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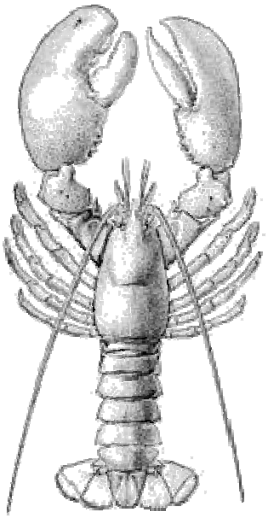
Canadian Science Advisory Secretariat
Science Advisory Report 2013/023

ASSESSMENT OF LOBSTER (*HOMARUS AMERICANUS*) IN LOBSTER FISHING AREAS (LFA) 35-38



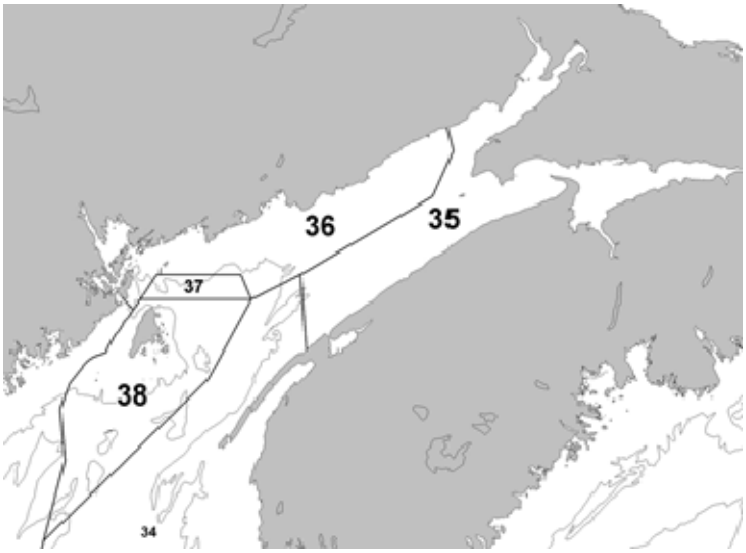


Figure 1. Lobster Fishing Areas (LFAs) 35-38 (Bay of Fundy).

Context

The landed value of the lobster fishery in Atlantic Canada ($396 million in 2010) is the highest of any fishery in Canada. Landings in Lobster Fishing Areas (LFAs) 35-38 (Figure 1) have reached record highs in recent years. The status of the lobster resources in LFAs 35-38 was last assessed in 2007. DFO's Fisheries and Aquaculture Management has requested updated information on the status of the LFA 34-38 lobster stocks.

A review of the Assessment Framework was held for LFAs 34-38 on July 10-12, 2012, in Digby, Nova Scotia. The objectives were to describe the basis of the management units in the context of stock structure; to identify strengths and weaknesses of fishery and survey data inputs; to present preliminary analyses of indicators of Fishery Performance, Abundance, Reproduction and Fishing Pressure; to review relevant biological and ecological information; to present the rationale for current landings-based reference points and potential alternatives; and to develop the assessment schedule. One outcome of the Framework review was the confirmation of two stock assessment units: LFA 34 and LFAs 35-38.

This Science Advisory Report is from the February 12-14, 2013, Review of Framework and Assessment for LFA 34-38 Lobster Stocks: Part 2 – Assessment. The objectives were to assess the stock status of the LFA 34-38 lobster stocks as of the end of the 2011-2012 seasons, including status in relation to reference points identified in the Assessment Framework; to estimate the level of incidental catch (including lobster), the retention of non-lobster species, and to report on information available on the survival of discarded species; as well as to provide implications for fishery management of the current estimates of the 50% size at onset of maturity for females, and other indicators of stock reproduction. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

The Fishery

- Current lobster (*Homarus americanus*) landings are very high in the Bay of Fundy (Lobster Fishing Areas, LFAs 35-38) as a whole and in the individual LFAs. Landings in 2011-12 were more than 5 times the 50-year annual mean (1,628 t), were more than 2 times higher than 2005-06 (latest year in the 2007 assessment), and each of the last 5 years has been a new record high.
- Reported effort in LFAs 35-38 has increased both in terms of average days fished since 1997-98 and in total trap hauls since 2005-06 (1.2 times those reported for 2005-06).
- Commercial catch per unit effort (CPUE in kg/trap haul) in the Bay of Fundy has increased in all LFAs since 2005-06. In the Bay of Fundy as a whole, the 2011-12 CPUE (1.9 kg per trap haul) was 1.8 times that of 2005-06. This increase in CPUE, coupled with increased fishing effort, explains the increase in landings in the Bay of Fundy since 2005-06.
- The largest size of female lobsters in the legal portion of the catch in commercial traps has trended downward in the last decade in some parts of the Bay of Fundy (LFA 36 and part of LFA 35).

Assessment

- Two fishery dependent indicators of the abundance of legal size (landings and commercial CPUE) are at record highs.
- The catch rate in the Fishermen's and Scientists Research Society standard traps is considered an indicator of sublegal abundance. The time series is short, but the catch rates in the last two years are two of the highest for LFA 35.
- The proportion of summer Research Vessel survey sets with lobsters indicates a wider distribution of lobsters at sufficient density to be caught routinely in the trawl survey.
- The mean number of lobster per tow in the summer Research Vessel survey was consistently low from 1970 to the late 1990s and increased thereafter. Numbers increased dramatically in the most recent years (2011 and 2012).
- There is insufficient information to reliably estimate the exploitation rate for the Bay of Fundy as a whole, but the rate is expected to be lower than in LFA 34. Given that the environmental conditions remain favorable for lobster, the current levels of fishing effort do not appear to threaten the sustainability of lobster stocks in LFAs 35-38.
- Historical and current estimates of size at maturity for the Bay of Fundy (North Head) were evaluated. Evidence indicates that the size at maturity has declined in the Bay of Fundy since the 1980s.
- The contribution of egg production from larger females has declined in recent years.
- Given the important gap between the minimum legal size and size at onset of 50% maturity (SOM50), and the low reproductive capability of small mature individuals, additional measures that increase or maintain egg production from larger sizes (e.g. protection of large females greater than SOM50) should be considered. Such measures can improve stock resilience if conditions become less favorable for lobster production.

- Despite an increase in lobster abundance over the last 20 years, observed egg production has not increased in the same manner. Mating success of small mature females was lower and, thus, their contribution to egg production was lower than expected.
- A precautionary approach proposed for lobster in LFAs 35-38 utilizes reference points for the abundance of legal sizes (landings, commercial catch rate), and legal and sublegal sizes (summer RV catch rate). These indicators are above their Upper Stock References (USR), indicating that the lobster stock in LFAs 35-38 is in the healthy zone.
- Landings-based reference points for the abundance of legal size lobsters are based on the median of the lobster landings from 1985-2009. The USR for LFAs 35-38 as a whole is 1,575 t. The 3-year running mean is 6,936 t for the season ending 2011-12, putting these LFAs in the healthy zone, well above this USR.
- A proposed USR for abundance of legal size lobster is 50% of the median commercial CPUE for the period 2005-06 to 2008-09. The current 3-year mean (1.6 kg per trap haul) is well above the proposed USR (0.58 kg per trap haul).
- A proposed fishery-independent USR for legal and sublegal lobster abundance is 80% of the median catch rate in summer Research Vessel survey in the Bay of Fundy for the period 1985-2009. The median for this period is 2.4 lobsters per tow, the proposed USR is 80% of this, or 1.9 lobsters per tow. The 3-year running mean as of 2012 was 25.7 lobsters per tow, which is well above the proposed USR.

Ecosystem Considerations

- Based on previous patterns in the North Atlantic Oscillation, warmer than average water temperatures might be expected on the southwest Scotian Shelf and Bay of Fundy in the next few years. In terms of longer term trends in temperature, there is a slightly increasing trend in the Bay of Fundy that may be significant, but the Halifax station indicates no long term trend in temperature.
- The trends in the summer Research Vessel survey biomass indices for potential predators of lobster (e.g. Atlantic wolffish, cod, cusk, haddock, longhorn sculpin, sea raven, spiny dogfish, white hake) indicate most are at low levels relative to their long-term means.
- The area affected by lobster traps (fishery footprint) in any given year in LFAs 35-38 is calculated to be less than 0.05% of the total area.

