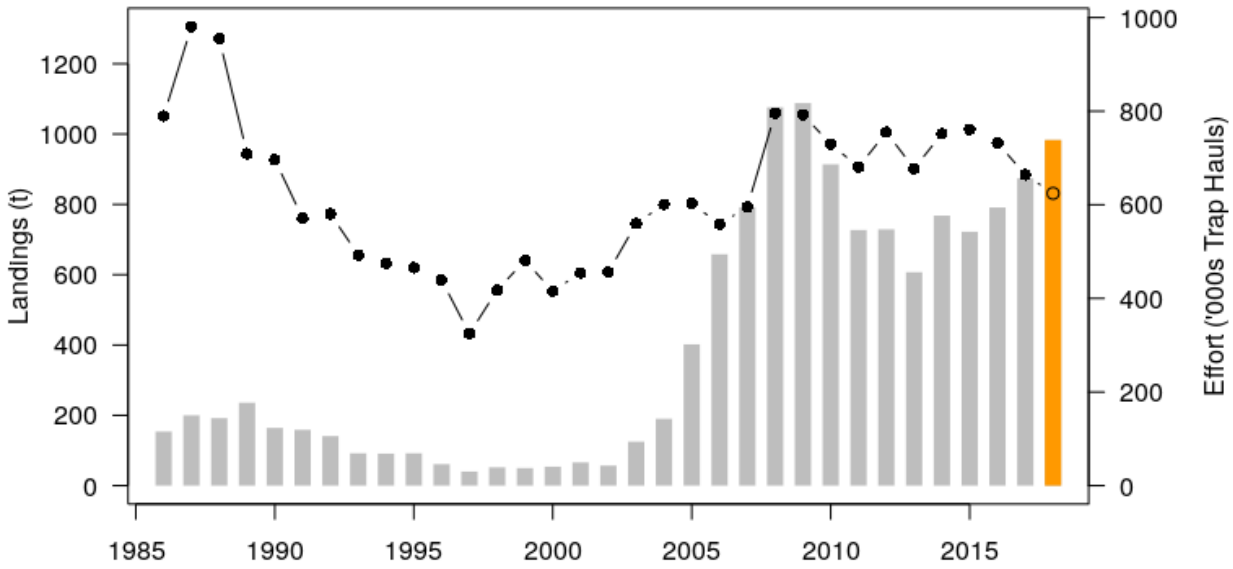


Figure 13. Time series of landings (bars) and effort (sold line with points) for LFA 29. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

The results from the FSRS recruitment trap models, showing the median number of sub-legal and legal size lobsters per trap including the 95% credible intervals, are presented in Figure 14. The trend in the legal and sub-legal size classes is similar to the trend in CPUE and landings, with an increase from 2004–2007, a decline from 2010–2012, and increase thereafter. In 2018, the estimates of catch rates for both legal and sub-legal size lobsters are the highest in the time series. The trend in legal size lobster also appears to lag the trend in sub-legal size lobsters, with increases in legal size lobsters observed in the recruitment traps a year after they are observed in the sub-legal size lobsters.

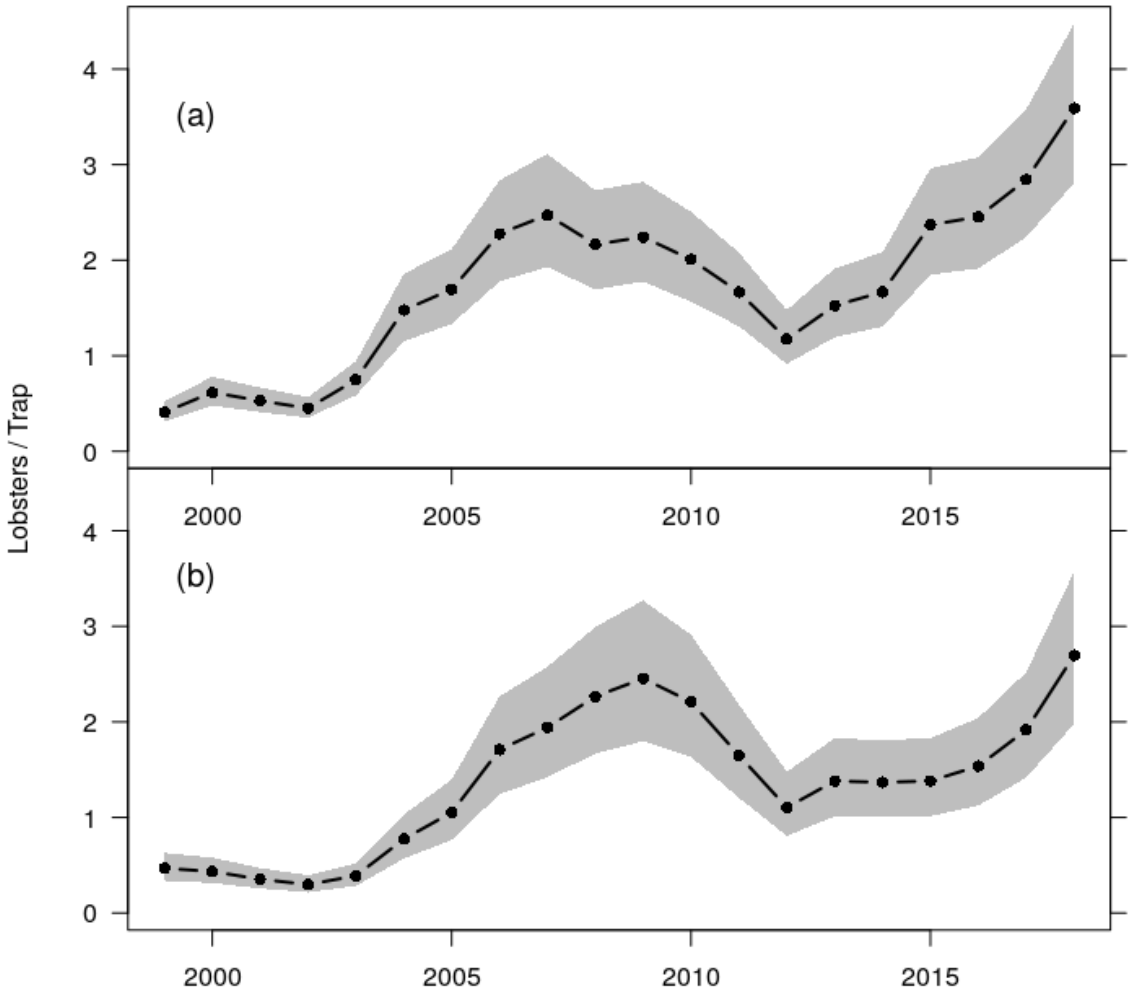


Figure 14. Time series of FSRS recruitment trap catch rates (black line), with 95% credible intervals (grey shading) from modelled results for (a) sub-legal (70 mm to <84 mm) and (b) legal (≥84 mm) sized lobsters in LFA 29.

Contextual Indicators

The first two principal component axes describe 35% and 17% of the variance in the 19 indicators used in this analysis. The time series trends of PCA1 increase through the late 1980s, decline up to 2000, and show an overall increase since that time (Figure 15). The indicators that were the major contributors to the first principal component were reproductive potential, landings, commercial catch rates, and the FSRS short, sub-legal, and legal catch rates (Figure 16). During the late 1990s, when landings and overall production fell, there were increases in the median and maximum size and proportion of mature lobsters in the catch. The increase since 2000 has been largely driven by the increase in productivity, viewed as the increases in landings, catch rates, and reproductive potential, measured as both the proportion of berried females and the size frequency data (Figure 16). During the same period, a decrease in CCIR exploitation was detected. The timing of the initiation of the increase in productivity corresponded to the implementation of additional conservation measures during 1998–1999. Specific measures in this LFA included increasing the MLS from 81 mm to 84 mm, introducing a maximum hoop size of 153 mm, and reducing the trap limit from 275 to 250 per license. These conservation measures had the goal of increasing the proportion of mature lobster in the fishery

(increasing MLS), protecting large lobsters (restricting hoop size) and reducing exploitation (trap limits), all of which contribute to increasing productivity.

These contextual indicators support the determination, based on the primary and secondary indicators, that the stock is healthy.

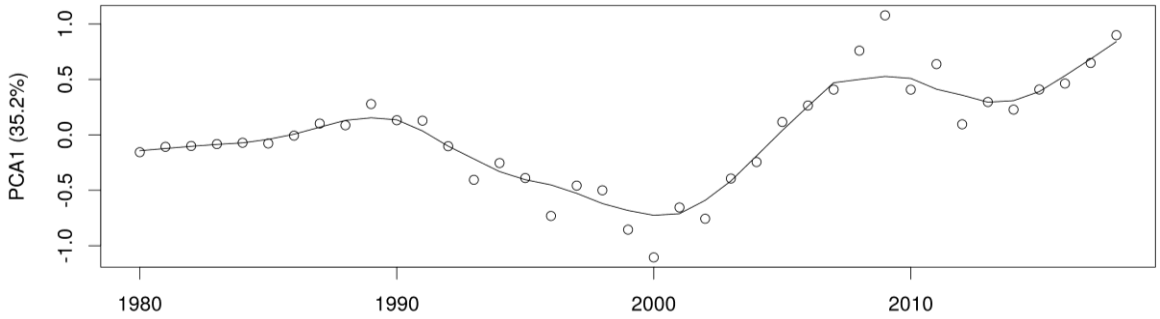


Figure 15. Time series of the first principal component of a multivariate ordination of indicators representing the lobster stock and fishery in LFA 29. The solid line represents a loess smooth.

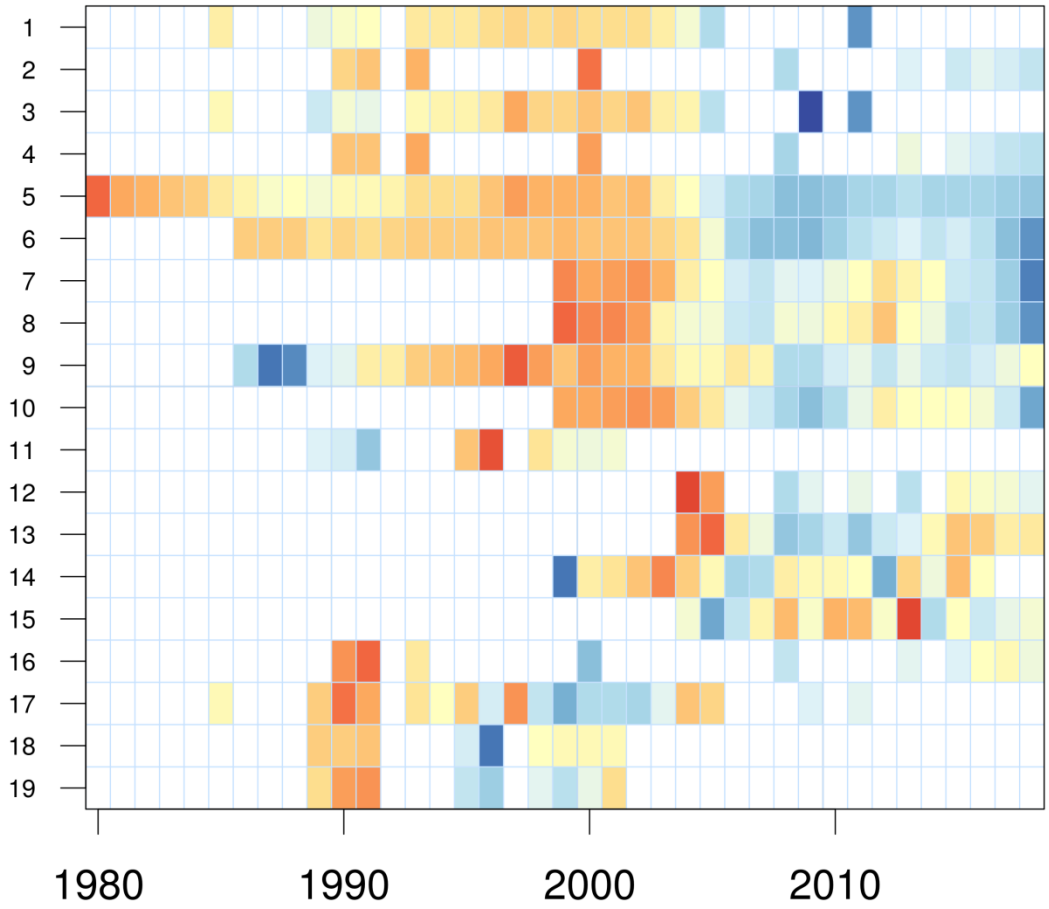


Figure 16. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 29. See Table 4 for description of variables. The blue blocks indicate levels above the mean, red blocks indicate levels below the mean, and yellow blocks indicate levels near the mean. White blocks indicate <20 observations were available for that indicator and time period.

Table 4. Description of biological and ecosystem indicators associated with LFA 29 ranked by loading in Principal Component Analysis (PCA) 1.

