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Framework and Assessment for American Lobster, *Homarus americanus*, Fisheries in the Southern Gulf of St. Lawrence: LFA 23, 24, 25, 26A and 26B Cadre de travail et évaluation des pêcheries de homard, *Homarus americanus*, dans le sud-ouest du golfe du Saint-Laurent : ZPH 23, 24, 25, 26A et 26B

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ABSTRACT

The 2005 lobster (Homarus americanus) stock status of the five Lobster Fishing Areas (LFA) located in the Gulf Region has been assessed using indicators primarily based on a fisheryindependent trawl survey in LFA 25 and part of LFA 26A, SCUBA surveys in LFAs 23, 25, 26A, fishery-based data from DFO official catch statistics, at-sea sampling, voluntary indexharvesters logbooks, voluntary recruitment-index logbooks, and biological sampling. The abundance indicators based on landings of legal size lobster from all LFAs except 25, are close to or above the long-term median. Landings in the central Northumberland Strait (southern half of 25 and western half of 26A) are below the long-term median. Similar trends in abundance were observed based on the fishery-independent trawl survey. The fishing pressure indicators show that most of the catches consist of new recruits (i.e., lobsters growing to commercial sizes and entering the fishery for the first time). There is further evidence that the fishing pressure is too high based on estimates that 50% of traps are empty over the season in four of the five LFAs (LFA 24 had 24%). The production indicators based on pre-recruit logbook program and the trawl survey are negative in Northumberland Strait and positive elsewhere. An increase in berried females catch rates was observed, except in LFA 25 and part of LFA 26A located in the Northumberland Strait. Fishery-independent data (SCUBA) show that the density of 1-2 year olds (<40 mm carapace length) has increased in LFA 23, since 2000. It was low in LFAs 25 and 26A in 2005 and 2006, the only years sampled. The ecosystem indicators show that climatic conditions for the sGSL are warming, and temperature has been rising in all areas. In terms of larval drift and survival, current observations and models suggest that the Northumberland Strait is essentially an isolated system relying on itself for recruitment unlike the rest of the sGSL. In LFA 25, rock crab form the largest part of the lobster diet and the principal predator on lobster is shorthorn sculpin. The lobster fishery continues to rely heavily on the annual recruitment and the exploitation rate remains high. A reduction in the exploitation rate would allow more lobsters to survive to grow to larger size. In LFA 25, the timing of the opening of the fishery overlaps with the lobster spawning period and impedes measures to increase egg production through the protection of berried females. Increases in the minimum legal size in all lobster fishing areas would also lead to increased egg production.