BACKGROUND

Lobster Biology

Off southwestern Nova Scotia and the Bay of Fundy, most female lobsters (*Homarus americanus*) mature between 90 and 105 mm carapace length (CL). The mature female mates after molting in midsummer and, in the following summer, produces eggs that attach to the underside of the tail. The eggs are carried for 10-12 months and hatch mainly in July or August. The larvae are planktonic for a few weeks to a month or more depending on temperature. There are 3 larval stages followed by a postlarval stage (“Stage 4”) that is planktonic for a few days until it begins diving to the bottom to begin the benthic phase of life. Once the post larvae find suitable shelter on the bottom, they tend to remain in or near the shelter to avoid predation. As lobsters moult and become larger, they leave their shelters more often to forage.

Off southwestern Nova Scotia and the Bay of Fundy, lobsters are thought to take 8-10 years on average to reach the legal size of 82.5 mm CL, but lobster age at size may be quite variable based on recent studies. The maximum age of lobsters is unknown but, based on growth information and long term holding studies, it is believed to be in the range of 50 years. Growth increments at moult are dependent upon size, sex and maturity with the mean growth increment for males and immature females between 12-16% (Carapace Length CL), while mature females exhibit a declining percentage increase with size as more energy is invested in egg production.

Lobsters seasonally migrate to shallower waters in summer and deeper waters in winter. Over most of the lobster's range, these movements amount to a few kilometres; however, in the Gulf of Maine, the offshore regions of the Scotian Shelf and off New England lobsters can undertake long distance migrations of tens to hundreds of kilometers.

Benthic stage lobsters are omnivorous, being mostly predators but scavenging prey items when available. Examination of juvenile and adult lobster stomach contents has found a wide variety of benthic organisms, including gastropods, bivalves (scallops, clams, mussels), chitons, crustaceans (e.g. rock crab), starfish and brittle stars, sea urchins, various marine worms (polychaetes), fish and occasionally plant material. Lobsters are also opportunistic feeders on fish eggs, discarded lobster shells and dead animals including fish, marine mammals and bait in lobster traps.

Stock Assessment Units

Based on the degree of spatial and temporal integrity of population characteristics, Lobster Fishing Areas (LFAs) 35 to 38 (Bay of Fundy) are assessed here as a single assessment unit but separately from adjacent LFAs. Studies indicate that there is exchange among the Bay of Fundy LFAs at various life history stages and that the landings in the different LFAs have trended in a similar manner. There is some exchange of lobsters at the benthic stage between LFAs 35-38 and LFA 34, but LFA 34 is large, has some genetic structure, and appears to receive a limited portion of its larvae from the Bay of Fundy. In addition, LFA 34 landings trends have differed from those of the Bay of Fundy.

Lobster stock structure in Atlantic Canada is currently being evaluated through a variety of approaches. While there may not be substantial changes to the current perspective, these studies will increase understanding of the levels of differentiation at different scales, and will test the findings from previous studies on larval exchange rates.

The Fishery

LFAs 35-38, in the Bay of Fundy (Figure 1), have unique seasons and trap limits differ in LFA 38 (375) compared to LFA 35 and 36 (300). LFA 37 is a shared area where fishermen from LFAs 36 and 38 are authorized by licence condition to fish.

Commercial lobster fishing began in the mid-1800s, and annual lobster landings for the Bay of Fundy were first recorded in 1893. In the Bay of Fundy, the landings peak in 1896 (2,791 t) was followed by a decline to 53 t in the early 1900s (Figure 2). Landings rose again until 1909 and then trended downwards until the late 1930s. Annual landings rose following World War II and were relatively stable for 20 years before declining to a low point in 1976. From 1986-87 to 1993-94, seasonal landings were stable with a mean of 994 t. Since the mid-1990s, there has been an unprecedented increase in the landings. This increasing trend is part of a pattern that extended over most of the range of lobster in the western Atlantic.

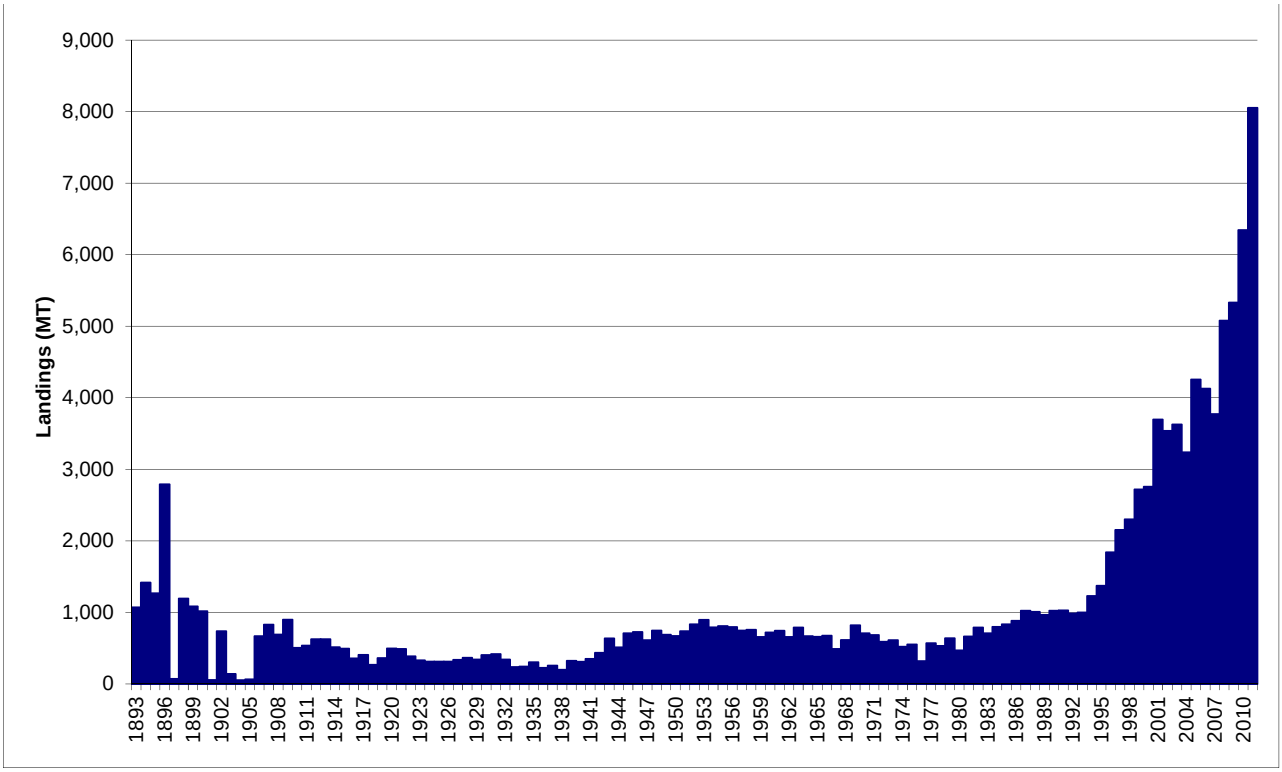


Figure 2. Annual lobster landings by the commercial fishery in LFAs 35-38, 1893 to 2011.

During the early part of the Bay of Fundy fishery, management regimes evolved independently in each lobster fishing area. As a consequence of improvement in technology, such as hydraulic haulers, bigger and faster boats, Loran C and eventually global positioning systems, and changes in the way that lobster fishing was conducted, outer boundary lines were established between LFAs in 1986. Evidence based on information from the grid based logbooks introduced in 2003 indicates that an important component of the Bay of Fundy lobster fleet has expanded their fishing effort to deeper water further from shore and from their home port, thereby exploiting most of the available lobster grounds.

Lobster fisheries in LFAs 35, 36 and 38 are managed by input controls including a minimum legal size of 82.5 mm CL, prohibition on landing of both V-notched or berried females, and limited entry, seasons and trap limits (Table 1). The trap limit is 300 in LFAs 35-36 and 375 in LFA 38. Other management measures include the requirement for escape vents to allow escapement of sublegal sizes, and biodegradable trap mechanisms to mitigate ghost fishing by lost traps.

In 1977, declarations by both Canada and the US delimited Exclusive Economic Zones (EEZ), also known as 200 mile limits. These declarations resulted in overlapping claims to marine territory in the Gulf of Maine, including the area surrounding Machias Seal Island. In summer 2002, a summer-fall lobster fishery was opened to Canadian fishermen in a disputed area being fished by American fishermen called the Grey Zone. This area is in the western part of the LFA 38 lobster fishing grounds during the regular fishing season, and it is fished by American fishermen throughout the year (including the summer months when LFA 38 is closed).