Rank	Variable	PCA1	PCA2	Description
1	Port.Landed.Abund	1.04	-0.21	The total number of legal size lobsters landed in the fishery using the size frequency information from port samples
2	At.Sea.Reprod.Pot	1.01	-0.01	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from at-sea samples
3	Port.Reprod.Pot	1.01	-0.24	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from port samples
4	At.Sea.Landed.Abund.	1	0.13	The total number of legal size lobsters landed in the fishery using the size frequency information from the at-sea samples
5	Landings.Wt	0.95	-0.31	Landings (in T)
6	CPUE	0.91	-0.35	Commercial catch rates
7	FSRS.Sub-legal.CPUE	0.89	0.19	Catch rates of lobsters (70–84 mm) from FSRS recruitment traps
8	FSRS.Shorts.CPUE	0.81	0.41	Catch rates of lobsters (<84 mm) from FSRS recruitment traps
9	Effort	0.79	-0.16	Total effort (trap hauls)
10	FSRS.Legal.CPUE	0.78	-0.39	Catch rates of lobsters (>84 mm) from FSRS recruitment traps
11	Port.Prop.NewRec	0.71	0.41	The proportion of newly recruited lobsters (MLS:MLS+11mm) in the port samples
12	BiomassRecruits	0.54	-0.91	Biomass of recruits estimated from total landings and exploitation rates of new recruits (CCIR)
13	FSRS.Rec.Prop.Berried	0.38	-0.93	The proportion of berried females from FSRS recruitment trap samples
14	Temperature	-0.06	-0.34	Bottom temperature (˚C)
15	ExploitationCCIR	-0.11	0.68	Continuous change in ratio exploitation rate
16	At.Sea.Prop.Mature	-0.44	-0.88	The proportion of lobster samples there were mature from at-sea samples
17	Port.Prop.Mature	-0.46	-0.97	The proportion of lobster samples there were mature from port samples
18	Port.Median.CL	-0.64	-0.36	Median carapace length from port samples
19	Port.Max.CL	-0.76	-0.57	Maximum (upper 95% CI) size of lobsters observed in port samples

Lobster Fishing Area 30

Catch Per Unit Effort

The trend in CPUE indicates that a large increase in the stock biomass began in 2005 (Figure 17). The CPUE time series was low between 1996 and 2005 when it began to increase up to 1.65 kg/TH in 2008, more than triple the USR. It has continued to remain high and has increased to a record high in 2018. The CPUE in LFA 30 is the highest of any LFA in the assessment; the 3-year running median value of CPUE for the 2018 season is 2.78 kg/TH, which is above the USR (0.56 kg/TH) and LRP (0.28 kg/TH).

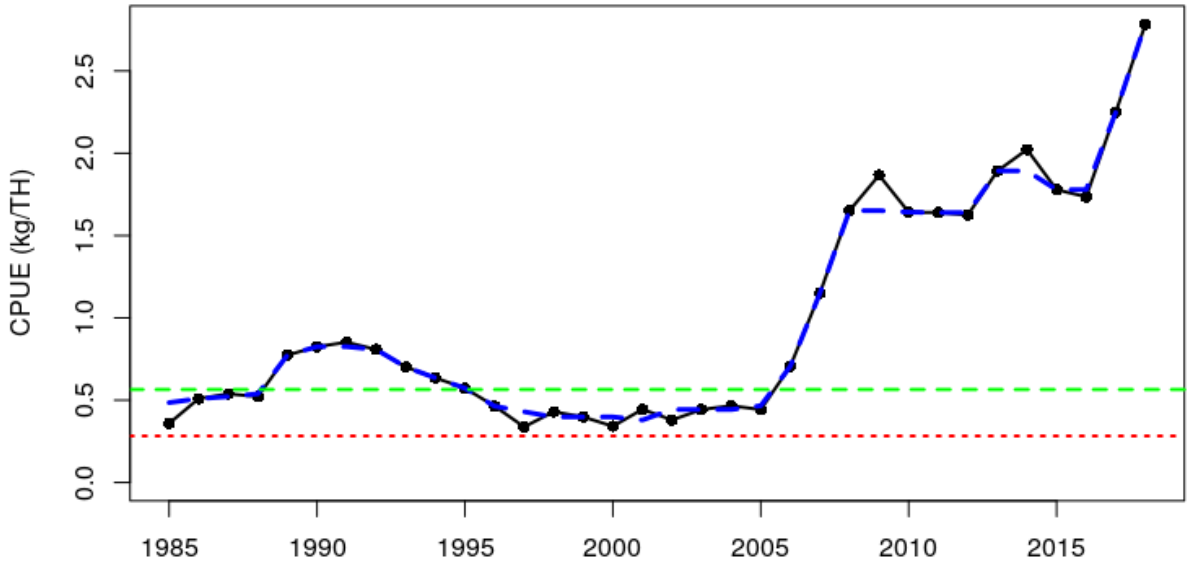


Figure 17. Time series of commercial catch rates (black line) for LFA 30, along with the three-year running median (dashed blue line). The horizontal lines represent the upper stock (dashed green line) and limit reference (dotted red line) points.

Continuous Change In Ratio

The time series of exploitation estimates is shown in Figure 18. The estimates of exploitation cover the time period where biomass was increasing in LFA 30. While estimates of exploitation fluctuate throughout the time series, they are consistently lower in LFA 30 than other LFAs in this report. The 3-year running median shows an overall declining trend for the time series. The 3-year running median value of CCIR exploitation for the 2018 season is 0.41, which is below the RR (0.77).

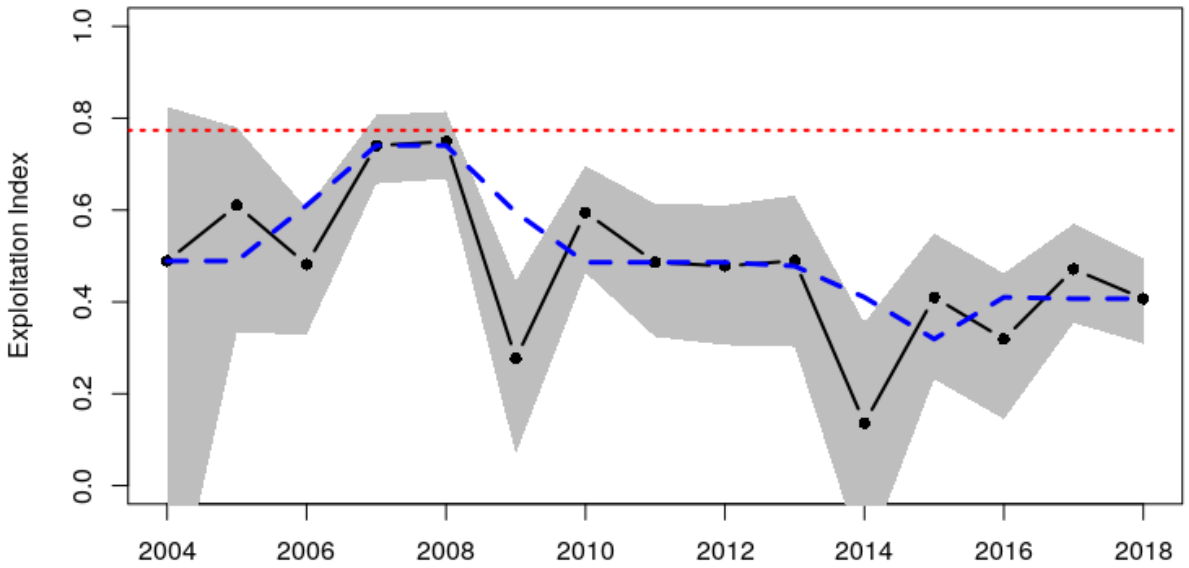


Figure 18. Time series of CCIR exploitation estimates (black line) for LFA 30, with 95% credible intervals (grey shading), 3-year running median (blue line) and the removal reference (dotted red line).

Landings and Effort

The trend in landings is similar to the trend in CPUE, as effort has fluctuated annually with an increasing trend over time (Figure 19). There has been an increase in landings over the last ten years that corresponds with an increase in CPUE.

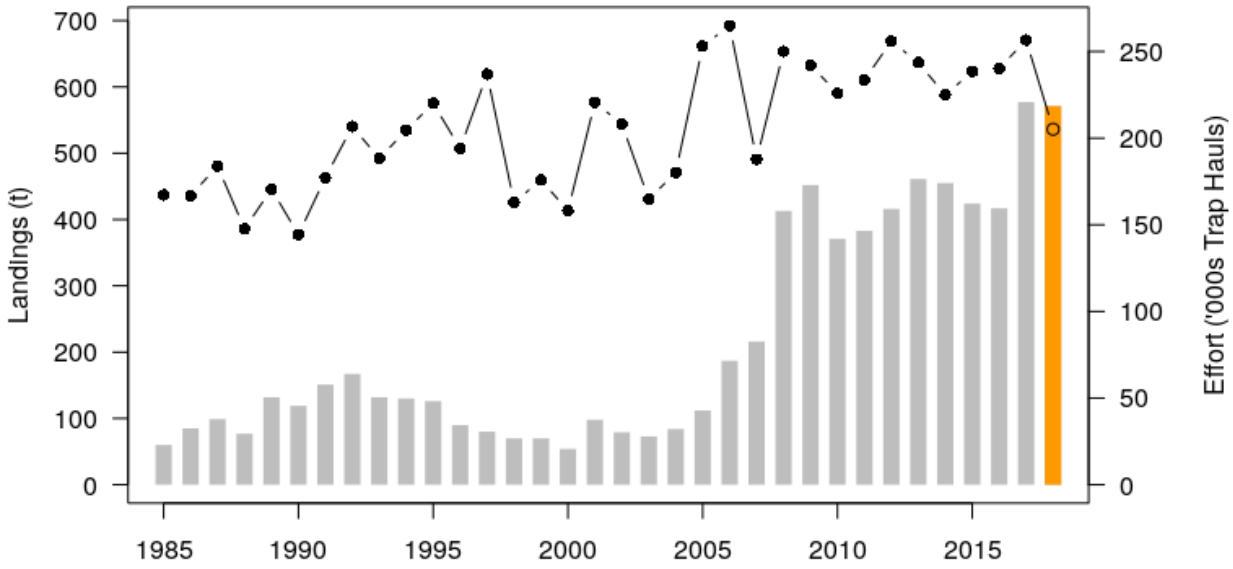


Figure 19. Time series of landings (bars) and effort (sold line with points) for LFA 30. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

The results from the FSRS recruitment trap models, showing the median number of sub-legal and legal size lobsters per trap including the 95% credible intervals, are presented in Figure 20. The trend in the legal size classes is similar to the trend in CPUE and landings with an increase

from 2005–2008, remaining stable from 2008–2016 and an increase in the last two years. While there tends to be fewer sub-legal lobsters captured in recruitment traps in LFA 30, the trend is still consistent with other primary and secondary indicators. The number of sub-legal lobsters per trap increased from 2000–2005 from approximately 0.5 to 1 lobsters, then remained stable until 2018, where it increased again to 1.5 lobsters per trap.

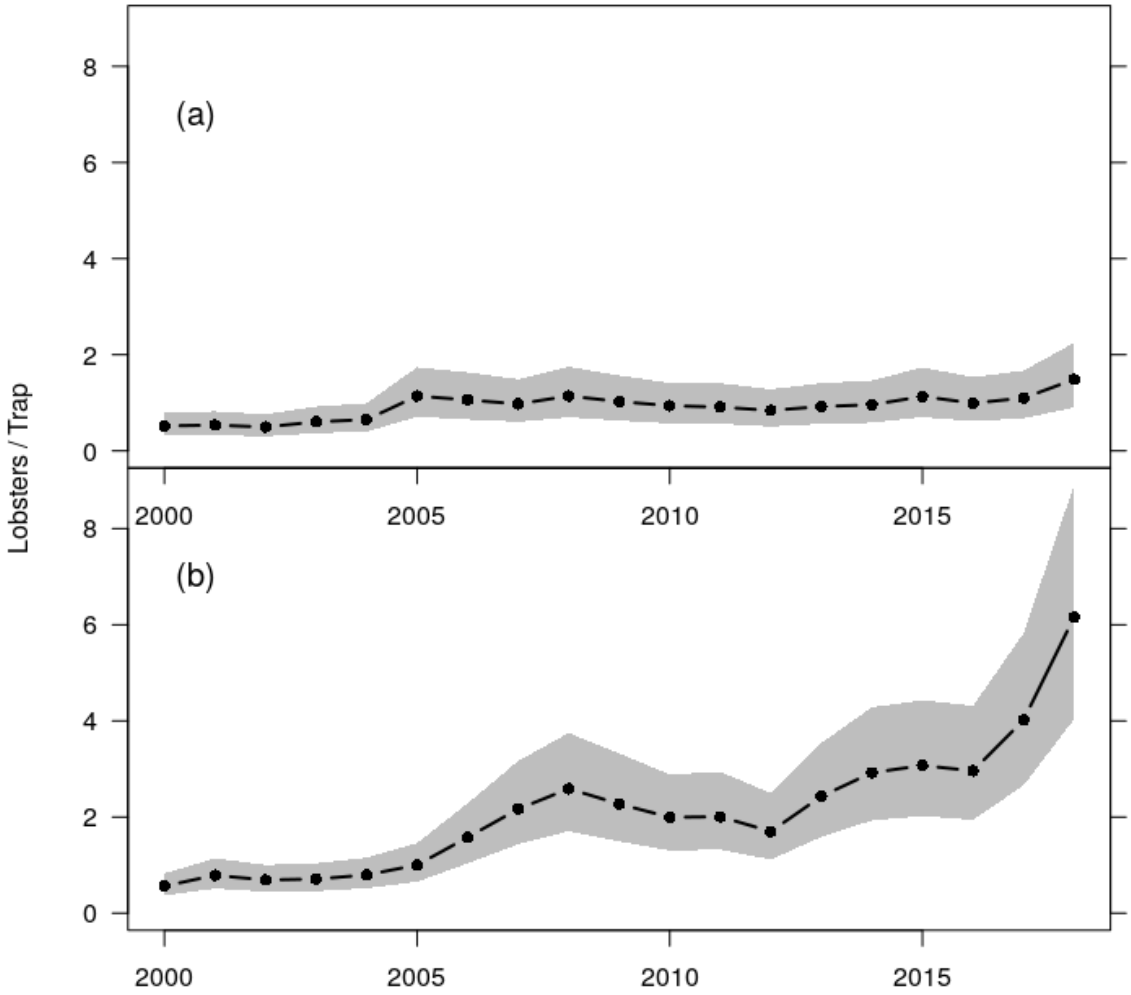


Figure 20. Time series of FSRS recruitment trap catch rates (black line), with 95% credible intervals (grey shading) from modelled results for (a) sub-legal (70 mm to <82.5 mm) and (b) legal (≥82.5 mm) sized lobsters for LFA 30.