RÉSUMÉ

L'état des stocks de homard des cinq Zones de Pêche au Homard (ZPH) de la région du Golfe a été évalué en utilisant principalement des indicateurs indépendants de la pêche issus d'un relevé scientifique au chalut effectué dans la ZPH 25 ainsi que dans une portion de la ZPH 26A et de relevés en plongée sous-marine dans les ZPH 23, 25 et 26A. Des indicateurs dépendants de la pêche issus des statistiques officielles des débarquements, de projets d'échantillonnage en mer et biologique et de programmes volontaires de journaux de bord (« pêcheurs repères » et « indice de recrutement ») ont aussi été utilisés pour l'évaluation de 2005. Les indices d'abondance provenant des données de débarquements pour les homards de taille réglementaire sont similaires ou supérieurs à la médiane à long terme pour toutes les ZPH à l'exception de 25. Les débarquements dans le centre du détroit de Northumberland (portion sud de 25 et ouest de 26A) sont inférieurs à la médiane à long terme. Les résultats du relevé au chalut indépendant de la pêche démontrent des tendances similaires concernant l'abondance de homard. Les indicateurs de pression de pêche révèlent que la majorité des captures est composée de nouvelles recrues (i.e. des homards venant tout juste d'atteindre la taille réglementaire et qui sont accessibles à la pêche pour la première fois). De plus, le pourcentage élevé de casiers vides (50% sur l'ensemble de la saison de pêche) dans quatre des cinq ZPH (24% de casiers vides dans ZPH 24) indique que la pression de pêche est trop élevée. Les indices de production provenant du relevé au chalut et du programme de journaux de bord pour les pré-recrues sont négatifs dans le détroit de Northumberland mais positifs ailleurs. Une augmentation du taux de capture des femelles ovigères a été observée dans toutes les ZPH, hormis dans la ZPH 25 et dans la partie de 26A située dans le détroit de Northumberland. Les données indépendantes de la pêche (relevés en plongée) révèlent que la densité des homards de 1-2 ans (<40 mm de longueur de carapace) a augmenté dans la ZPH 23 depuis 2000 mais était basse dans 25 et 26A en 2005 et 2006 (seules années échantillonnées). Les indices écosystémiques indiquent que les conditions climatiques dans le sud du golfe du Saint-Laurent (sGSL) se réchauffent; la température étant à la hausse dans toutes les zones. Concernant la dérive des larves ainsi que leur survie, les observations actuelles ainsi que les modèles suggèrent que le détroit de Northumberland est un système essentiellement fermé (recrutement interne, peu d'apport externe) contrairement au reste du sGSL. Dans la ZPH 25, la diète du homard est composée majoritairement de crabe commun et le chaboisseaux à épines courtes est le principal prédateur de homard. La pêche du homard compte beaucoup sur le recrutement annuel et le taux d'exploitation demeure élevé. Une réduction de ce taux d'exploitation pourrait permettre à un plus grand nombre de homards de survivre et d'atteindre des tailles plus grandes. Dans ZPH 25, l'ouverture de la saison de pêche a lieu durant la saison de ponte et nuit aux mesures de conservation afin d'augmenter la production d'œuf en utilisant la protection des femelles ovigères. Une augmentation de la taille minimale réglementaire dans toutes les zones de pêche pourrait aussi augmenter la production d'œufs.

1. INTRODUCTION

The American lobster (*Homarus americanus*) fishery in Canada began in the mid-1800s throughout the Atlantic Provinces. In the southern Gulf of St. Lawrence (sGSL), the lobster fishery operates in all three Maritime Provinces (i.e. New Brunswick (NB), Nova Scotia (NS) and Prince Edward Island (PEI)) and Quebec (stock status assessed in a separate document). Over more than a century, the fishery in the sGSL essentially developed as a near shore smallboat fishery, involving a large number of harvesters using only lobster traps as fishing gear (DeWolf 1974; Brun 1985; Landry 1994).

1.1 Fishery Management

The Gulf Region of the Department of Fisheries and Oceans (DFO) managed 5 Lobster Fishing Areas (LFA) within the sGSL. The sGSL will hereafter refer to these 5 LFAs. The lobster fishery in the sGSL is managed entirely by effort control (input fishery) (Table 1). The four most important measures in controlling effort are the fixed number of lobster fishing licences, an individual trap allocation, restrictions on gear characteristics, and a delimited fishing season. Starting in 1934, the fishing activities were also limited by LFA (Fig. 1). In addition to those management controls, other measures were implemented to protect key components of lobster populations. Lobsters can only be retained if they comply with a minimum legal size (MLS) designed to allow some lobsters to reach sexual maturity before being harvested. Egg-bearing lobsters must also be released.

In 1994, the federal fisheries Minister asked the Fisheries Resource Conservation Council (FRCC) to review the current approaches to conservation, and to recommend strategies for sustainable exploitation of all Canadian lobster stocks. In their report (FRCC 1995), they concluded that the present fisheries were operating at excessively high exploitation rates; harvesting primarily immature animals; and not allowing for adequate egg production (estimated to be as low as one to two percent of what might be expected in an unfished population). While they accepted that lobster stocks have historically been resilient, they concluded that the risk of recruitment failure was unacceptably high and suggested that egg production be increased. A precautionary biological reference point was recommended in the form of an arbitrary target level of egg production per recruits (E/R) equivalent to 5% of that of an unfished population.