The LFA 38B fishing season begins June 30 each year, at 0001 hours and ends at 2400 hours on the Friday immediately preceding the opening of the regular LFA 38 lobster season. The trap limit is 375 for a single lobster licence and 563 for a partnership licence.

Table 1. Seasons, trap limits, licenses (as of January 2013) and minimum legal size for LFAs 35-38.

	Lobster Fishing Area (LFAs)		
	LFA 35	LFA 36	LFA 38
Fishing Season	Oct 14 to Dec 31; Feb 28 to Jul 31st	2nd Tuesday in Nov to Jan 14; Mar 31 to Jun 29	2nd Tuesday in Nov to Jun 29
Number of traps per Category A (License B)	300 (90)	300 (90)	375 (113)
Number of traps per Category A Partnerships			
Category A Licences	75	135	65
Category A Partnerships	2	26	54
Category B	3	1	1
Commercial Communal Category A	13	13	12
Commercial Communal Partnership	2	2	4
Minimum legal size	82.5 mm carapace length		

ASSESSMENT

Data Sources

Data sources used in this assessment are as follows:

1. Historical landings and landings from various sources; effort, catch and location from Lobster Catch and Settlement Reports (logbooks), begun in 2004 and generally adopted by 2005-06.

2. Samples of the at-sea trap catch to estimate size, sex and reproductive status.

3. Annual DFO Science summer Research Vessel (RV) survey from 1970-present.

4. Annual joint DFO/industry groundfish survey (ITQ survey), which records lobster as a bycatch. This is a fixed station bottom trawl survey that began in 1995.

5. The Fishermen and Scientists Research Society (FSRS) recruitment trap project. Begun in LFA 35 in 2006-07. Volunteer fishermen keep daily records of lobster count, size and sex in two standard traps.

6. Annual survey for scallops, which began in 1982 and captures lobsters as a bycatch.

The Bay of Fundy, with its three LFAs, is a diverse fishing area, with specific Grid Groups identified for assessment purposes (Figure 3). Some Grid Groups were based on depth of water to give a nearshore and deeper water area perspective. Others were developed based on historical lobster size differences.

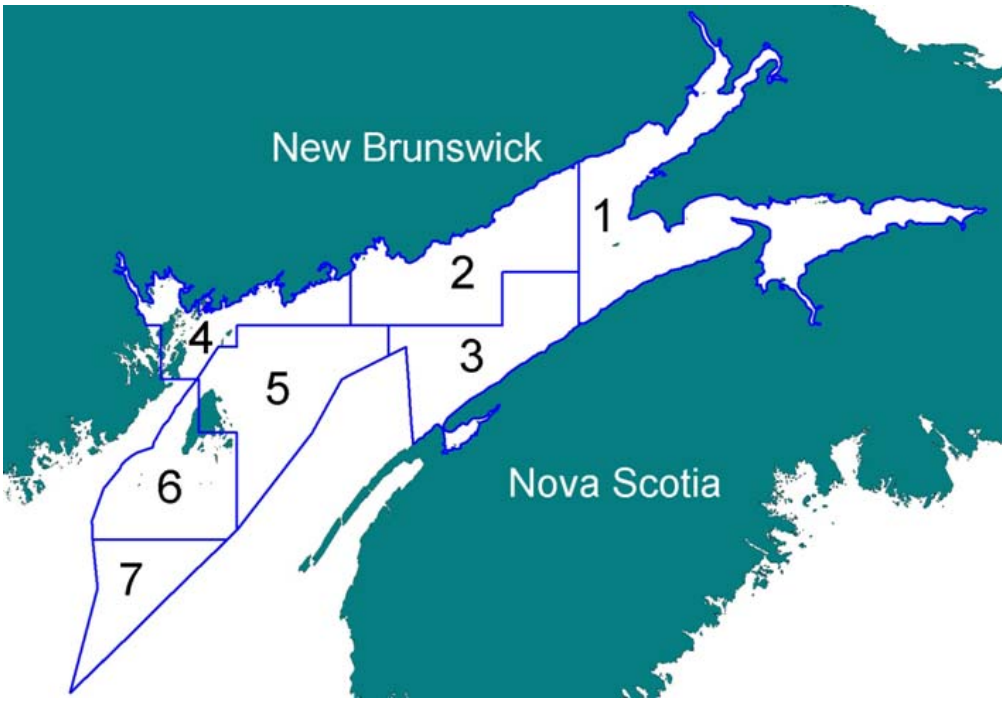


Figure 3. Grid Groups from combinations of 10 minute grids in LFA 35-38 logbooks.

Fishery Performance

Landings and catch rate have been used as abundance indicators; trends in these measures are reported, as well fishing effort and the size of lobsters in commercial traps.

Fishery Landings

Current lobster landings are very high in the Bay of Fundy as a whole and in the individual LFAs (Table 2). Landings in 2011-12 were more than 5 times the 50-year annual mean (1961-2010 = 1,628 t), were more than 2 times higher than 2005-06 (latest year in the 2007 assessment), and each of the last 5 years has been a new record high. Considering the period from 1975-76 to 2011-12, nine of the last ten years are in the upper quartile, the other year was in the third quartile.

Within the Bay of Fundy LFAs, the landings increase has been widespread. For example, from 2001-02 to 2011-12, the landings in each LFA increased by a factor of 2.0 (LFA 36) to 2.6 (LFA 38).

Table 2. LFA 35-38 landings from the 1975-76 season to the 2011-12 season, as of Jan 1, 2013. Each cell is coloured depending on whether it is below the 25th percentile (black), between the 25th and 75th percentiles (grey) or above the 75th percentile (white). Values include commercial communal removals. Food, Social and Ceremonial (FSC) landings are not included but, given the effort deployed, are expected be no more than of 0.1-0.5% of the totals in recent years.

FISHING SEASON	LFA35	LFA36	LFA38	LFA 35-38
1975/1976	132	115	294	541
1976/1977	120	58	170	348
1977/1978	157	47	351	555
1978/1979	137	176	302	615
1979/1980	75	126	347	548
1980/1981	132	156	236	524
1981/1982	133	195	390	718
1982/1983	135	225	378	738
1983/1984	164	211	365	740
1984/1985	226	266	334	826
1985/1986	246	281	316	843
1986/1987	330	327	329	986
1987/1988	265	340	384	989
1988/1989	271	310	468	1,049
1989/1990	255	221	467	943
1990/1991	227	271	495	993
1991/1992	261	260	512	1,033
1992/1993	239	257	472	968
1993/1994	241	274	523	1,038
1994/1995	338	318	661	1,317
1995/1996	546	427	600	1,573
1996/1997	738	680	551	1,969
1997/1998	837	788	701	2,326
1998/1999	923	826	809	2,558
1999/2000	910	879	826	2,615
2000/2001	1,074	1,032	984	3,090
2001/2002	1,219	1,261	1,145	3,625
2002/2003	1,234	1,155	1,073	3,462
2003/2004	1,337	1,169	1,133	3,639
2004/2005	1,172	1,143	1,363	3,678
2005/2006	1,235	1,295	1,595	4,125
2006/2007	1,191	1,138	1,413	3,742
2007/2008	1,488	1,477	1,855	4,820
2008/2009	1,617	1,596	1,638	4,851
2009/2010	1,898	1,594	2,035	5,527
2010/2011	2,546	1,916	2,352	6,814
2011/2012	3,245	2,481	2,741	8,467

Fishery Effort

The total annual trap hauls reported in 2011-12 for LFAs 35-38, adjusted for reporting, were 1.2 times those reported for 2005-06 (Table 3). Reported effort in terms of average days fished has also increased. From the 1997-98 season to the 2011-12 season, the average days fished increased from 64 to 68 (LFA 35), 37 to 52 (LFA 36) and 42 to 62 (LFA 38). The trends in the

annual number of trap hauls and in the average number of days fished provide evidence for a gradual increase in fishing effort in the Bay of Fundy over the last 6 years and since 1997-98.

It is noted that even though the average number of days fished has increased within the Bay of Fundy, overall it is still lower than in LFA 34. Total number of days fished is also lower in LFAs 35-38, as is the total number of trap hauls on an area basis.

To summarize, reported effort in LFAs 35-38 has increased both in terms of average days fished since 1997-98 and in total trap hauls since 2005-06 (1.2 times those reported for 2005-06).