Contextual Indicators

The first two principal components described 38% and 21% of the variability in the 17 indicators used in this analysis (Figure 21). The PCA 1 was relatively stable until the late 1990s, when it decreased until 2003, increased until 2009 and has been relative stable since that time. The indicators that comprise component 1 were landings, abundance, commercial catch rates, FSRS legal, short, and sub-legal catch rates, and reproductive indicators, which have been increasing since 2003–2005. Additionally, CCIR exploitation has been decreasing in recent years (Figure 22). The reduction in CCIR exploitation rates provides further support to an increasing overall population size. Conservation measures implemented in 1998–1999 included an increase in the MLS from 81 mm to 82.5 mm and the return of all females >135 mm, both of which would have improved the reproductive capacity and overall reproductive potential of

lobster in this LFA. Furthermore, with the increase in recruitment evident in the FSRS trap project, the overall median and maximum size would decrease due to a shift in the size distribution favoring the increased recruits. These contextual indicators support the determination, based on the primary and secondary indicators, that the stock is healthy.

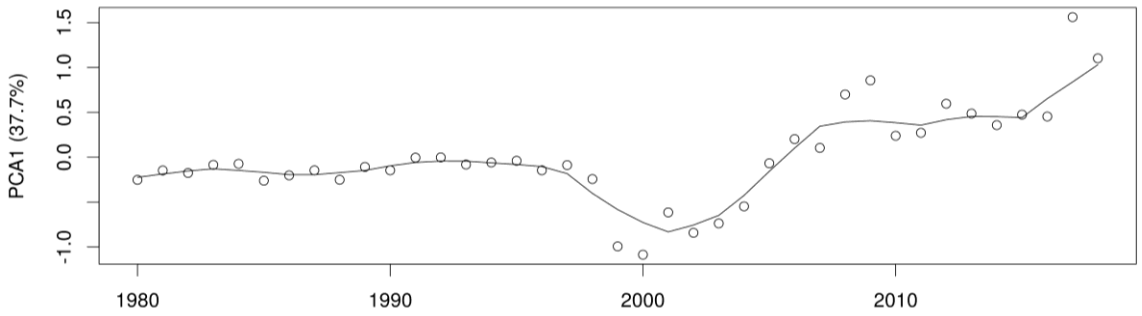


Figure 21. Time series of the first principal component of a multivariate ordination of indicators representing the lobster stock and fishery in LFA 30. Solid line represents a loess smooth.

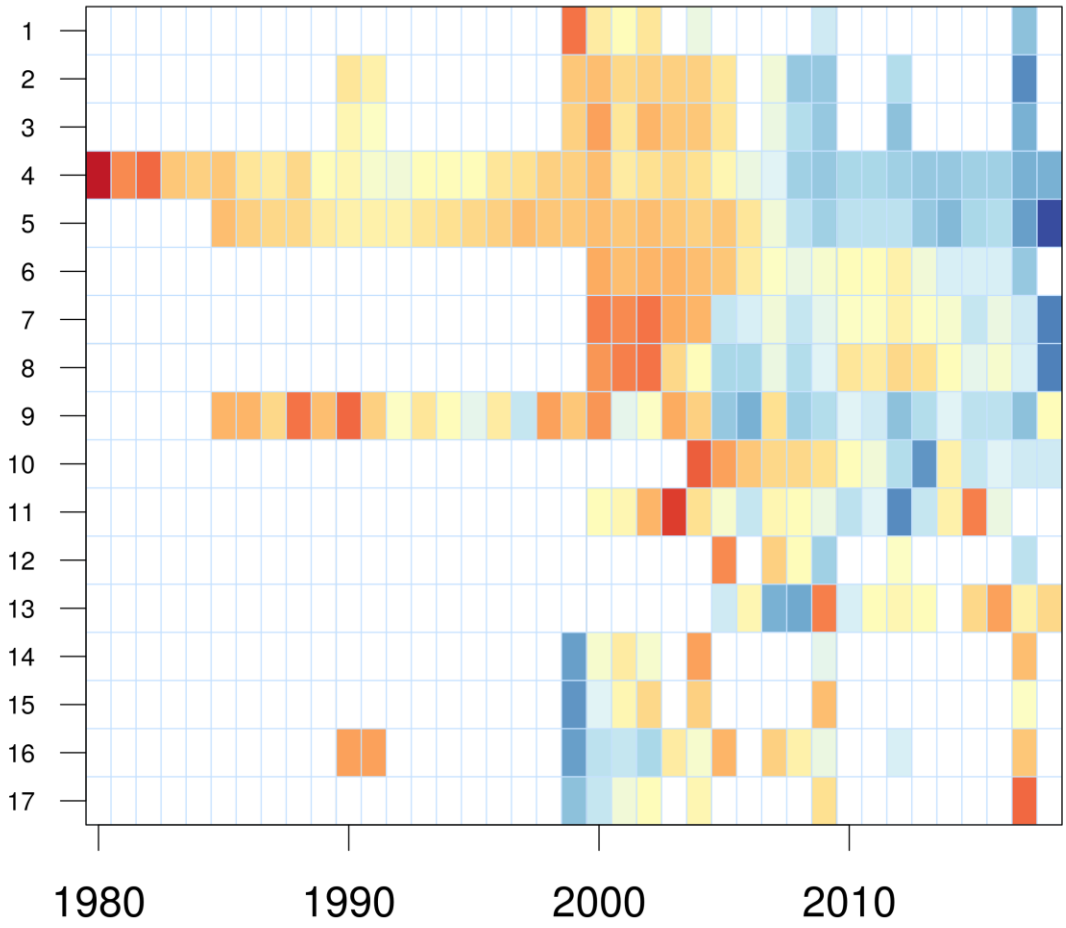


Figure 22. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 30. See Table 5 for description of variables. The blue blocks indicate levels above the mean, red blocks indicate levels below the mean, and yellow blocks indicate levels near the mean. White blocks indicate <20 observations were available for that indicator and time period.

Table 5. Description of biological and ecosystem indicators associated with LFA 30 ranked by loading in Principal Component Analysis (PCA) 1.

Rank	Variable	PCA1	PCA2	Description
1	At.Sea.Prop.NewRec	1	0.62	The proportion newly recruited lobsters (MLS:MLS+11mm) in the at-sea samples
2	At.Sea.Landed.Abund.	0.98	-0.35	The total number of legal size lobsters landed in the fishery using the size frequency information from the at-sea samples
3	At.Sea.Reprod.Pot	0.96	-0.39	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from at-sea samples
4	Landings.Wt	0.95	-0.35	Landings (in T)
5	CPUE	0.93	-0.35	Commercial catch rates
6	FSRS.Legal.CPUE	0.9	-0.14	Catch rates of lobsters (>82.5 mm) from FSRS recruitment traps
7	FSRS.Sub-legal.CPUE	0.85	0.17	Catch rates of lobsters (70–82.5 mm) from FSRS recruitment traps
8	FSRS.Shorts.CPUE	0.72	0.34	Catch rates of lobsters (<82.5 mm) from FSRS recruitment traps
9	Effort	0.7	-0.11	Total effort (trap hauls)
10	FSRS.Rec.Prop.Berried	0.63	-0.33	The proportion of berried females from FSRS recruitment trap samples
11	Temperature	0.43	-0.25	Bottom temperature (˚C)
12	BiomassRecruits	0.27	-1.19	Biomass of recruits estimated from total landings and exploitation rates of new recruits (CCIR)
13	ExploitationCCIR	-0.05	1.01	Continuous change in ratio exploitation rate
14	At.Sea.Median.CL	-0.4	-0.81	The median carapace length of at-sea sampled lobsters
15	At.Sea.Prop.Berried	-0.44	0.14	The proportion of berried lobsters from the at-sea samples
16	At.Sea.Prop.Mature	-0.59	-0.68	The proportion of lobster samples there were mature from at-sea samples
17	At.Sea.Max.CL	-0.97	-0.62	The maximum (upper 95% CI) size of lobster observed in an at-sea sample

Lobster Fishing Area 31A

Catch Per Unit Effort

The trend in CPUE for LFA 31A increased between 2005–2009 from 0.42 kg/TH to 1.15 kg/TH. From 2012–2016 it declined to approximately 0.90 kg/TH and increased in the last two years to the highest in the time series at 1.20 kg/TH (Figure 23). The 3-year running median value for CPUE for the 2018 season is 1.20 kg/TH, which is above the USR (0.31 kg/TH) and LRP (0.16 kg/TH).

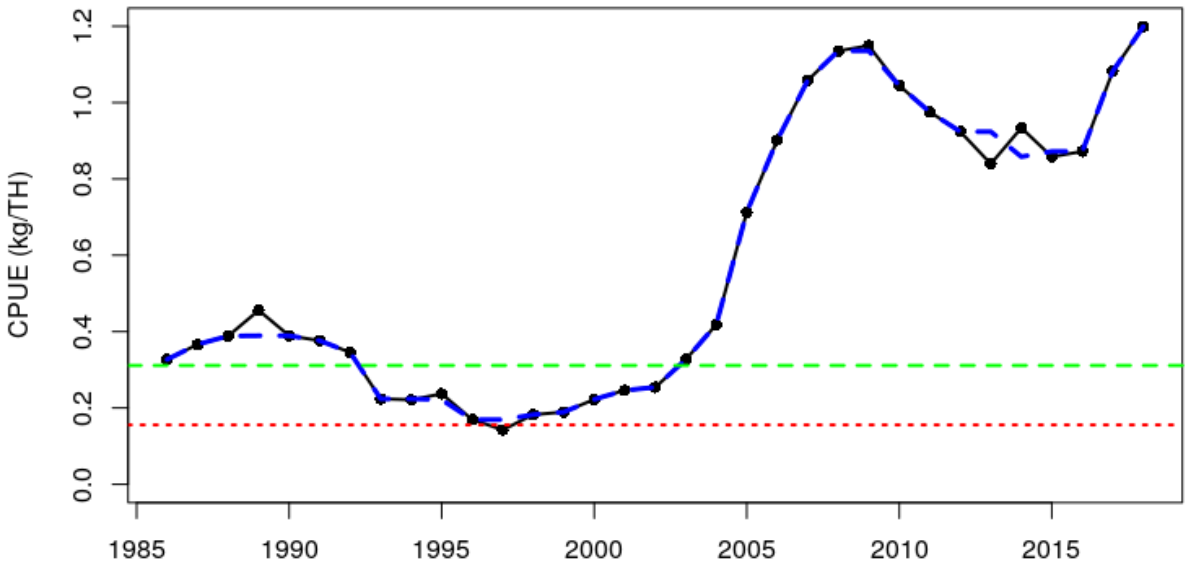


Figure 23. Time series of commercial catch rates (black line) for LFA 31A, along with the 3-year running median (dashed blue line). The horizontal lines represent the upper stock (dashed green line) and limit reference (dotted red line) points.

Continuous Change In Ratio

The time series of exploitation estimates for LFA 31A is shown in Figure 24. The estimates of exploitation have fluctuated around a mean of 0.67. There was indication of decreased exploitation in 2013 and 2015; however, credible intervals for the estimated exploitation in those years were wider than other years. Recent estimates have been closer to the mean value. The 3-year running median of CCIR exploitation for the 2018 season is 0.70, which is below the RR (0.89).

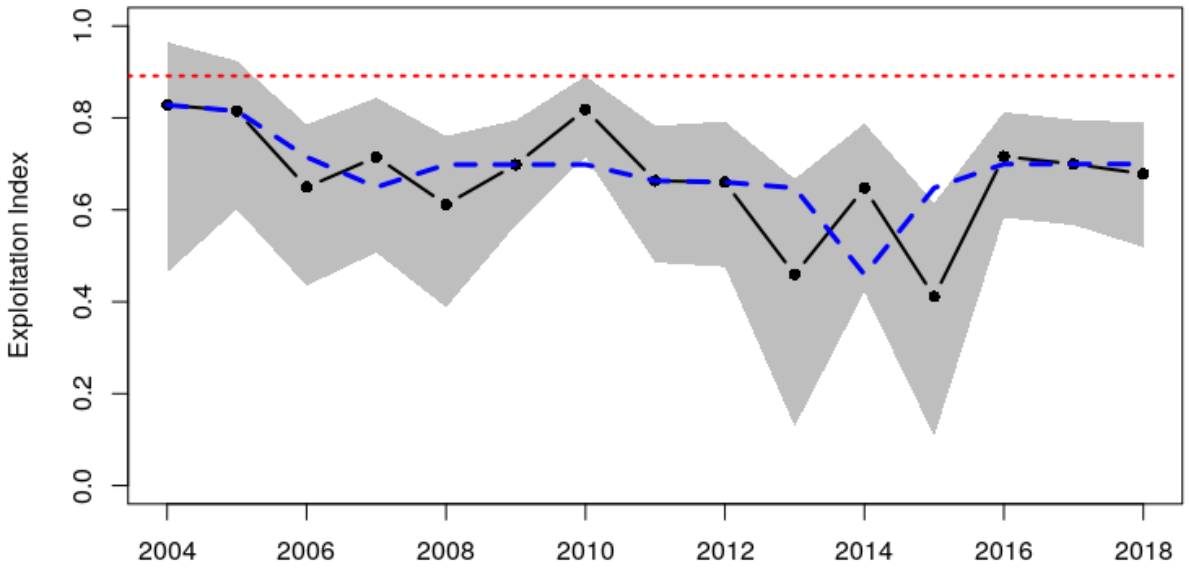


Figure 24. Time series of CCIR exploitation estimates (black line) for LFA 31A, with 95% credible intervals (grey shading), 3-year running median (blue line), and the removal reference (dotted red line).