In 1998, the Department of Fisheries and Oceans (DFO) announced the first multiyear conservation plan (1998-2001) for the lobster fisheries in sGSL. After extensive consultations with the fishing industry, it was decided to double E/R values (from 0.5% to 1.0%) instead of the target of 5% proposed by the FRCC. To reach that target, all LFAs (except LFA 26B) increased their minimum legal size (MLS) and implemented a 50% v-notching on egg bearing females (except LFA 24). In addition, harvesters in LFA 23 reduced their trap allocation by 75 per harvester (25 per year for 3 years). Although the initial objective of doubling E/R was not achieved in all LFAs (mainly due to the non-compliance of 50% v-notch of the egg bearing females), progress was made in terms of increasing egg production (Lanteigne et al. 2004). To reach the initial goal, a second multiyear conservation plan (2003-2005) was announced that mainly dealt with further MLS increases and mandatory release of window-size (115-129 mm)

females. In 2004, the window-size female regulation was replaced by a maximum legal size of 114 mm of carapace length (CL) for females in LFA 25.

1.1.1 Lobster Fishing Areas

From 1934 to 1985, the sGSL lobster fishery was partitioned in four zones: 7B, 7B1, 7C, and 8. These zones were then renamed in the mid-1980s to: 24, 26, 23, and 25 respectively. In 1987, LFA 26 was further divided into 26A and 26B (Fig. 1). Starting in 1995, some harvester groups within LFA 26A wanted to be more proactive with lobster conservation measures and, to accommodate that initiative, some "sub-areas" were defined within LFA 26A. In 2006, LFA 26A had four sub-areas. Different management measures are implemented in these sub-areas (Table 1).

Since LFAs were not established based on the biological characteristics of individual populations but for management purposes, some encompass portions of different habitats and oceanographic regimes. Assessing the lobster fishery solely based on the existing management division might not reflect adequately the status of the lobster populations and/or the fishery itself. Therefore, for the purpose of this assessment, LFAs were divided in nine sub-regions (Fig. 1) to better reflect the lobster biological properties. LFA 23 was sub-divided in two: LFA 23BC that encompasses all of Baie des Chaleurs and LFA 23G which is the remainder of LFA 23 located on the GSL side. LFA 25 has also been divided in two sub-regions as specified in the last stock status meeting in 2004 (Comeau et al. 2004). LFA 25N refers to the northern part west of the Northumberland Strait neck (narrowest part of the western Strait near West Point) and LFA 26APEI includes all wharves from the eastern side of PEI, and LFA 26ANS includes mainland NS east of Pictou Island (a.k.a. the area east of the mud hole by local harvesters).

1.1.2 Number of lobster fishing licences

Following the introduction of limited access to lobster fishing licences in 1967, the number of licence holders has remained fairly stable (Table 1). In 2006, the sGSL (excluding Quebec waters) counted 3,273 licence holders. There are two types of licences (bona fide and communal) and three sub-types that dictate the number of traps allowed. The majority of licences is bona fide and benefit from a full trap allocation.

1.1.3 Trap allocation

The number of traps allowed per fishing licence has remained stable in the last 20 years except in LFA 23. Bona fide licence holders in that area were allowed 375 traps each but that allocation was reduced by 25 traps for three consecutive years starting in 1998 to finally reach 300 traps in 2000. The full trap allocation is 300 traps for LFAs 23, 24, 26A, and 26B and 250 in LFA 25.

1.1.4 Fishing gear restrictions

The only allowed gear to fish lobster in Canada is the trap. Trap dimension and design have changed and evolved through time and the arrival of hydraulic haulers on fishing vessels has allowed the use of larger lobster traps. However, the majority of traps currently in use are still under the maximum allowable dimensions of 125 x 90 x 50 cm (length, width, height). Building material (wood, metal, or a combination of both) and trap's shape (rectangular or bow) have changed over time as well as the number of entrances and parlors, the offsetting and inclination of the entrances, and the increase of the entrance's hoop ring diameter. In 1995, a maximum hoop ring diameter was implemented (152 mm) in LFA 23 followed in 2006 by LFA 25. No other LFA has a maximum hoop ring diameter regulation.