Commercial Catch Rate

Commercial catch per unit effort (CPUE in kg/trap haul) in the Bay of Fundy has increased in all LFAs since 2005-06 (Table 3). In the Bay of Fundy as a whole, the 2011-12 CPUE (1.9 kg per trap haul) was 1.8 times that of 2005-06. This increase in CPUE, coupled with increased fishing effort, explains the increase in landings in the Bay of Fundy since 2005-06. The CPUE in the Bay of Fundy has increased in Grid Groups 1 to 5, but has shown no trend in Grid Groups 6 and 7, east of Grand Manan (Figure 4).

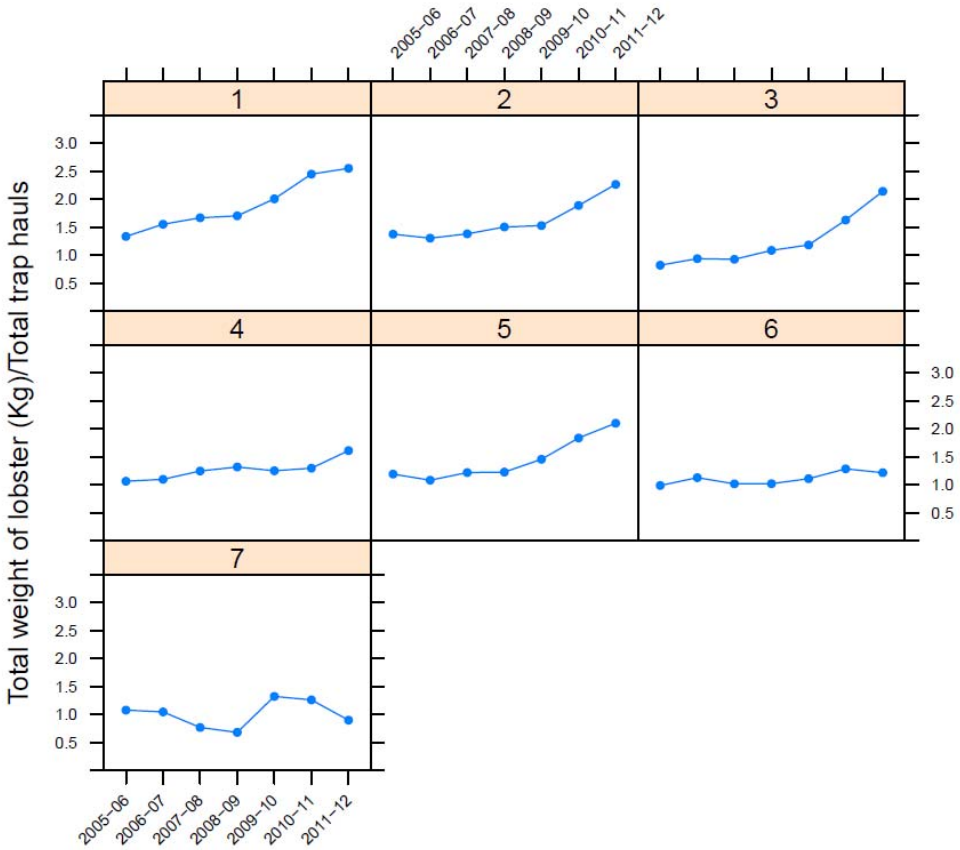


Figure 4. Commercial lobster CPUE in Bay of Fundy Grid Groups 1 to 7.

Table 3. Landings, effort and commercial CPUE in LFAs 35-38 from the estimate portion of fishermen logbooks (Lobster Catch and Settlement Records). CPUE is calculated only from those records that have data for landings, effort and location.

LFA	Season	Weighout slip landings (t)	Records with landings or effort data		Records with landings, effort and grid location			Adjusted Effort (no. trap hauls)
			Landings (t)	Effort (no. trap hauls)	Landings (t)	Effort (no. trap hauls)	CPUE (kg/th)	
35	2005-06	1,235	1,220	799,558	707	736,986	0.96	1,286,663
	2006-07	1,191	1,191	770,500	839	719,351	1.17	1,020,923
	2007-08	1,488	1,458	1,185,804	1,385	1,126,189	1.23	1,210,317
	2008-09	1,617	1,681	1,215,644	1,542	1,132,433	1.36	1,187,128
	2009-10	1,898	1,996	1,274,617	1,793	1,161,987	1.54	1,229,841
	2010-11	2,546	2,782	1,361,352	2,389	1,190,569	2.01	1,268,854
	2011-12	3,245	3,618	1,471,667	3,137	1,319,638	2.38	1,364,860
36	2005-06	1,295	1,232	792,037	816	708,501	1.15	1,123,838
	2006-07	1,138	1,122	725,816	765	666,551	1.15	991,943
	2007-08	1,477	1,432	1,060,996	1,333	1,041,201	1.28	1,153,823
	2008-09	1,596	1,523	1,078,437	1,395	1,029,394	1.36	1,177,831
	2009-10	1,594	1,611	1,202,730	1,445	1,112,384	1.30	1,227,214
	2010-11	1,916	1,921	1,292,233	1,703	1,188,572	1.43	1,337,349
	2011-12	2,481	2,587	1,419,790	2,219	1,274,447	1.74	1,425,035
38	2005-06	1,595	1,550	1,078,747	1,059	1,015,729	1.04	1,530,259
	2006-07	1,413	1,410	841,430	907	809,024	1.12	1,260,724
	2007-08	1,855	1,805	1,650,193	1,704	1,605,781	1.06	1,748,087
	2008-09	1,638	1,593	1,443,874	1,424	1,338,779	1.06	1,539,497
	2009-10	2,035	2,001	1,626,506	1,808	1,510,269	1.20	1,699,866
	2010-11	2,352	2,272	1,532,987	2,064	1,447,913	1.43	1,650,122
	2011-12	2,741	2,725	1,670,693	2,315	1,518,713	1.52	1,797,855
35-38	2005-06	4,125	4,002	2,670,342	2,583	2,461,216	1.05	3,931,270
	2006-07	3,742	3,723	2,337,746	2,511	2,194,926	1.14	3,271,459
	2007-08	4,820	4,695	3,896,993	4,421	3,773,171	1.17	4,113,337
	2008-09	4,851	4,797	3,737,955	4,362	3,500,606	1.25	3,893,217
	2009-10	5,527	5,608	4,103,853	5,046	3,784,640	1.33	4,145,276
	2010-11	6,814	6,975	4,186,572	6,156	3,827,054	1.61	4,236,428
	2011-12	8,467	8,930	4,562,150	7,672	4,112,798	1.87	4,539,140

Size in Commercial Traps

Considering at-sea samples from 1989 to the present, the largest size (95th percentile, Figure 5) of female lobster in the legal portion of the catch in commercial traps has trended downward in the last decade in some parts of the Bay of Fundy (LFA 36 and part of LFA 35).

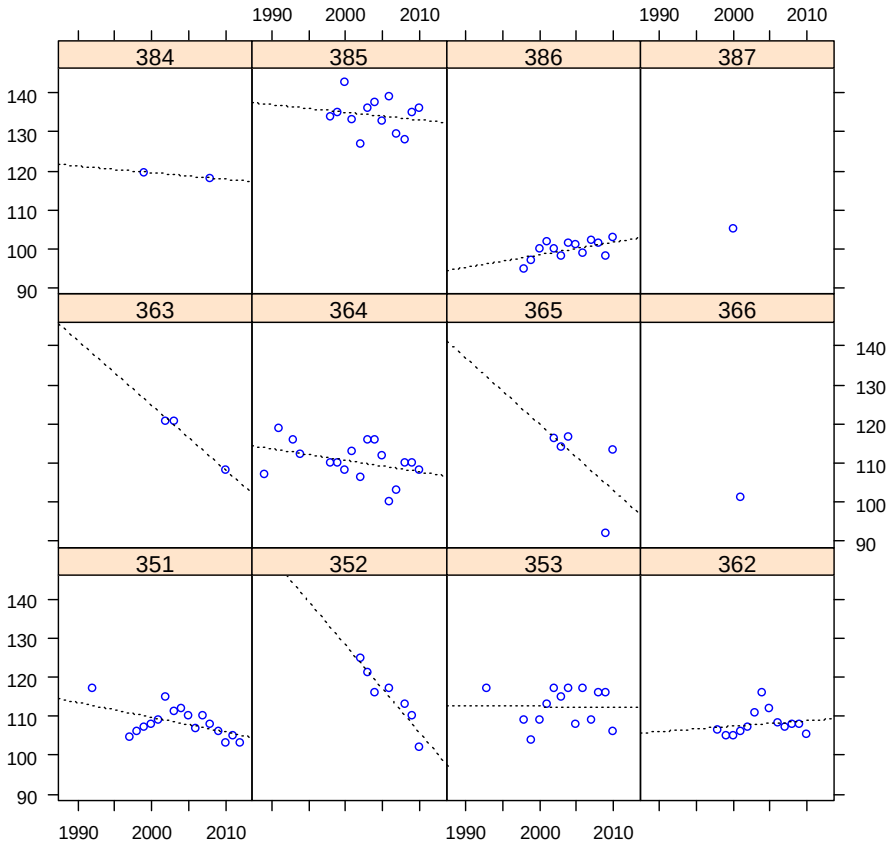


Figure 6. Trend in large female size lobster from the legal (≥82.5 mm) portion of at-sea samples in LFA 35-38 Grid Groups, 1989-2012. The 95th percentile by year is shown. Ovigerous females are excluded. The dotted line is the linear fit. Subpanel labels are comprised of the LFA (first two digits) and Bay of Fundy Grid Group (last digit).