Landings and Effort

Generally, the trend in landings is similar to the trend in the primary indicator CPUE, with an increase between 2004 and 2008 and remaining high since then (Figure 25). Effort also increased during this time but experienced a decrease since 2015.

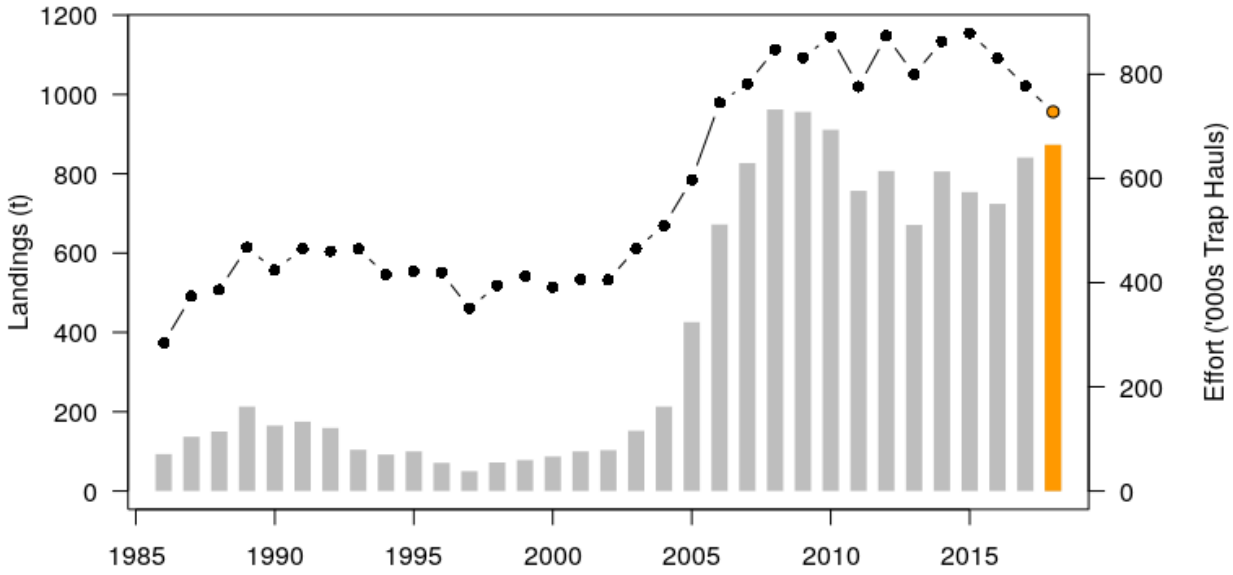


Figure 25. Time series of landings (bars) and effort (sold line with points) for LFA 31A. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

The results from the FSRS recruitment trap models, showing the median number of sub-legal and legal size lobsters per trap including the 95% credible intervals, are presented in Figure 26. Catches of sub-legal size classes show a similar trend to the CPUE; however, increases in sub-legal abundance are observed one year prior to being observed in the commercial fishery, indicating that in this LFA the recruitment traps are a good indicator of recruitment. Increases in sub-legal abundance have occurred in the last four years, which is a positive sign for the next year's fishery. The trends in the abundance of legal size lobsters in recruitment traps and CPUE are also similar.

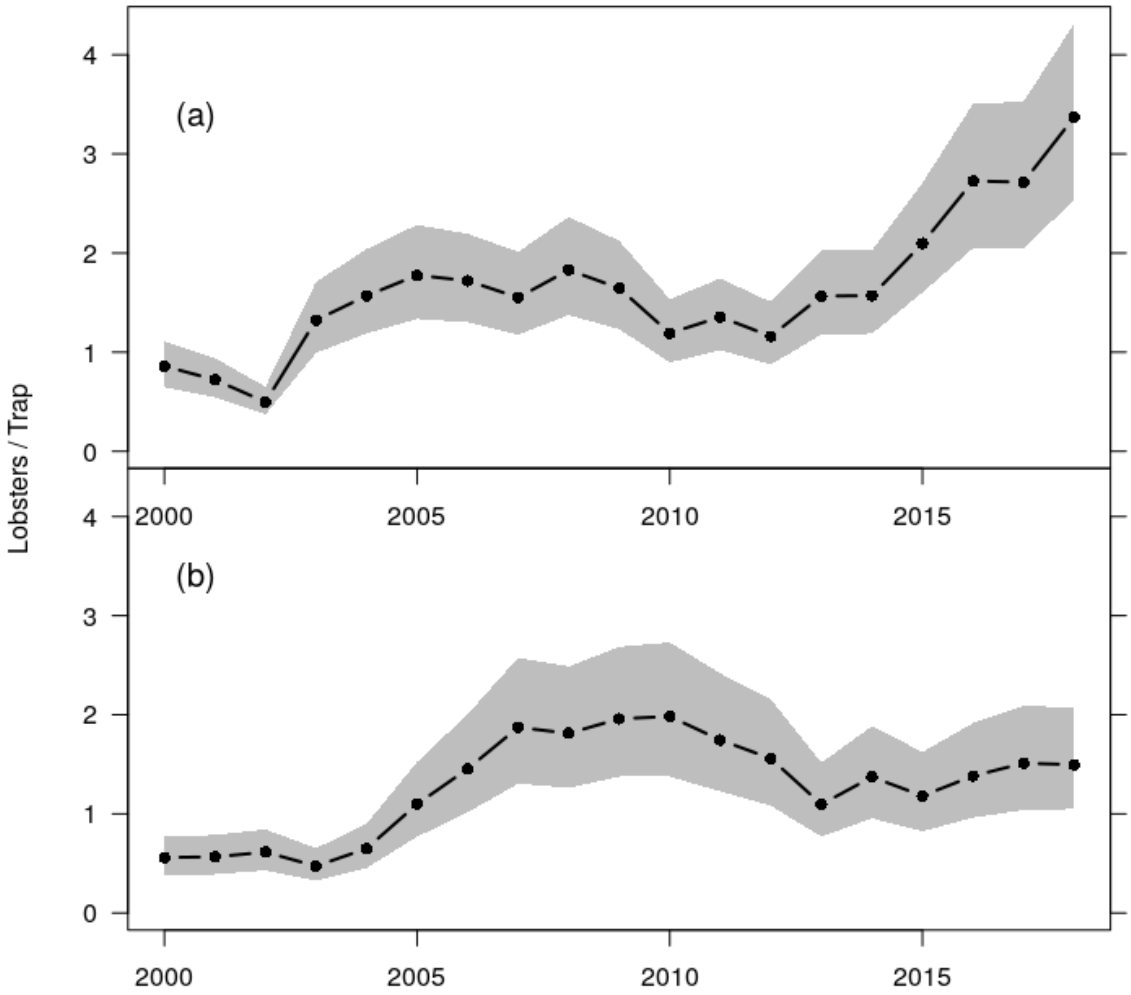


Figure 26. Time series of FSRS recruitment trap catch rates (black line), with 95% credible intervals (grey shading) from modelled results for (a) sub-legal (70 mm to <82.5 mm) and (b) legal (≥82.5 mm) size lobsters for LFA 31A.

Contextual Indicators

The first two components of the multivariate analysis described 41% and 12% of the overall variance in the 23 indicators available for this area (Figure 27). Similar to other LFAs in this report, there was an increase in the time series for component 1 during the late 1980s and early 1990s, which was followed by a decline until 2003. From 2004 to 2010, there was an increase in component 1, which has been stable since that time. The indicators that largely comprise component 1 are landings, biomass, commercial catch rates, FSRS legal, sub-legal and short catch rates, and reproductive potential indicators, which have all been increasing since 2002-2003 (Figure 28). During this same time period, the proportion of mature lobster in the landings, CCIR estimated exploitation, and maximum size were decreasing. These patterns suggest increased productivity in LFA 31A since the early 2000s, which has been relatively stable since 2010. In the last several years, there has been a reduction in the proportion of berried females in the at-sea samples; however, the FSRS proportion of berried females has been stable or increasing.

The conservation measures implemented in LFA 31A include increasing the MLS from 81 mm to 86 mm between 1998 and 2000, followed by decreases to 84 mm in 2004 and to 82.5 mm in 2007. Additional protection was placed on female lobsters in 1998, with females from 114 to 124 mm returned to the water. The conservation measures need to be considered when examining the indicator trends, as the decrease in maximum and median CL and proportion of mature lobsters corresponds to the decreases in MLS following 2000, when MLS was 86 mm. These contextual indicators support the determination, based on the primary and secondary indicators, that the stock is healthy.

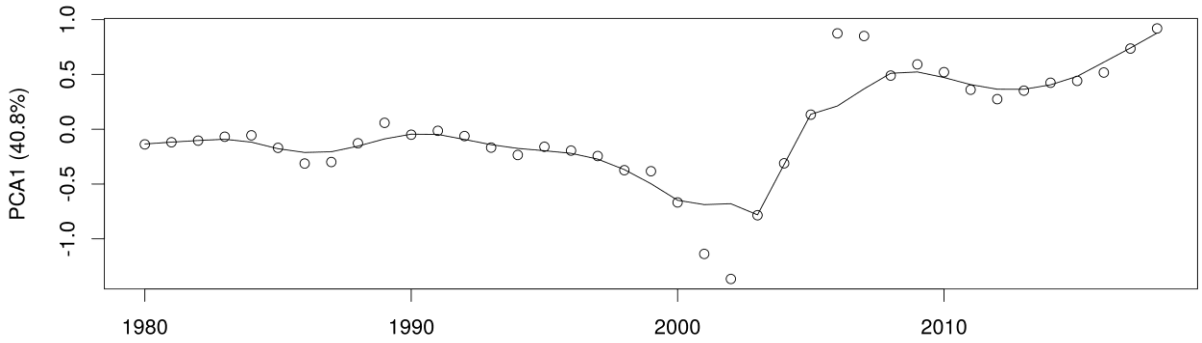


Figure 27. Time series of the first principal component of a multivariate ordination of indicators representing the lobster stock and fishery in LFA 31A. Solid line represents a loess smooth.

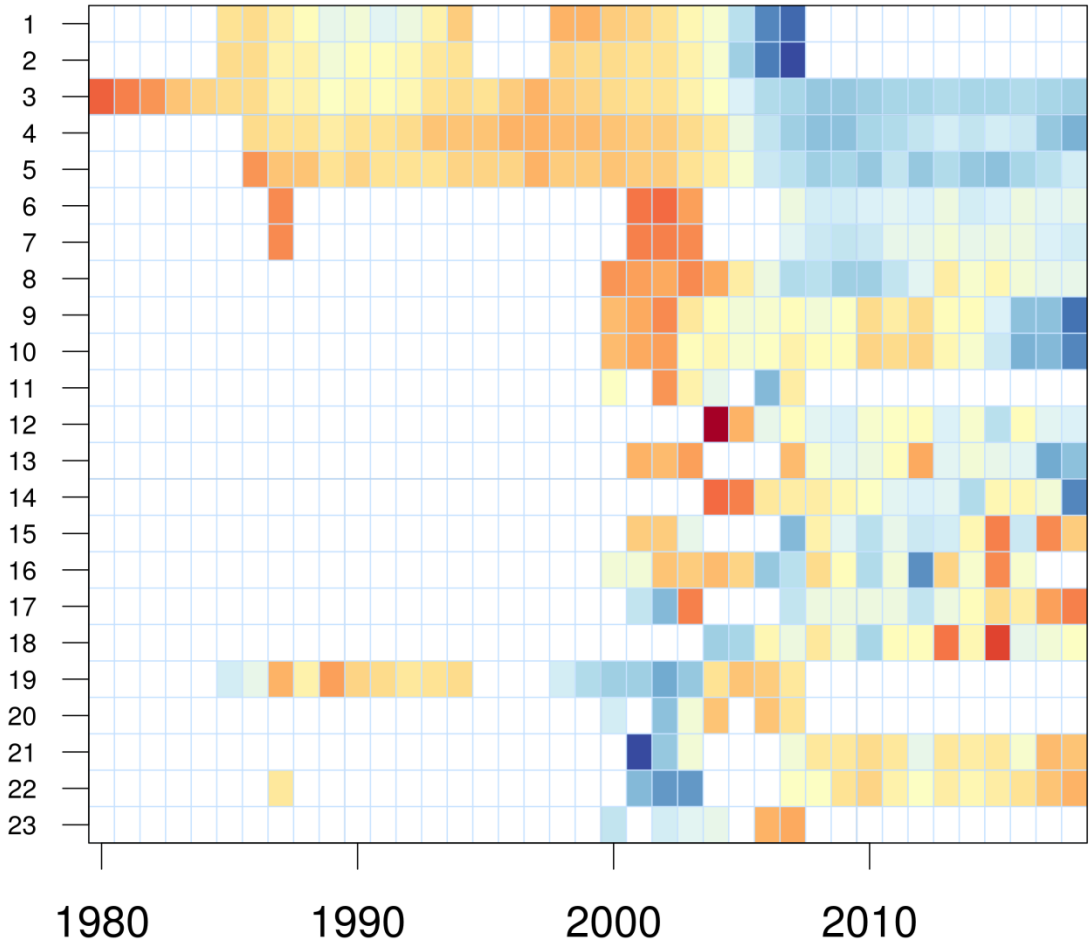


Figure 28. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 31A. See Table 6 for description of variables. The blue blocks indicate levels above the mean, red blocks indicate levels below the mean, and yellow blocks indicate levels near the mean. White blocks indicate <20 observations were available for that indicator and time period.