Some conservation measures were implemented to minimize waste or indirect fishing mortality by allowing sub-legal animals to avoid capture. These regulations stipulate that each trap must be fitted with both escape vents and biodegradable mechanisms. The escape vent consists of an opening, near the base of the trap, allowing sub-legal size lobsters to exit the trap before its being hauled to the surface. These vents are installed in the parlor section of the traps (section with no entrance from the outside). Since 1996, traps equipped with a rectangular shape mechanism are mandatory and the current dimensions for an escape opening are 127 mm (width) by 40 mm (height). The biodegradable mechanism consists of a portion of the trap wall that can detach or decompose if the trap is lost at sea. Because roughly 3% of the traps in use in the sGSL are lost at sea annually (Lanteigne 1999), the goal of this measure is to reduce the impact of those traps as they continue trapping marine animals (ghost fishing), including lobsters. The biodegradable panels' conservation measure was implemented in 1995 and a current standard panel must have a minimum opening of 89 X 184 mm.

1.1.5 Fishing season

There are two distinct lobster fishing seasons in the sGSL; the spring fishery (LFAs 23, 24, 26A and 26B) and the summer fishery (LFA 25), the latter generally incorrectly referred to as the "fall" fishery despite most of the lobster being caught before mid-September.

1.1.6 Minimum legal size

Numerous changes in MLS were implemented since the 1900s in sGSL. The most prominent one was the MLS of 63.5 mm that was imposed in 1957 (Table 2). Between 1987 and 2006, the MLS increased in the sGSL at different rate in different LFAs to reach 70 mm in LFAs 23, 24, 25, the majority of 26A, and 75 mm in LFA 26B. At the end of the current multiyear management plan, the MLS in LFA 26B will be at 76 mm CL (already implemented in LFA 26A west). The MLS is fixed primarily to allow a sufficient number of mature animals to produce offspring and ensure a sustainable recruitment (i.e., egg production). Significant progress was made in the sGSL to achieve a higher number of mature animals in the population. Hence, with a MLS of 63.5 mm less than 5% of the primiparous females were protected. For a more sound management, the minimum level of protection of primiparous females should be 50%. At a MLS of 70 mm, 35% of the primiparous females are now protected in most LFAs (Table 3) with LFAs 26A west and

26B (in 2007) going beyond the 50% protection level. Adjusting MLS with the size at the onset of sexual maturity at 50% would be a precautionary step for all LFAs.

1.1.7 Window-size and maximum size females

The overall steady decline of lobster landings in the sGSL prompted the implementation in 2003 of a new conservation measure aimed at protecting the larger brood stock to enhance egg production. All female lobsters having a CL between 115 and 129 mm were to be returned to the water. This conservation measure is still applied in spring fisheries, while all females larger than 114 mm in LFA 25 (summer-fall fishery) have to be released. Between 2003 and 2005, male lobster larger than 129 mm CL in LFA 25 also had to be released.

1.2 Landings

Lobster catch information for the sGSL can be traced back to the 1890s. High lobster landings reported at the turn of the 20th century were rapidly followed by an overall decline in the early part of the 1900s. Annual catches decreased from 15,000 t in 1895 to around 8,000 t between 1915 and 1975. Starting in the mid 1970s, lobster landings in the sGSL increased sharply (>2.5-fold) to the highest landing recorded of 22,000 t in 1990 (Fig. 2). Landings in 2005 (15,314 t) were still 53% above the long-term median (9,997 t) observed between 1947 and 2004. Although part of this latest increase in landings could be attributed to an increase in fishing power, favorable environmental factors are thought to be responsible for strong lobster recruitment success over its entire range from Labrador to North Carolina.

While landings increased in all LFAs, the timing of the peaks varied between LFAs as did the pattern of decline of landings following the peaks (Fig. 3). This reflects the heterogeneity of the spatial distribution and the temporal variability of the lobster resource in the sGSL. The exception to the pattern observed in the other LFAs is LFA 24, where the landings peaked in 2004 (Fig. 3). Also, it seems that the declining trend has been less pronounced in the spring fisheries with LFAs 26A and 26B currently experiencing somewhat stable landings. This is not the case in LFAs 23 and 25 where declining trends have been observed for years. LFA 25 has by far experienced the steepest declining trend (Fig. 3).