Abundance Indicators – Fishery Dependent

Two fishery dependent indicators of the abundance of legal size (landings and commercial CPUE, as described above) are at record highs.

The catch rate in the FSRS standard traps is considered an indicator of sublegal abundance. While the traps used are not commercial and are designed to retain small lobsters, they are deployed during fishing operations and are, in that sense, fishery dependent. Data from the standardized traps were used to evaluate abundance trends of sublegal lobsters using a Generalized Additive Mixed Model (GAMM), which allows for the incorporation of zeros and uses the number of traps hauled as an offset. The time series is short (2005-06 to 2011-12), but the catch rates in last two years are two of the highest for LFA 35.

Abundance Indicators - Fishery Independent Surveys

The summer RV trawl survey is a source of fishery independent information on lobster. The survey has been conducted since 1970. However, nearshore areas (<50 m depth) where lobsters are most abundant are not sampled because of untrawlable bottom. Strata 490-495 cover the Bay of Fundy, including a portion of LFA 34 (Figure 7).

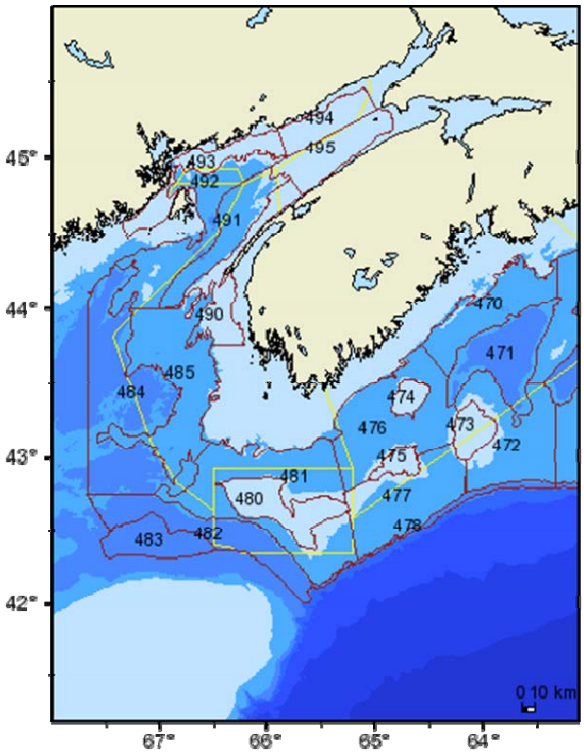


Figure 7. Summer Research Vessel survey strata in the western portion of the Maritimes Region.

Expansion and contraction in spatial range or in depths occupied by a species can be an indicator of the changes in population size or shifts in distribution due to the environmental changes. The proportion of summer Research Vessel sets with lobsters, increasing from <20% in the mid-1990s to averaging over 80% in the last 10 years, indicates a wider distribution of lobsters at sufficient density to be caught routinely in the trawl survey (Figure 8).

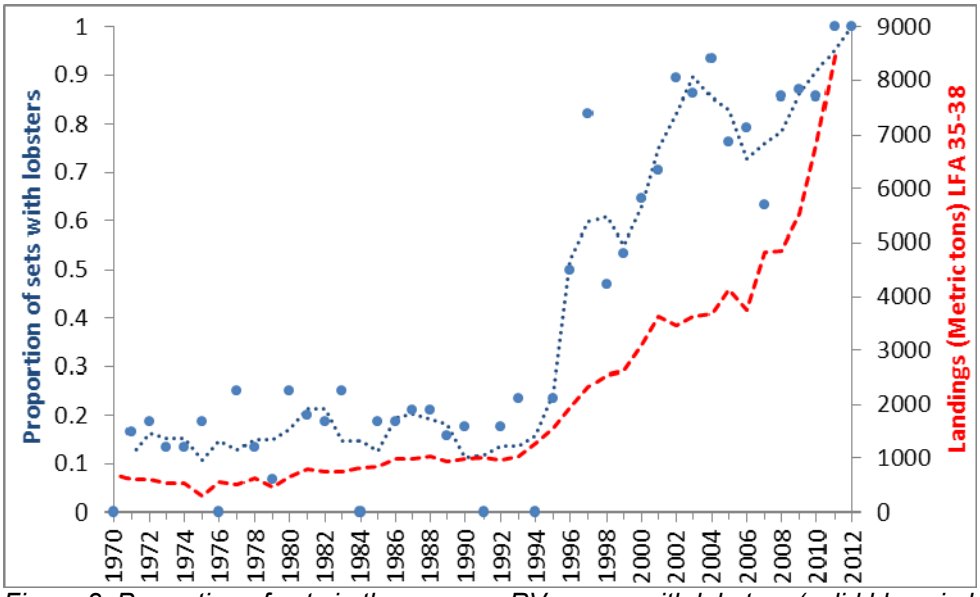


Figure 8. Proportion of sets in the summer RV survey with lobsters (solid blue circles), with the 3-year moving average (blue dotted line) and LFA 35-38 lobster landings (red dashed line).

The mean number of lobster per tow in the summer RV survey, considered as a primary indicator of lobster abundance, was consistently low from 1970 to the late 1990s and increased thereafter (Figure 9). Mean number per tow increased dramatically in the most recent years (2011 and 2012).

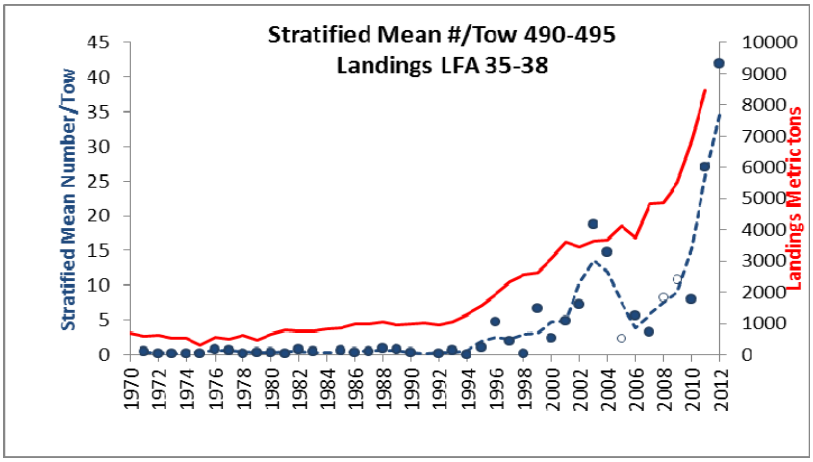


Figure 9. Stratified mean number of lobster per tow in LFAs 35-38 in the summer RV survey. Dotted line is the 3-year moving average. The landings for LFA 35-38 (red solid line) are also shown.

The ITQ survey mean number of lobster per tow (Bay of Fundy) is provided as a secondary indicator of lobster abundance in the Bay of Fundy (Figure 10). The trend in the mean number per tow corroborates the trends in the RV survey and lobster landings.