Table 6. Description of biological and ecosystem indicators associated with LFA 31A ranked by loading in Principal Component Analysis (PCA) 1.

Rank	Variable	PCA1	PCA2	Description
1	Port.Reprod.Pot	1.01	-0.02	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from port samples
2	Port.Landed.Abund	1	-0.02	The total number of legal size lobsters landed in the fishery using the size frequency information from port samples
3	Landings.Wt	0.98	-0.13	Landings (in T)
4	CPUE	0.96	-0.13	Commercial catch rates
5	Effort	0.92	-0.1	Total effort (trap hauls)
6	At.Sea.Reprod.Pot	0.91	0.19	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from at-sea samples
7	At.Sea.Landed.Abund.	0.9	0.24	The total number of legal size lobsters landed in the fishery using the size frequency information from the at-sea samples
8	FSRS.Legal.CPUE	0.86	0.15	Catch rates of lobsters (>82.5 mm) from FSRS recruitment traps
9	FSRS.Sub-legal.CPUE	0.77	-0.18	Catch rates of lobsters (70–82.5 mm) from FSRS recruitment traps
10	FSRS.Shorts.CPUE	0.68	-0.24	Catch rates of lobsters (<82.5 mm) from FSRS recruitment traps
11	Port.Prop.NewRec	0.66	0.31	The proportion newly recruited lobsters (MLS:MLS+11mm) in the port samples
12	BiomassRecruits	0.64	-0.76	Biomass of recruits estimated from total landings and exploitation rates of new recruits (CCIR)
13	At.Sea.Prop.NewRec	0.63	-0.52	The proportion newly recruited lobsters (MLS:MLS+11mm) in the at-sea samples
14	FSRS.Rec.Prop.Berried	0.5	-0.63	The proportion of berried females from FSRS recruitment trap samples
15	At.Sea.Prop.Berried	0.4	1.01	The proportion of berried lobsters from the at-sea samples
16	Temperature	0.39	0.52	Bottom temperature (˚C)
17	At.Sea.Median.CL	-0.27	0.53	The median carapace length of at-sea sampled lobsters
18	ExploitationCCIR	-0.28	0.53	Continuous change in ratio exploitation rate
19	Port.Prop.Mature	-0.73	-0.4	The proportion of mature lobster samples from port samples
20	Port.Median.CL	-0.81	-0.67	Median carapace length from port samples
21	At.Sea.Max.CL	-0.83	0.12	The maximum (upper 95% CI) size of lobster observed in an at-sea sample
22	At.Sea.Prop.Mature	-0.83	-0.03	The proportion of mature lobster samples from at-sea samples
23	Port.Max.CL	-1.06	-0.02	The maximum (upper 95% CI) size of lobsters observed in port samples

Lobster Fishing Area 31B

Catch Per Unit Effort

The trend in CPUE indicates that an increase in the stock biomass began in 2004 (Figure 29). The time series of CPUE was low between 1993 and 2002 but increased to 1.11 kg/TH in 2007, more than triple the USR. It remained high and has continued to increase in recent years. In LFA 31B, the 3-year running median value for CPUE for the 2018 season is 1.28 kg/TH, which is above the USR (0.32 kg/TH) and LRP (0.16 kg/TH).

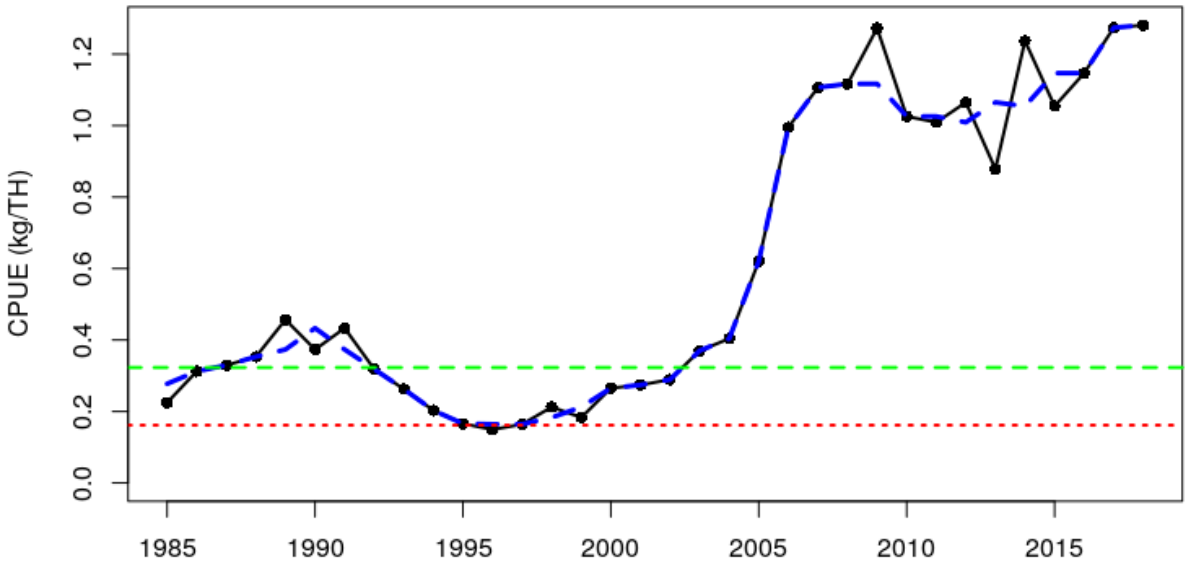


Figure 29. Time series of commercial catch rates (black line) for LFA 31B, along with the 3-year running median (blue). The horizontal lines represent the upper stock (dashed green line) and limit reference (dotted red line) points.

Continuous Change In Ratio

The time series of exploitation estimates for LFA 31B is shown in Figure 30. The estimates of exploitation have been highly variable, fluctuating around a mean of 0.58. The running median indicates a decrease in exploitation between 2009 and 2015, while recent estimates have been higher. The 3-year running median of CCIR exploitation for the 2018 season is 0.76, which is below the RR (0.82).

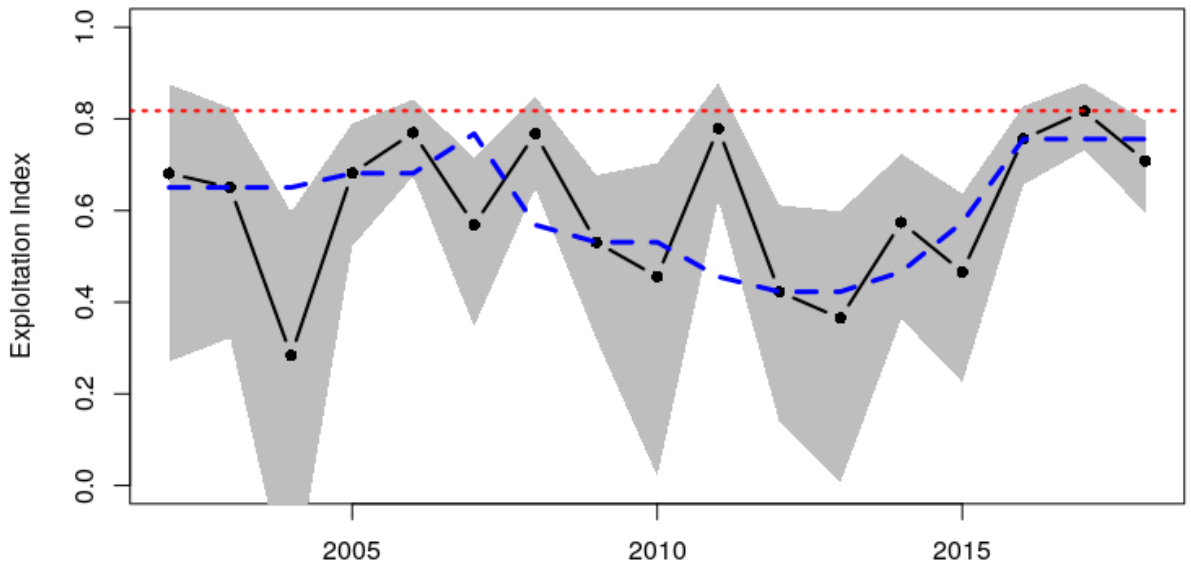


Figure 30. Time series of CCIR exploitation estimates (black line) for LFA 31B, with 95% credible intervals (grey shading), 3-year running median (blue line) and the removal reference (dotted red line).

Landings and Effort

The trend in landings is similar to the trend in CPUE with an increase from 2005–2007 and remaining high since then (Figure 31). Effort gradually increased from 1985 to 2007 and has remained stable since that time.

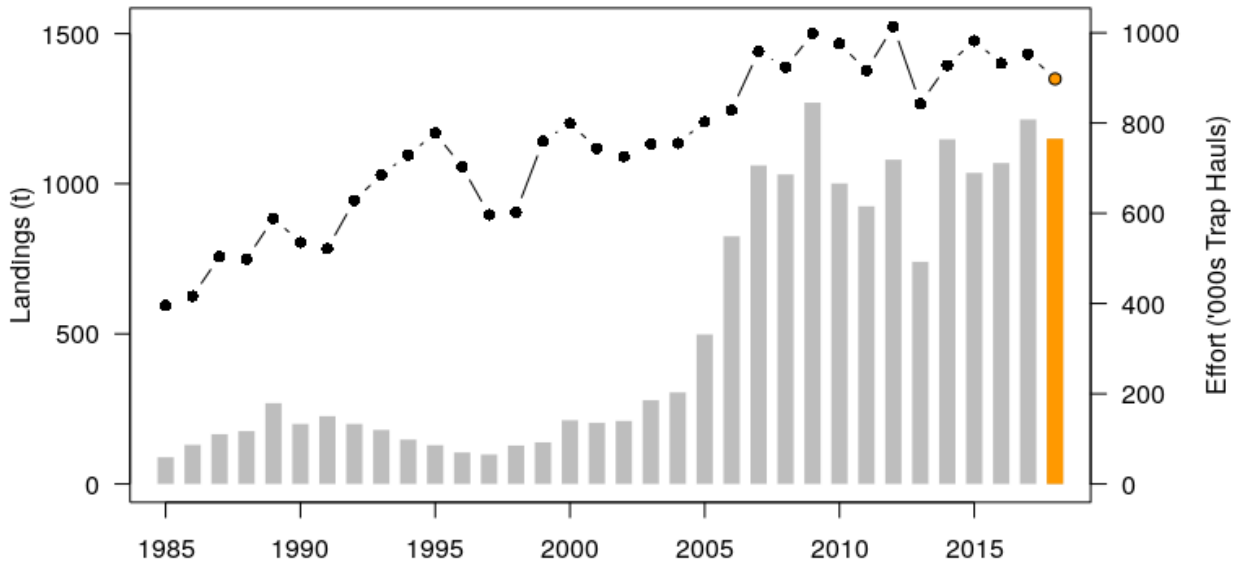


Figure 31. Time series of landings (bars) and effort (sold line with points) for LFA 31B. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

The results from the FSRS recruitment trap models, showing the median number of sub-legal and legal size lobsters per trap including the 95% credible intervals, are presented in Figure 32. The trend in the legal and sub-legal size classes is similar to the trend in CPUE and landings.

However, the trend in landings and CPUE lags the trend in sub-legal size lobsters observed in recruitment traps.

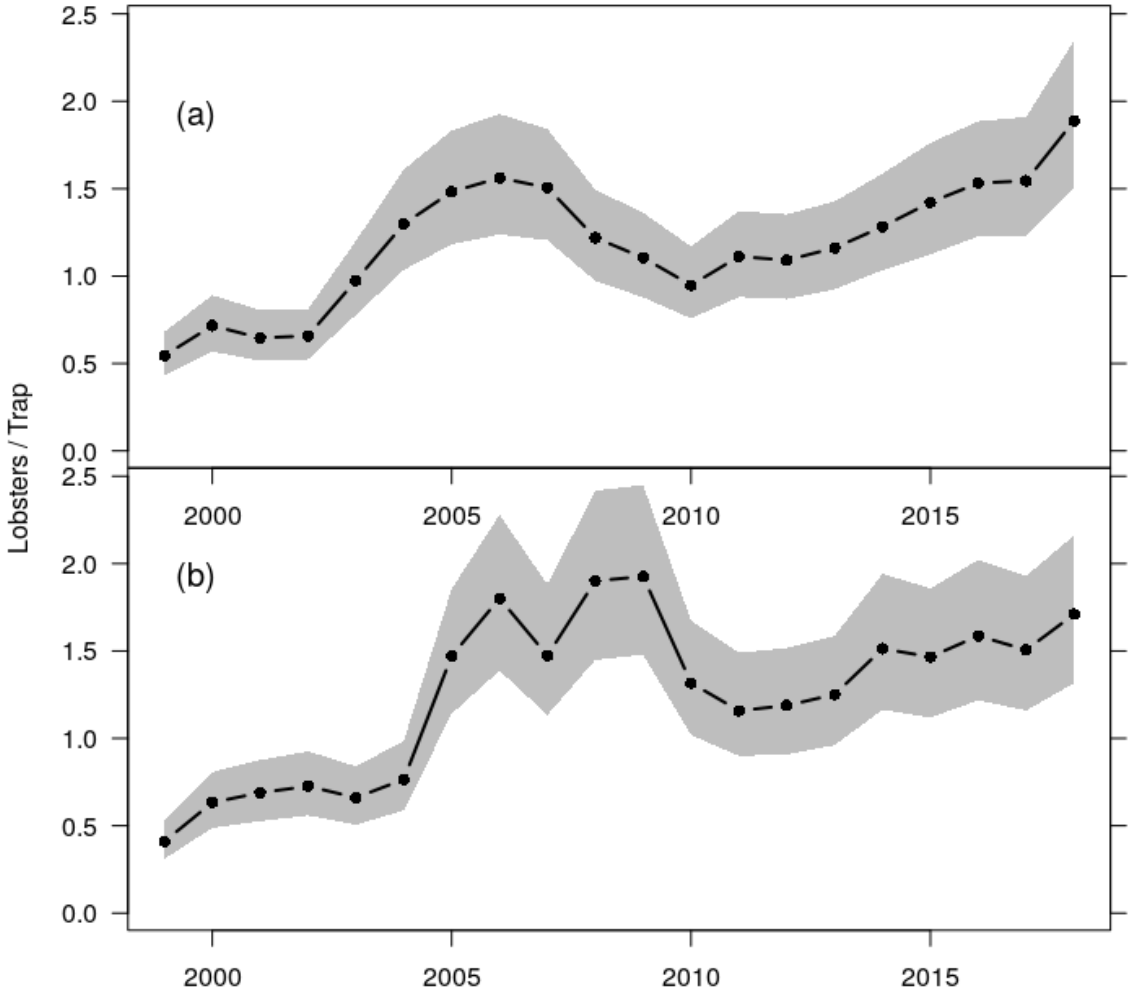


Figure 32. Time series of FSRS recruitment trap catch rates (black line), with 95% credible intervals (grey shading) from modelled results for (a) sub-legal (70 mm to <82.5 mm) and (b) legal (≥82.5 mm) sized lobsters for LFA 31B.