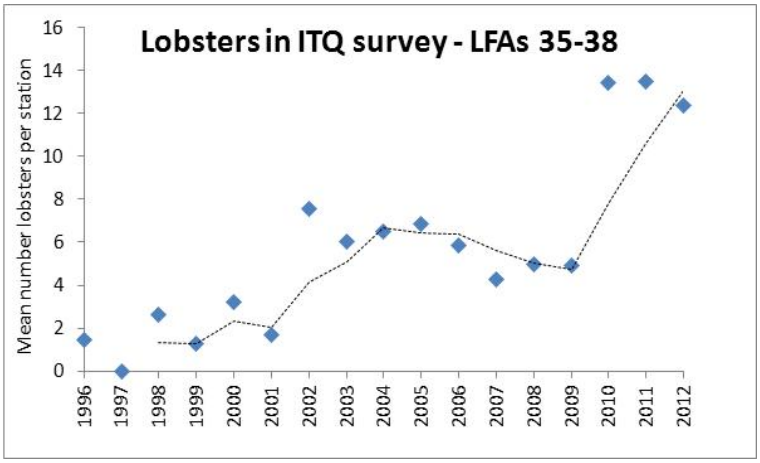


Figure 10. Mean number of lobster per tow in the ITQ survey in the Bay of Fundy, 1996-2012. The dotted line is the 3-year moving average.

Scallop survey catch rates of lobsters show trends similar to the summer RV and ITQ surveys where comparisons are possible. The scallop surveys have more limited application as fishery independent indicators of lobster abundance as they have changed in design (spatial coverage, timing) and have lower catch rates per tow of lobsters.

To summarize, the summer RV and the ITQ survey number of lobsters per tow have both increased since 1996. There has been an expansion of the area with lobster catches in the surveys, which suggests a widespread increase in abundance.

Fishing Pressure

The Continuous Change in Ratio (CCIR) method is used to estimate Exploitation Rate (ER). As this method requires data on sublegal and legal sizes, the FSRS data from LFA 35 were utilized. There is insufficient information to reliably estimate the exploitation rate for the Bay of Fundy as a whole. Data were limited to the fishing seasons 2007-08 to 2011-12 and two Bay of Fundy Grid Groups (Grid Group 1 in the upper Bay, and Grid Group 3 on the Nova Scotia side of the lower Bay).

CCIR estimates ER for a size fraction of the exploitable stock based on the change in ratio of the harvestable fraction to an unharvestable ("reference") fraction. To avoid potential problems with differential catchability, it is best to limit the exploitable sizes to those close to the reference size class. As such, the ER estimates provided here are for lobsters between 82.5 and 90 mm CL, a size fraction that makes up a high proportion of the catch in LFA 35. This size fraction is highly relevant, but it is important to recognize that the CCIR estimates do not include the larger size fractions.

Results for LFA 35 are summarized in Table 4. The CCIR method applied here resulted in a high proportion of estimates with wide confidence intervals, so partial results for just 4 years are displayed in Table 4. Of the available estimates with confidence intervals less than +/- 0.3, the average was 0.66 for Grid Group 1 in the upper Bay and 0.88 for Grid Group 3 in the lower Bay. It is expected that the exploitation rate in the Bay of Fundy is lower than in LFA 34.

Table 4. Average annual exploitation estimates for LFA 35 for seasons 2006-07 to 2011-12, for male and female lobsters. Brackets contain the number of years the estimate is based on.

	Males	Females	Total
LFA 35, Grid Group 1	0.61 (3)	0.74 (2)	0.66
LFA 35, Grid Group 3	0.91 (1)	0.84 (1)	0.88
Total	0.68	0.77	0.72

Reproduction

Historical and current estimates of size at maturity for the Bay of Fundy (North Head) were evaluated by accessing an unpublished data set from the 1980s and by conducting a new field study. Evidence indicates that the size at maturity has declined in the Bay of Fundy since the late 1970s. The size at onset of 50% maturity (SOM50) was estimated at 99.8 mm CL versus 108.3 mm CL in Campbell and Robinson (1983).

Several new estimates of SOM50 were obtained for lobsters in the Bay of Fundy in 2011. These varied among locations from 90.2 mm to 103.6 CL. This variability is hypothesized to be an artefact caused by mating failure and small sample sizes. In locations where mating success was higher, SOM50 was around 91 mm CL, indicating that a downward shift in maturity has occurred since the late 1970s. This trend is corroborated by the decreasing size of the smallest berried females in the Bay of Fundy.

Because of the downward shift in the SOM50 and the increased abundance of lobsters, the total egg production potential (predicted from the maturity ogive) increased substantially in four representative locations (Alma, Dipper Harbour, North Head and Seal Cover) when comparing the last 5-7 years to a historical time period in the 1980s (Figure 11). However, the observed egg production index, based on catch rates and fecundity-at-size of ovigerous females, did not increase to the same extent. This discrepancy between the observed egg production versus egg production potential was caused by a lower than expected contribution to egg production by small

mature females (Figure 12), likely because of low mating rates, and a reduction in the catch rates of large females. In addition, egg production is hypothesized to be limited by a lack of large males, especially for North Head (i.e. sperm limitation), or saturation of the mating grounds because the proportion of males has increased in some regions (e.g. Alma, Dipper Harbour, and Seal Cove). This is consistent with the declining trend in large berried females.

In summary, despite an increase in lobster abundance over the last 20 years, observed egg production has not increased in the same manner. Mating success of small mature females was lower and, thus, their contribution was lower than expected.

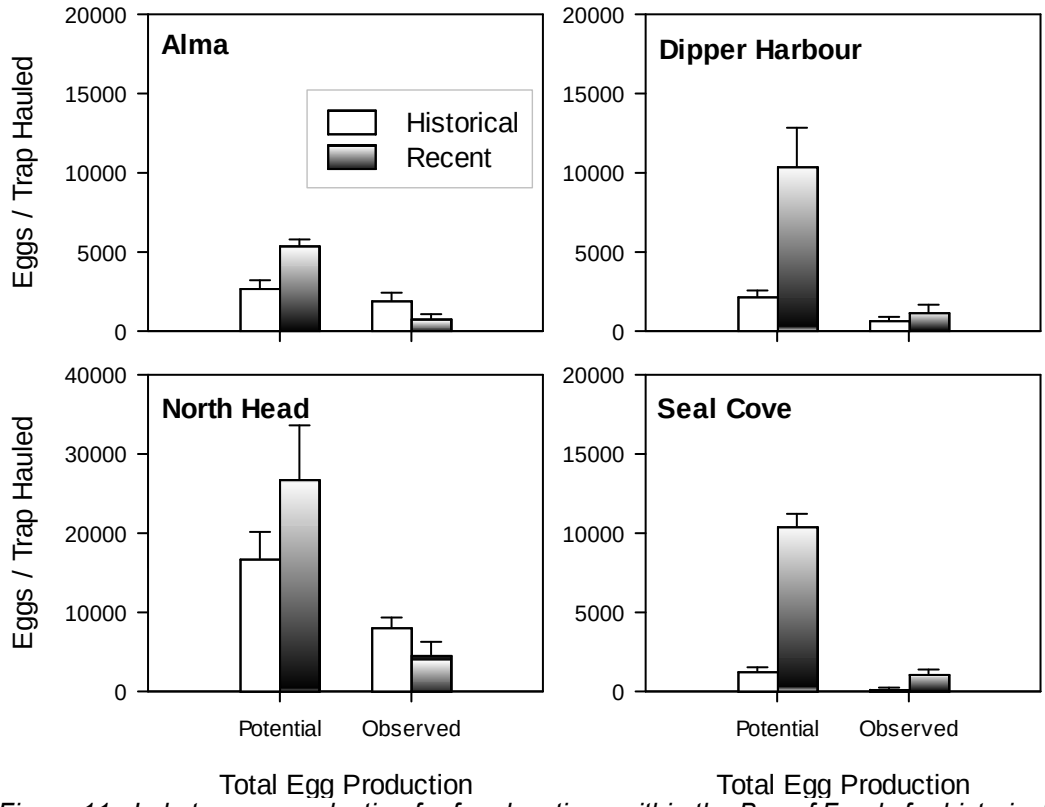


Figure 11. Lobster egg production for four locations within the Bay of Fundy for historical (1980s) and recent time (past 5-7 years) periods. Potential egg production (based on non-ovigerous females) and observed egg production (based on ovigerous females) are shown.

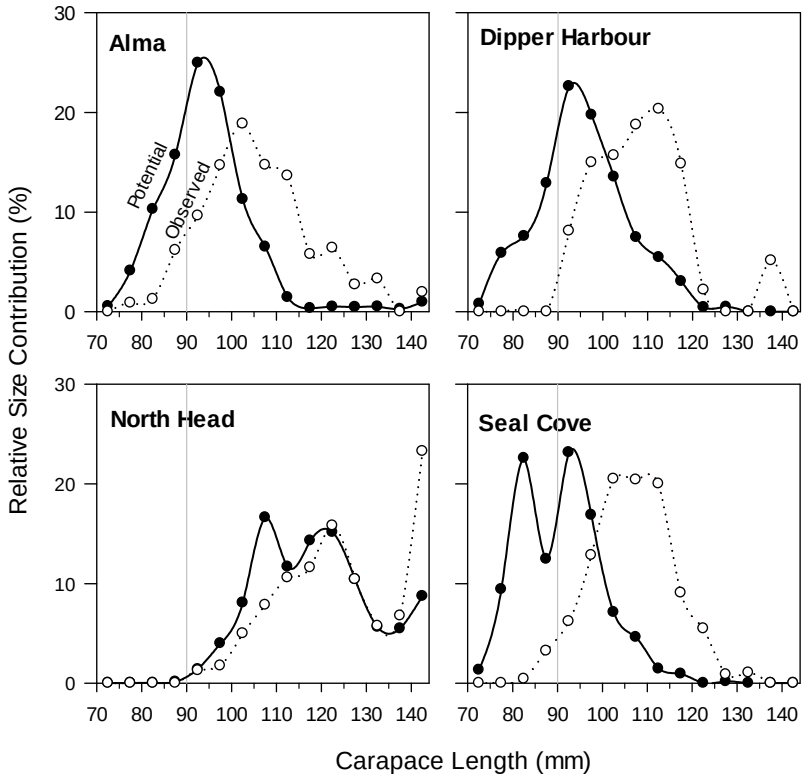


Figure 12. Contribution of different sized lobsters to egg production in four locations within the Bay of Fundy for the past 5-7 years. Solid line is the potential egg production (based on non-overigerous females) and the dotted line is the observed egg production (based on overigerous females). Grey vertical lines represent size at onset of 50% maturity.

Ecosystem Considerations

Temperature

The North Atlantic Oscillation (NAO) plays a major role in year-to-year changes in ocean climate off eastern US/Canada. In the past, the NAO Index has been considered a potential predictor of temperature in the following 2+ years, with a low NAO index often resulting in lower temperatures on the southwest Scotian Shelf and Bay of Fundy. However, a very low 2010 NAO index resulted in very warm 2012 temperatures throughout the region, the warmest on record, and throughout the water column (up to 2 degrees higher than average in some places). In 2012, the NAO index was high. Based on previous patterns, warmer than average water temperatures might be expected on the southwest Scotian Shelf and Bay of Fundy in the next few years. In terms of longer term trends in temperature, there is a slightly increasing trend in the Bay of Fundy that may be significant, but the Halifax station indicates no long term trend in temperature.

Predation

The increase in lobster abundance in the Gulf of Maine has been hypothesized to be a release from predation by groundfish and/or a shift to a more favorable climate. Known and suspected predators of lobsters include cunners, longhorn sculpins, skates, cod, spiny dogfish, sea ravens, cusk, wolfish, haddock, hake, crabs and seals. Predation rates are highly size-specific and decline as lobsters get larger. The trend in the summer RV survey biomass indices for potential predators

of lobster indicate most are at low levels relative to their long-term means (Table 5). The exception is sea raven, which is well above its long term mean. Atlantic wolfish and cod are both low, at 4% and 13%, respectively, of their long-term means (1970-2009). The recent summer RV survey index for haddock is closer to its long-term mean but still below. Recent summer RV survey indices for cusk, spiny dogfish, white hake and longhorn sculpin, are at 30-64% of their long-term means. Given the current low summer RV survey indices for most of these potential lobster predators, a near-term increase in the natural mortality of lobsters in the Bay of Fundy due to these species is not expected.

Table 5. Summer RV survey biomass index (t) of potential predators of lobster in the Bay of Fundy. The long term mean estimates and the estimates for recent years as a percentage of long-term values are shown. The area used to calculate the survey indices was North Atlantic Fisheries Organization subdivisions 4Xopqrs.

Species	Long-term mean 1970-2009	Recent mean 2010-2012	Recent mean as % of long-term mean
Atlantic Wolffish	861	33	4%
Cod	13,410	1,718	13%
Cusk	2,166	464	21%
Haddock	21,240	15,141	71%
Longhorn Sculpin	1,195	759	64%
Sea Raven	1,468	1,916	131%
Spiny Dogfish	79,821	28,291	35%
White Hake	16,437	8,966	55%

Fishery Footprint

LFA 35-38 encompasses approximately 15,000 km^2. The area affected by lobster traps ("footprint") on an annual basis in LFAs 35-38 was estimated using the number of trap hauls per season times the area of a typical lobster trap. This was then divided into the total area of LFAs 35-38. The trap size used was 21"x48" (American style trap), which does not account for movement of the traps. However, the analysis assumes that traps are dropped in a new location each time, which does not account for the expected overlap in trap footprints over time. The area affected by traps (fishery footprint) in any given year in LFAs 35-38 is calculated to be less than 0.05% of the total area.

Reference Points

A precautionary approach proposed for lobster in LFAs 35-38 utilizes reference points for the abundance of legal sizes (landings, commercial catch rate), and legal and sublegal sizes (summer RV catch rate). These indicators are above their Upper Stock References (USR), indicating that the lobster stock in LFAs 35-38 is in the healthy zone.

Landings-based reference points for the abundance of legal size lobsters are based on the median of the lobster landings from 1985-2009 as a Biomass at Maximum Sustainable Yield (B_{MSY}) proxy (Tremblay, Pezzack and Gaudette 2012; Table 6). For the upper stock reference (USR) and limit reference point (LRP), the values of 80% and 40% were used. These values are provided for each LFA in the Integrated Fisheries Management Plan for LFA 27-38 (DFO 2011). For assessment purposes, landings reference points are evaluated for the Bay of Fundy as a whole. The Upper

Stock Reference (USR) for LFAs 35-38 as a whole is 1,575 t. Where there were observations of lower landings from 1985-2009 from which the fishery recovered, the lowest point of a 3-year running average was used as the LRP. The mean of the last 3 years is taken as the metric to assess whether landings have dropped below the USR. The 3-year running mean is 6,936 t for the season ending 2011-12, putting these LFAs in the healthy zone, well above this USR.

Table 6. Landings-based reference points for LFAs 35, 36 and 38.

	LFA 35-38
B_{MSY} proxy - Median 1984-85 to 2008-09	1,969 t
Upper Stock Reference	1,575 t
Limit Reference Point	788 t
3-Year Running Mean	6,936 t

A USR based on commercial CPUE is proposed. For LFAs 35-38, the time series of reliable catch and effort data is only 7 years. It is proposed that the median CPUE from the start of the CPUE series (2005-06) to 2008-09 (=1.16 kg/ trap haul) be used as a basis for the USR. Because the short time series is restricted to a period of high abundance, the USR is adjusted to the expected CPUE levels in the mid-1990s based on landings and estimated effort; thus, the proposed USR is set at 50% of the median (0.58 kg per trap haul) (Figure 13).

As for the landings based USR, it is proposed that the mean of the last 3 years be taken as the metric to assess whether CPUE has dropped below the USR. The current 3-year mean (1.6 kg per trap haul) is well above the proposed USR.

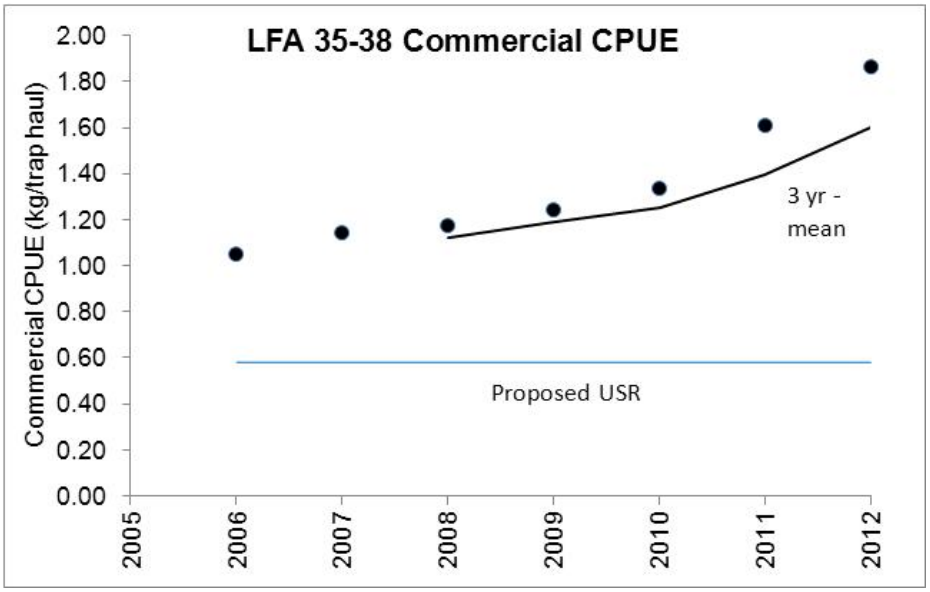


Figure 13. Proposed Upper Stock Reference (USR) based on CPUE for LFAs 35-38. Shown is annual commercial CPUE (total weight landed/total trap hauls). Proposed USR (0.58 kg/trap haul) is 50% of the median CPUE for the period 2005-06 to 2008-09 (1.16 kg/trap haul). Also shown is the 3-year running mean (= 1.6 after 2011-12 season).