Contextual Indicators

The first two components of the multivariate analysis described 37% and 15% of the variability in the 20 indicators, respectively. The time series for component 1 shows relative stability between 1980 and 2000, increased between 2005 and 2010, and has been stable or slightly decreasing since that time (Figure 33). As in other LFAs, the primary drivers of the trend is component 1 are the increases in landings, biomass, abundance, commercial catch rates, FSRS legal and sub-legal catch rates, and reproductive potential indicators. The decrease in exploitation estimated through CCIR, proportion of mature lobster in the landings, and maximum size also contributed to the first principal component (Figure 34). Similar to LFA 31A, trends in indicators based on fisheries data must be placed in the context of changes in fishing practices and may not reflect changes in population characteristics. Specifically, the conservation criteria implemented in LFA 31B increased the MLS from 82.5 to 84 mm between 1998 and 1999 and decreased it back to 82.5 mm in 2000. Further contributing to the decrease in these indicators was the increase in recruitment, evident from the FSRS recruitment traps, which affects the

overall size distribution. The increased productivity from higher landings, increased biomass of recruits, and reproductive potential likely contributed to the current healthy status of the LFA. These contextual indicators support the conclusion, based on the primary and secondary indicators, that the stock is healthy.

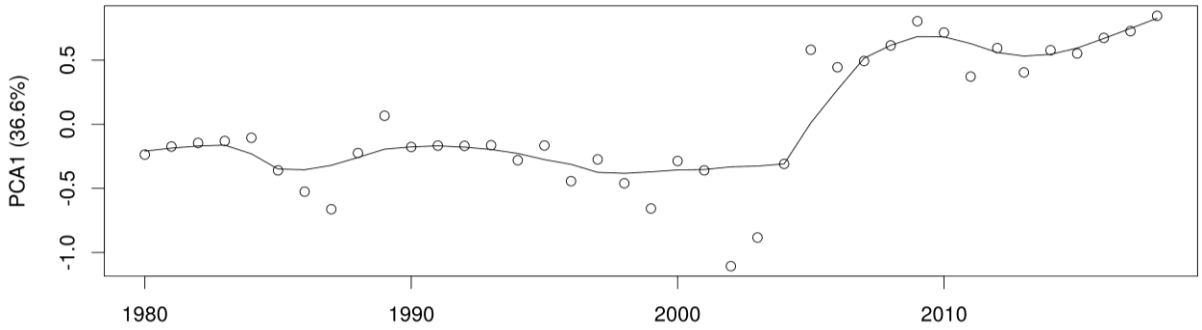


Figure 33. Time series of the first principal component of a multivariate ordination of indicators representing the lobster stock and fishery in LFA 31B. The solid line represents a loess smooth.

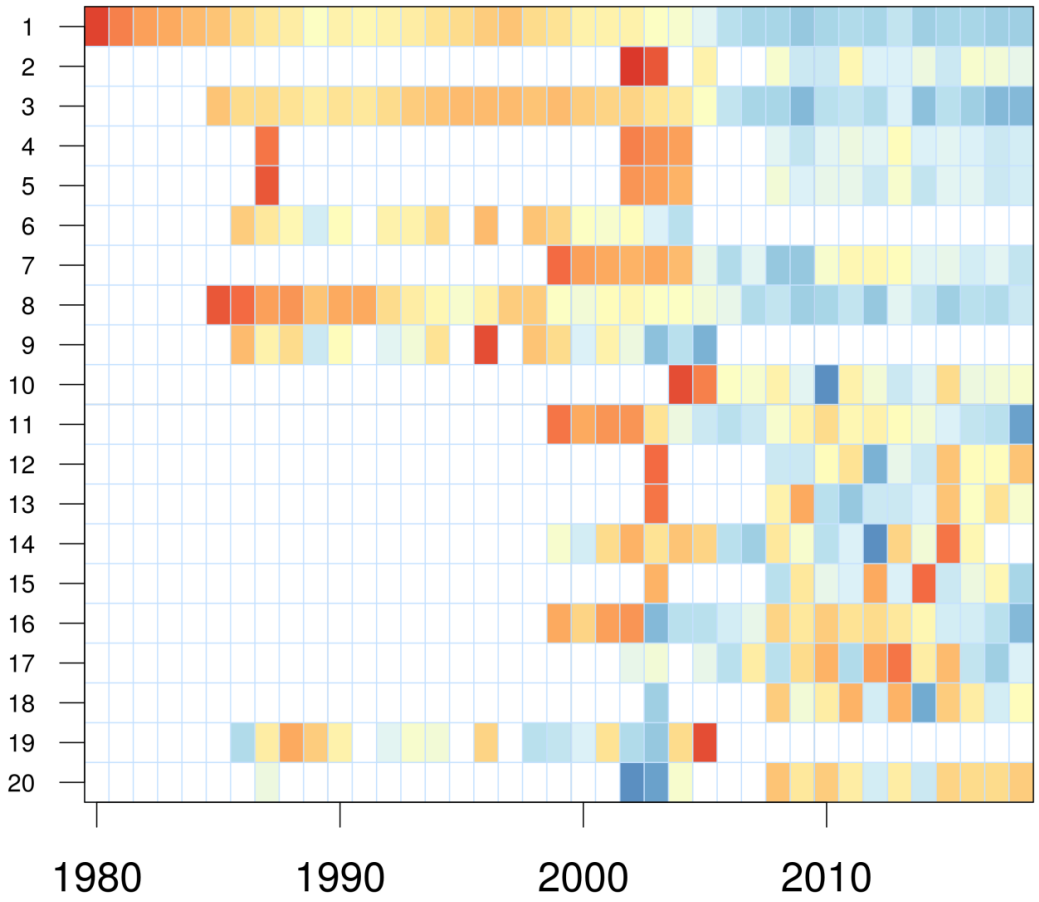


Figure 34. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 31B. See Table 7 for description of variables. The blue blocks indicate levels above the mean, red blocks indicate levels below the mean, and yellow blocks indicate levels near the mean. White blocks indicate <20 observations were available for that indicator and time period.

Table 7. Description of biological and ecosystem indicators associated with LFA 31B ranked by loading in Principal Component Analysis (PCA) 1.

Rank	Variable	PCA1	PCA2	Description
1	Landings.Wt	1.02	-0.04	Landings (in T)
2	BiomassRecruits	0.99	-0.14	Biomass of recruits estimated from total landings and exploitation rates of new recruits (CCIR)
3	CPUE	0.98	0	Commercial catch rates
4	At.Sea.Landed.Abund.	0.98	-0.18	The total number of legal size lobsters landed in the fishery using the size frequency information from the at-sea samples
5	At.Sea.Reprod.Pot	0.94	-0.32	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from at-sea samples
6	Port.Landed.Abund	0.92	0.4	The total number of legal size lobsters landed in the fishery using the size frequency information from port samples
7	FSRS.Legal.CPUE	0.92	0.25	Catch rates of lobsters (>82.5 mm) from FSRS recruitment traps
8	Effort	0.8	-0.34	Total effort (trap hauls)
9	Port.Reprod.Pot	0.78	0.24	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from port samples
10	FSRS.Rec.Prop.Berried	0.7	-0.39	The proportion of berried females from FSRS recruitment trap samples
11	FSRS.Sub-legal.CPUE	0.7	0.67	Catch rates of lobsters (70–82.5 mm) from FSRS recruitment traps
12	At.Sea.Median.CL	0.42	-0.75	The median carapace length of at-sea sampled lobsters
13	At.Sea.Prop.Berried	0.3	-0.59	The proportion of berried lobsters from the at-sea samples
14	Temperature	0.26	-0.69	Bottom temperature (˚C)
15	At.Sea.Prop.NewRec	0.23	0.37	The proportion newly recruited lobsters (MLS:MLS+11mm) in the at-sea samples
16	FSRS.Shorts.CPUE	0.21	0.88	Catch rates of lobsters (<82.5 mm) from FSRS recruitment traps
17	ExploitationCCIR	-0.06	0.55	Continuous change in ratio exploitation rate
18	At.Sea.Max.CL	-0.18	-0.09	The maximum (upper 95% CI) size of lobster observed in an at-sea sample
19	Port.Prop.Mature	-0.56	-0.47	The proportion of mature lobster samples from port samples
20	At.Sea.Prop.Mature	-0.66	-0.18	The proportion of mature lobster samples from at-sea samples

Lobster Fishing Area 32

Catch Per Unit Effort

The trend in CPUE indicates that stock biomass has been increasing steadily from a low in 1995, when it was near the LRP (Figure 35). The CPUE surpassed the USR in 1999, continued to rise steadily until 2017, and is currently 0.80 kg/TH. The 3-year running median for CPUE for the 2018 season is 0.80 kg/TH, which is above the USR (0.29 kg/TH).

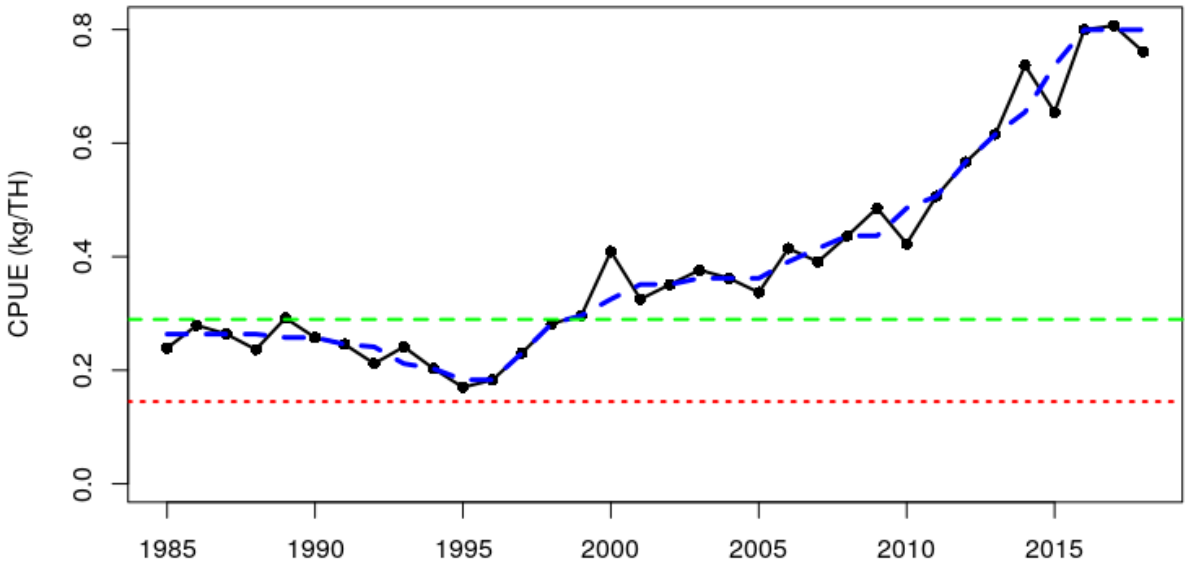


Figure 35. Time series of commercial catch rates (black line) for LFA 32, along with the 3-year running median (blue line). The horizontal lines represent the upper stock (dashed green line) and limit reference (dotted red line) points.

Continuous Change In Ratio

The time series of exploitation estimates is shown in Figure 36. The mean exploitation in LFA 32 was estimated at 0.66. Throughout the estimable period of 2000 to 2018, exploitation appears to be largely stable with a slight increase in recent years. The 3-year running median of CCIR exploitation for the 2018 season is 0.74, which is below the RR (0.84).