A fishery independent USR is proposed for legal and sublegal lobster abundance in the Bay of Fundy based on the median catch rate in the summer RV surveys in strata 490-495. It is proposed to use the period 1985-2009 as the basis for comparison of future trawl catch rates of lobsters. The median for this period is 2.4 lobsters per tow, the proposed USR is 80% of this, or 1.9 lobsters

per tow (Figure 14). The 3-year running mean as of 2012 was 25.7 lobsters per tow, which is well above the proposed USR (1.9 lobsters per tow).

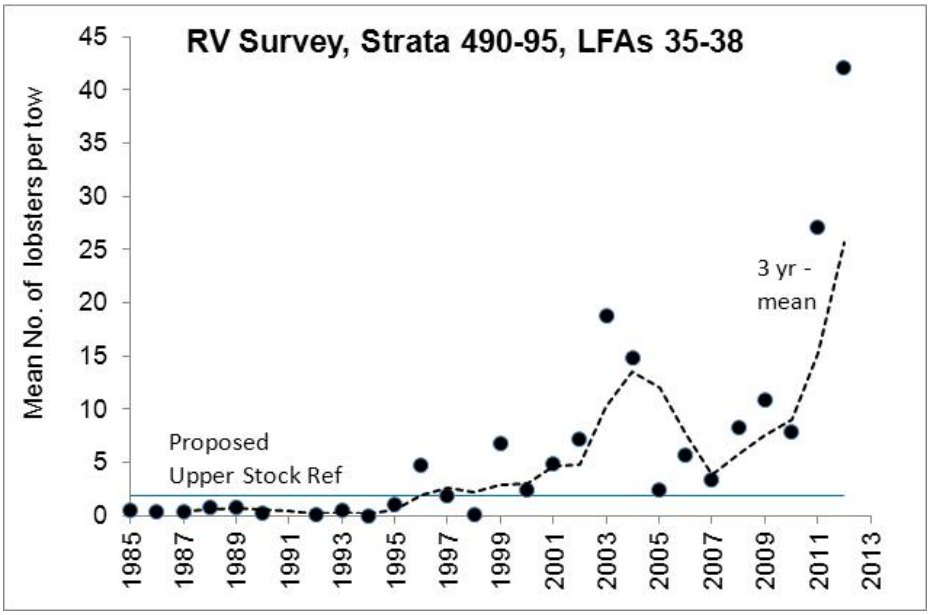


Figure 14. Proposed reference point for lobster abundance in LFA 35-38 based on summer RV survey. The median for 1985 to 2009 (2.4 lobsters/tow) is used as the B_{MSY} proxy. Proposed Upper Stock Reference is 80% of the median (1.9 lobsters/tow). Solid line is 3-year running mean.

Secondary indicators may both change the perception of stock status and inform the type of response to a stock that has entered the cautious zone (Tremblay et al. 2012). The primary indicators need to be interpreted in the light of secondary indicators related to Abundance/biomass (commercial sizes), Production (recruitment, reproduction), Demography (size structure, sex ratio), Fishing Pressure (effort, exploitation) and the Environment. Spatial changes in distribution should also be considered. For example, if the RV trawl catch rate for the Bay of Fundy declines, the changes within the Grid Groups should be examined. While these secondary indicators will not necessarily be evaluated on an annual basis, they will be evaluated should the primary indicators change substantially. The reduction in the contribution of larger lobsters to reproduction is an aspect that needs to be monitored at the level of the secondary indicators.

Sources of Uncertainty

It is assumed that the subset of commercial fishing logbooks with useable data is representative of all logbooks. This is reasonable given that useable records in recent years accounted for upwards of 80% of all records and catches, and 90% of all effort.

Landings are a function of abundance, the level of fishing effort (trap hauls, soak-days, timing of effort and fishing strategy) and catchability. Catchability in turn is affected by environmental conditions, gear efficiency including trap design and bait, and other factors. Changes in any of these can affect landings and catch rates. Thus, landings do not necessarily reflect the changes in abundance. Area-specific commercial CPUE should be more closely related to true abundance but will still be affected by catchability.

Any changes in fishing efficiency (or “effective effort”) have not been accounted for here. If fishing efficiency has increased in the last five years due to larger vessels, better navigation or improved fishing strategy, then the catch rate index may inflate the perception of abundance in recent years. Given that the catch rate of lobsters in fishery independent surveys has showed a trend similar to that based on commercial logbooks, recent changes in fishing efficiency are unlikely to be important to the perception of abundance.

Number of sea sampling trips has generally been low for most years and, thus, intra-annual sampling variability as well as potential annual differences in catchability are sources of uncertainty in the egg production indices. However, averaging trends among different time periods is believed to alleviate the issue of this low sampling intensity and, therefore, the trend described here is expected to reflect what is happening in the stock.

FSRS traps are limited to small portions of LFA 35 and may not represent the sublegal sizes in the rest of LFAs 35-38.

The fishery independent surveys show abundance trends similar to those seen in fishery dependent data, but examination of size structure has not detected changes over the last 10 years as might be expected given a surge in recruitment. In addition, there is interannual variation in the number of lobsters per tow that is reflected in both sublegal and legal size lobsters.

Exploitation rate for the Bay of Fundy was estimated from a limited number of FSRS traps in a few locations of LFA 35. Other datasets were insufficient to provide estimate for the Bay of Fundy as a whole. Additional data is required to be able to reliably estimate exploitation rates.

CONCLUSIONS AND ADVICE

Abundance of lobsters in the Bay of Fundy is near record highs. Conditions for lobster production in the Bay of Fundy are very favorable now. Although effort has increased since the last assessment in 2007, exploitation rates are not as high as some adjacent Lobster Fishing Areas. Given that the environmental conditions remain favorable for lobster, the current levels of fishing effort do not appear to threaten the sustainability of lobster stocks in LFAs 35-38.

A concern should environmental conditions become less favorable is that the contribution of egg production from larger females has declined in recent years and is lower now than in the 1980s. Given the important gap between the minimum legal size (82.5 mm CL) and SOM50 (>91mm), and the low reproductive capability of small mature individuals, additional measures that increase or maintain egg production from larger sizes (e.g. protection of large females greater than SOM50) should be considered. Such measures can improve stock resilience if conditions become less favorable for lobster production.

OTHER CONSIDERATIONS

Although current exploitation rates are unlikely to threaten sustainability of lobsters in LFA 35-38 under current conditions, through “recruitment overfishing”, lower exploitation rates would very likely increase yield per recruit. Previous estimates of yield per recruit for some of these LFAs (Miller et al. 1987, Idoine et al. 2001) indicated yield per recruit would increase with decreased effort or increased minimum legal size. A yield per recruit analysis was outside the scope of this assessment and would have to account for changes since the last analysis, such as updated values for size at maturity. Potential density dependent effects on growth and maturity would also need consideration. Economic considerations could also be built into the analysis.

Future of surveys, particularly fishery independent surveys, to support the indices and ongoing evaluation of stock status are uncertain. If these were to change, indicators and reference points may need to be re-evaluated.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 12-14, 2013, Review of Framework and Assessment for LFA 34-38 Lobster Stocks: Part 2 - Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Campbell, A., and D.G. Robinson. 1983. Reproductive potential of three American lobster (*Homarus americanus*) stocks in the Canadian Maritimes. Can. J. Fish. Aquat. Sci. 40(11): 1958-1967.

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