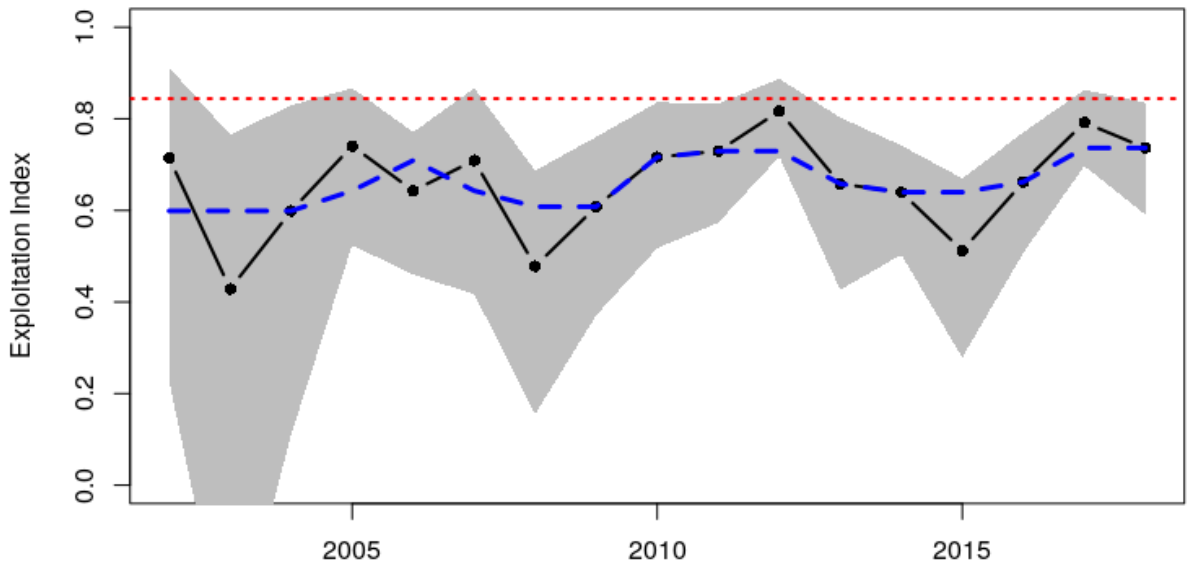


Figure 36. Time series of CCIR exploitation estimates (black line) for LFA 32, with 95% credible intervals (grey shading), 3-year running median (blue line), and the removal reference (dotted red line).

Landings and Effort

Generally, the trend in landings is similar to the trend in the primary indicator CPUE (Figure 37). Landings were low in the 1980s, increased through the mid-1980s to early-1990s, remained constant in the early 2000s, and have increased to record highs in recent years. Effort increased from 2004–2006 to about 1,500,000 THs per year, where it has remained as landings have continued to increase.

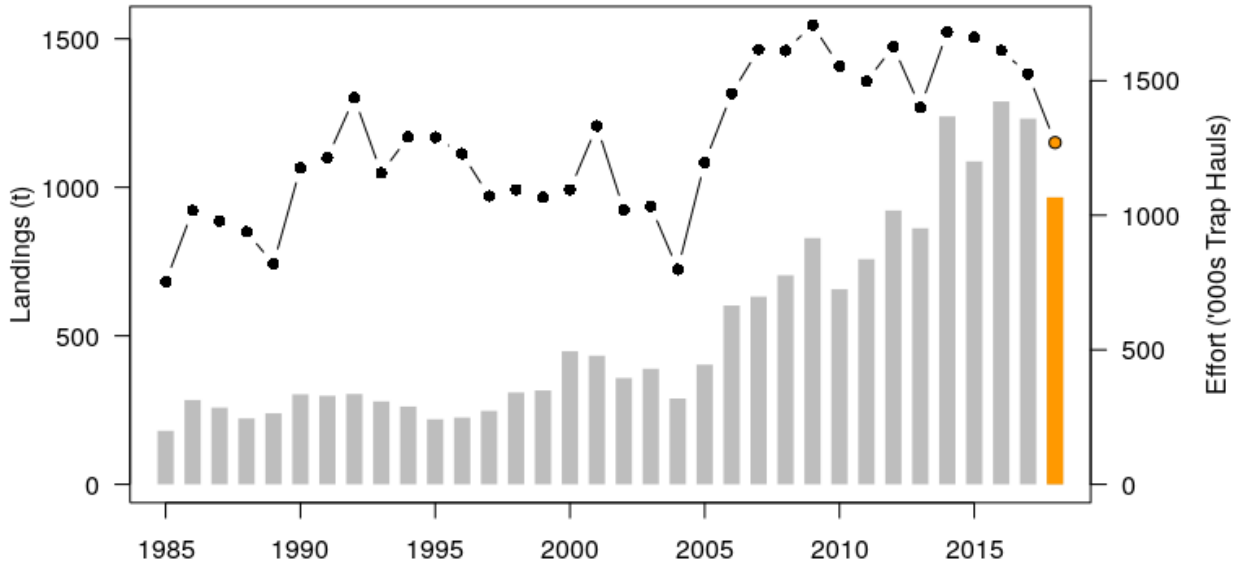


Figure 37. Time series of landings (bars), and effort (sold line with points) for LFA 32. Data for 2018 is incomplete (orange).

Recruitment Trap Legal and Sub-legal Catch Rates

The results from the FSRS recruitment trap models, showing the median number of sub-legal and legal size lobsters per trap including the 95% credible intervals, are presented in Figure 38. The trends in the legal and sub-legal size classes are similar to the trends in CPUE and landings. The trend in legal size lobster lags the trend in sub-legal lobsters so that increases in sub-legal size lobsters are observed in the FSRS traps a year before they are observed in the legal size lobsters and CPUE.

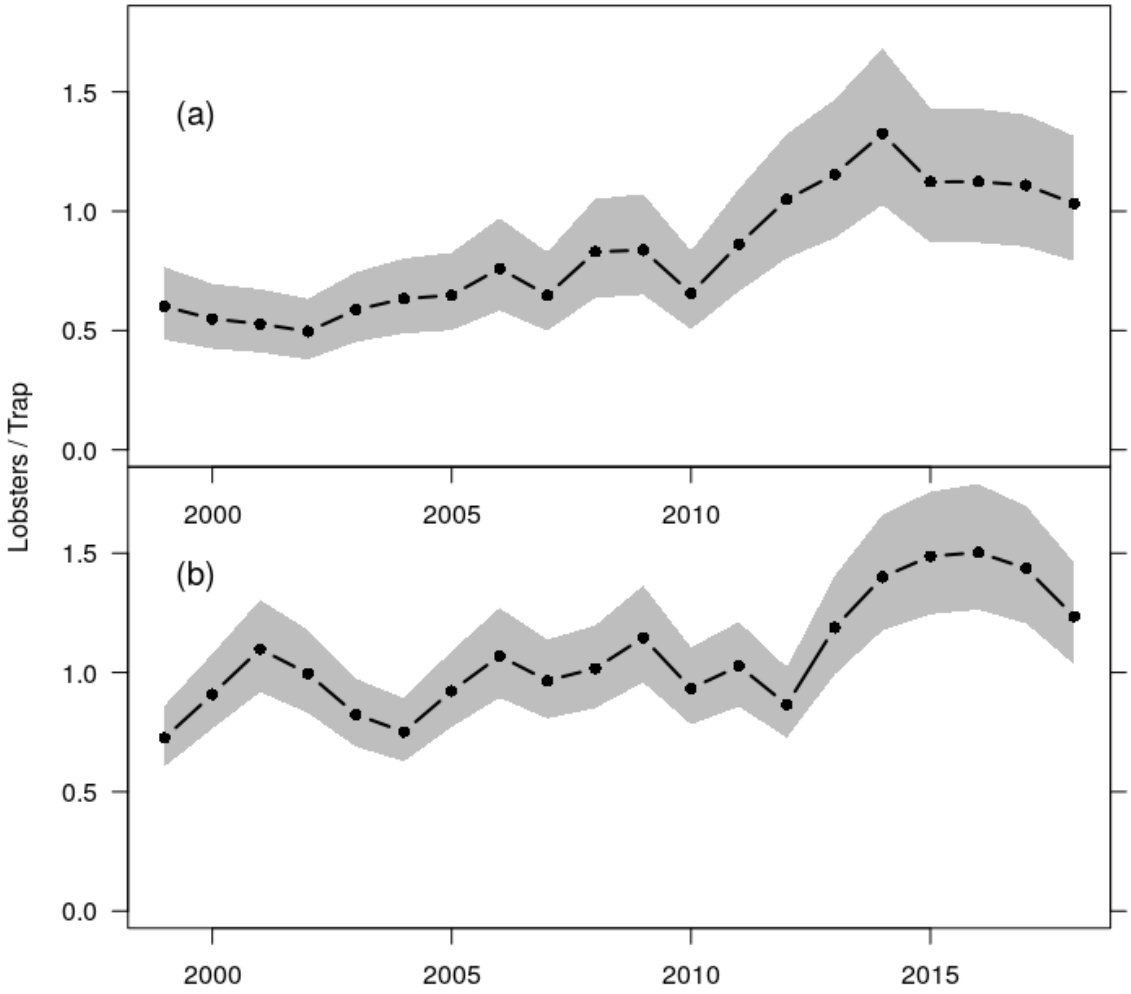


Figure 38. Time series of FSRS recruitment trap catch rates (black line), with 95% credible intervals (grey shading) from modelled results for (a) sub-legal (70 mm to <82.5 mm) and (b) legal (≥82.5 mm) sized lobsters for LFA 32.

Contextual Indicators

The first two principal component axes describe 34% and 19% of the variability in the 20 indicator time series included in this analysis (Figure 39). The time series of component 1 did not show the same increase in the late 1980s and early 1990s as in the more easterly LFAs, but it did show the same increase since approximately 2003. The first principal component was described by the time series trends of increasing landings, abundance, commercial catch rates, FSRS legal, sub-legal and short catch rates, and reproductive potential indicators (Figure 40). In LFA 32, there were decreasing trends in the proportion of berried females, and median and

maximum carapace length. Exploitation indices estimated through the CCIR method have also been decreasing with increased landings, suggesting an increase in overall abundance. The change in production occurred several years after the implementation of conservation measures in 2000. These measures included increasing MLS from 81 mm to 82.5 mm and the v-notching and release of 110 lbs of females per license per season, which would serve to increase the proportion of mature lobsters being captured and increase the overall reproductive potential.

Similar to other areas, the decrease in size metrics was largely due to the increase in new recruits, skewing the distribution toward more newly recruited individuals. These contextual indicators support the determination, based on the primary and secondary indicators, that the stock is healthy.

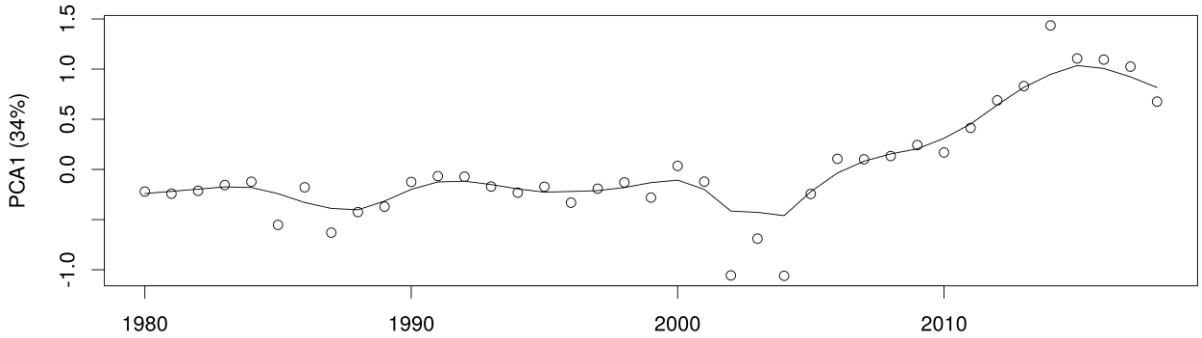


Figure 39. Time series of the first principal component of a multivariate ordination of indicators representing the lobster stock and fishery in LFA 32. Solid line represents a loess smooth.

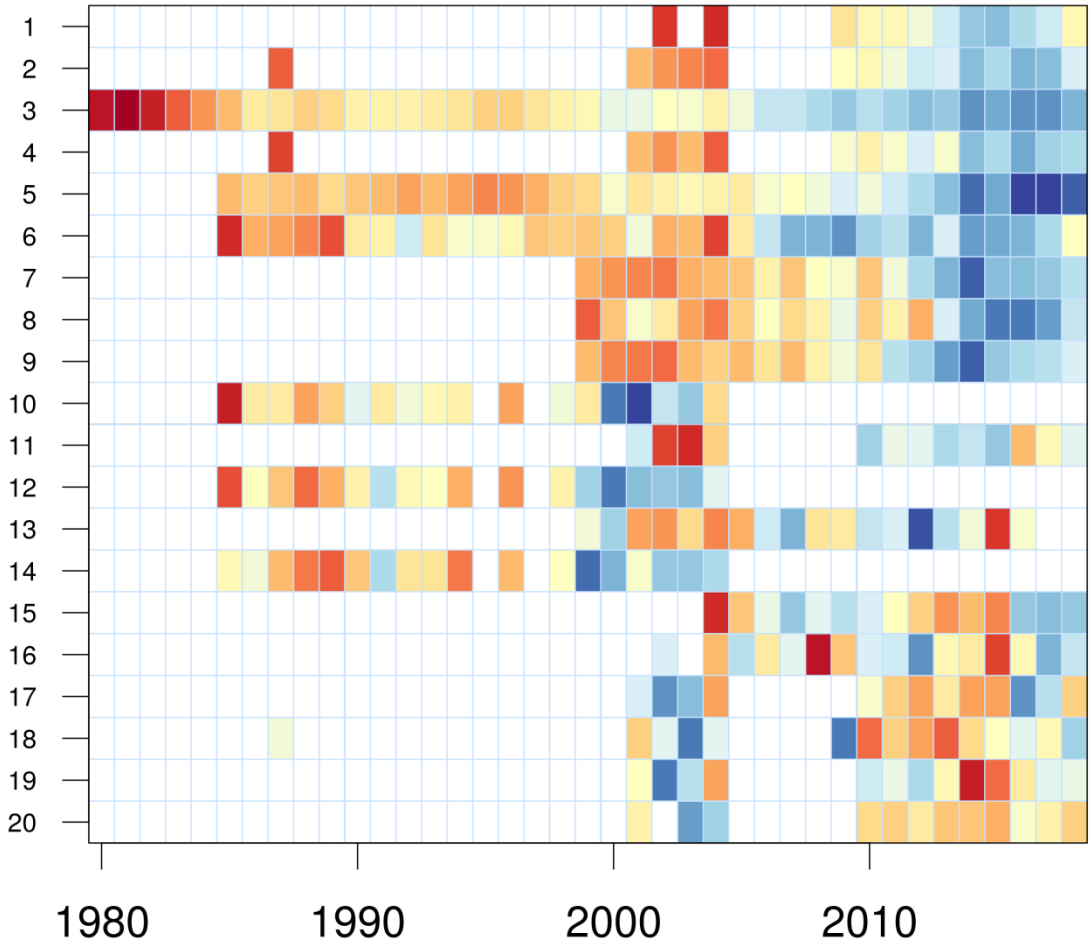


Figure 40. Time series of sorted ordination of the anomalies from the subset of biological and ecosystem indicators associated with LFA 32. See Table 8 for description of variables. The blue blocks indicate levels above the mean, red blocks indicate levels below the mean, and yellow blocks indicate levels near the mean. The white blocks indicate <20 observations were available for that indicator and time period.

Table 8. Description of biological and ecosystem indicators associated with LFA 32 ranked by loading in Principal Component Analysis (PCA) 1.

Rank	Variable	PCA1	PCA2	Description
1	BiomassRecruits	1.04	-0.15	Biomass of recruits estimated from total landings and exploitation rates of new recruits (CCIR)
2	At.Sea.Landed.Abund.	1.04	-0.08	The total number of legal size lobsters landed in the fishery using the size frequency information from the at-sea samples
3	Landings.Wt	1.04	-0.14	Landings (in T)
4	At.Sea.Reprod.Pot	1.01	-0.18	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from at-sea samples
5	CPUE	0.93	-0.13	Commercial catch rates
6	Effort	0.82	0.15	Total effort (trap hauls)
7	FSRS.Sub-legal.CPUE	0.79	0.49	Catch rates of lobsters (70–82.5 mm) from FSRS recruitment traps
8	FSRS.Legal.CPUE	0.79	0.15	Catch rates of lobsters (>82.5 mm) from FSRS recruitment traps
9	FSRS.Shorts.CPUE	0.76	0.54	Catch rates of lobsters (<82.5 mm) from FSRS recruitment traps
10	Port.Landed.Abund	0.64	-0.71	The total number of legal size lobsters landed in the fishery using the size frequency information from port samples
11	At.Sea.Prop.NewRec	0.59	0.56	The proportion of newly recruited lobsters (MLS:MLS+11mm) in the at-sea samples
12	Port.Reprod.Pot	0.55	-1.02	The estimated reproductive potential (number of eggs) estimated from sex ratios, maturity ogives, and length frequency information from port samples
13	Temperature	0.38	-0.32	Bottom temperature (˚C)
14	Port.Prop.Mature	0.29	-0.84	The proportion of mature lobster samples from port samples
15	FSRS.Rec.Prop.Berried	0.21	-0.38	The proportion of berried females from FSRS recruitment trap samples
16	ExploitationCCIR	0.15	-0.82	Continuous change in ratio exploitation rate
17	At.Sea.Median.CL	-0.21	-0.74	The median carapace length of at-sea sampled lobsters
18	At.Sea.Prop.Mature	-0.3	-0.31	The proportion of mature lobster from at-sea samples
19	At.Sea.Prop.Berried	-0.35	-0.76	The proportion of berried lobsters from the at-sea samples
20	At.Sea.Max.CL	-0.78	-0.5	The maximum (upper 95% CI) size of lobster observed in an at-sea sample

Ecosystem Considerations

Long-term increases in water temperature in the Gulf of Maine and other areas have been linked to increased moult frequency and growth rates (McMahan et al. 2016). Increased growth rates allow for more rapid transition through the sensitive early life stages and increased 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 to the 1990s and continue to remain at low levels (e.g., Atlantic cod, Mohn and Rowe 2012; Bundy et al. 2017). The decrease in groundfish stocks reduces the predation pressure on small lobsters, allowing for greater survival through early life stages, improved recruitment, and overall lobster production (Boudreau and Worm 2010). More research on the impacts of climate change on lobster in LFAs 27–32 is needed to provide greater insight into this complex relationship.

Bycatch

At-sea sampling data collected during commercial fishing trips is used to estimate the incidental catch in the lobster fishery. These data contain individual lengths of species caught; however, if length was not available, appropriate counts were recorded and converted to lengths using the estimated median length for that species from samples available in the At-Sea Sampled dataset. The weight of each individual was calculated using species (and where possible sex) specific length to weight conversion coefficients obtained from the Ecosystem Survey database. The mean weight per trap haul was estimated for each LFA, and was prorated to the amount caught in the fishery using the total number of traps hauled in the fishery for that season. The estimated weight of the top five bycatch species are presented for recent fishing seasons in Tables 9–13. For LFAs 29 and 30, there was insufficient data to estimate bycatch on an annual basis, so all available data was used to calculate an overall annual estimate that was stratified by year (Table 10).

Table 9. Estimated bycatch (tonnes) for recent fishing seasons in LFA 27.

Species	2011	2012	2013	2014	2015	2016	2017	2018
Atlantic Cod	15.47	38.01	13.78	16.42	10.91	18.73	27.16	16.77
Atlantic Rock Crab	28.31	68.35	25.83	6.92	6.77	23.94	11.76	15.90
Cunner	8.29	7.01	3.41	5.43	10.56	18.11	30.62	25.92
Sea Raven	0.00	6.28	1.19	6.43	6.92	20.96	13.17	23.60
Shorthorn Sculpin	9.25	51.38	11.30	14.71	18.99	28.61	25.29	31.29

Table 10. Estimated annual bycatch (tonnes) for recent fishing seasons between 2012–2018 in LFA 29 and LFA 30.

Species	LFA 29	LFA 30
Atlantic Cod	0.56	0.82
Atlantic Rock Crab	3.38	0.76
Cunner	0.63	1.01
Sculpin (ns[1])	2.92	0.92
Sea Raven	0.27	0.53

[1] Not Specified (contains Longhorn and Shorthorn Sculpin)

Table 11. Estimated bycatch (tonnes) for recent fishing seasons in LFA 31A.

Species	2015	2016	2017	2018
Atlantic Cod	2.11	2.27	5.71	2.57
Atlantic Rock Crab	6.95	7.57	5.85	8.02
Cunner	1.89	4.71	2.28	2.10
Sculpin (ns[1])	8.18	12.08	9.96	27.41
Sea Raven	0.36	0.39	0.11	0.80

[1] Not Specified (contains Longhorn and Shorthorn Sculpin)

Table 12. Estimated bycatch (tonnes) for recent fishing seasons in LFA 31B.

Species	2011	2012	2013	2014	2015	2016	2017	2018
Atlantic Cod	5.60	6.61	2.68	2.51	12.40	7.90	21.94	5.88
Atlantic Rock Crab	2.93	3.95	8.08	1.06	15.65	16.61	9.68	12.49
Cunner	0.38	0.87	0.13	0.00	0.14	1.43	1.02	1.80
Sculpin (ns[1])	1.64	6.37	4.35	0.88	12.54	17.39	7.83	16.88
Jonah Crab	13.94	7.07	1.39	0.31	0.20	0.32	0.76	2.09

[1] Not Specified (contains Longhorn and Shorthorn Sculpin)

Table 13. Estimated bycatch (tonnes) for recent fishing seasons in LFA 32.

Species	2011	2012	2013	2014	2015	2016	2017	2018
Atlantic Cod	15.89	8.56	5.38	2.88	14.99	7.96	9.52	14.61
Atlantic Rock Crab	46.92	21.66	15.66	7.95	5.64	10.72	21.37	16.52
Cunner	0.88	2.05	0.26	2.08	1.09	1.81	1.03	2.25
Sculpin (ns[1])	20.25	14.69	10.96	13.33	23.43	25.07	28.28	20.03
Jonah Crab	45.91	59.51	18.57	1.10	0.41	5.55	18.25	7.14

[1] Not Specified (contains Longhorn and Shorthorn Sculpin)

Assessment Frequency and Interim Updates

It was agreed that the Lobster stock in LFAs 27–32 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

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 positive signals for all LFAs. The stock status indicator, CPUE, is at its highest level in the time series for six of the seven LFAs. The primary indicator for exploitation, the CCIR models from the FSRS data, are annually variable; however, the 3-year running median indicates exploitation has been relatively stable in all LFAs, where data is available.

Precautionary approach reference points that were proposed at the 2018 Framework Assessment are illustrated in Figure 41. The phase plots show the relationship between commercial catch rates and CCIR exploitation rate in relation to the USR, LRP, and RR. The trends show increasing catch rates, with the CPUE index above the USR. The current status of the lobster stocks within each LFA is within the Healthy Zone and exploitation is below the RR.

The conservation measures implemented within these LFAs since the late 1990s and early 2000s, including increasing MLS, protecting windowed sized lobster, returning large females and v-notching program, have allowed for increased reproductive potential and productivity. The impacts of some conservation measures can be detected in some of the biological indicator trends (Cook et al. 2020). These conservation measures protect the reproductive components of the stock and buffer the impacts of years with suboptimal environmental conditions for lobster production.

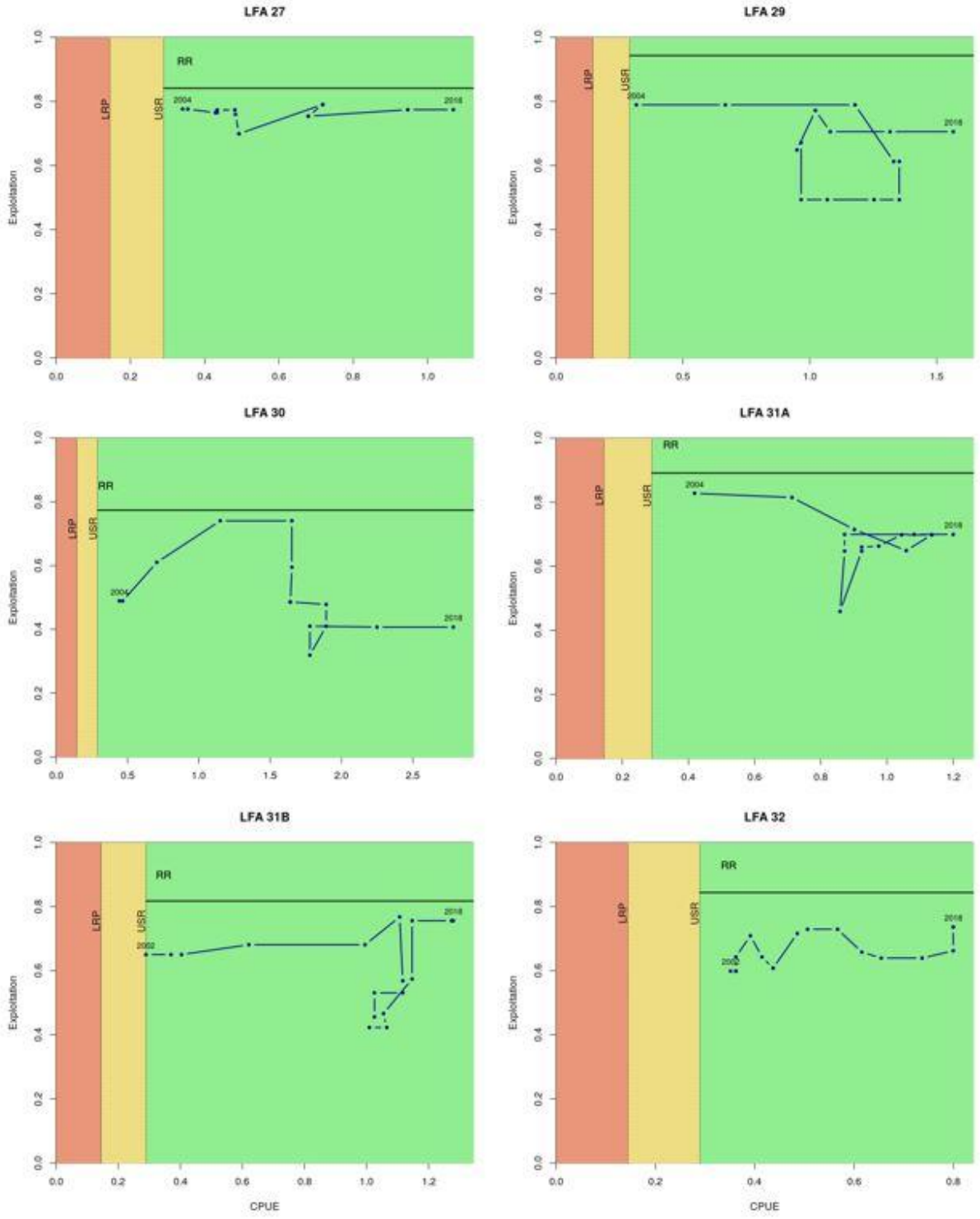


Figure 41. Phase plots using the 3-year running median of CPUE and 3-year running median of CCIR exploitation index compared against the proposed Upper Stock Reference (USR) and Limit Reference Point (LRP) based on commercial catch rates. The Removal Reference (RR) is the 75th quantile break of the posterior distribution for the maximum exploitation index respectively.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 11–12, 2019, LFA 27–32 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.

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