1.3 Purpose

The purpose of this document is to assess the 2005 stock status of lobster fisheries in the sGSL (LFAs 23, 24, 25, 26A and 26B) based on fishery and research trawl survey data, and to recommend an assessment framework, including indicators for monitoring the health of the lobster stocks and guide future assessments.

2. INDICATORS DERIVED FROM FISHERY INDEPENDENT DATA

2.1 Trawl Surveys in LFA25, 2000 to 2006

2.1.1 Methods and survey stations

The trawl survey was initially designed to detect between-year differences in abundance and distribution of commercial size-classes of lobster (Comeau et al. 2004) in LFA 25. Rather than a stratified random survey design, the study used a random-block experimental design where the blocks initially were of similar size and were based on differences in substrate particle size. A 2 X 2 nautical mile grid was placed over all of Northumberland Strait using 46° 30.000' North; 64° 00.000' West as the reference coordinate. For each grid, 30 to 40 primary stations and up to 15 alternate or optional stations were chosen at random (without replacement) from within each block (85 to 125 potential stations per block). Due to the draft of the survey ship, waters shallower than 4 m (at Lowest Normal Tide) were not sampled. For 2002 and part of 2003, wing width was recorded at 5 minutes, 10 minutes, and 15 minutes into each tow using ultra-sonic sensors (SCANMAR). The average wing width (\pm 95% CI) was 9.0 \pm 0.2 m (n = 149) and was used to calculate catch per unit effort (number per ha or per km²). Once the survey was fully converted to an ecosystem survey, stratum 4 in the central Strait (limits initially determined by the boundary of LFA 25) was eliminated and merged into adjacent strata (3 and 5) based on substrate characteristics. All indices were recalculated using the new stratum boundaries. In terms of kriging analyses (abundance indices and interpolation), stratum boundaries were never included in the analyses.

The survey net was a number 286 bottom trawl equipped with rubber "rock-hopper" footgear that has been used to sample demersal fishes and large crustaceans in the survey area since 1990 (Hanson 1996; Hanson and Lanteigne 2000; Voutier and Hanson 2007). Fishing was restricted to days when wind strength was $< 55 \text{ km h}^{-1}$. For the current set of surveys (2001 to 2006), the net was towed for 15 minutes, from the time of brake lock to brake release, at a speed of about 4.6 km h⁻¹. Fishing was usually done between 06:00 and 18:00 h. Time, water depth, latitude, and longitude were recorded at the beginning and end of each tow. Location was determined by means of dGPS. Annual sampling intensity was high (a map of stations fished during July-August 2003 is included as an example, Fig. 4), averaging one tow per 39 km² (Voutier and Hanson 2007). Additional samples were collected during July-August trawl surveys in 1999 (lobsters were captured with a 4.2 m beam trawl) and 2000 (the same bottom trawl used in 2001 to 2006 but with 80 kg doors). These two pilot surveys covered the same area and depths as in July-August 2001 to 2006 surveys but catch rates were not comparable because between-net calibration studies were not done. Animals captured during the 1999 and 2000 surveys were only used for diet analysis and to illustrate lobster distribution (2000 only).

The catch was sorted to species, each taxon weighed and numbers recorded. Carapace length and sex was recorded for all lobster, and carapace width and sex was recorded for all brachyuran crabs. Until 2005, total length was recorded only for selected fish species. For 2005 and 2006, total length (to the nearest 0.5 cm) was recorded for all fishes captured (or a random sub-set) on

every tow. Catch information was recorded in Excel sheets and the data were standardized to a one hectare swept area (or number per km² for purposes of kriging).

A length-frequency distribution was plotted for all lobster caught in the west-central zone for 2001-2006. Too few lobsters were caught in the central zone to permit meaningful comparisons between years.

Contours of lobster distribution were plotted using point kriging (Comeau et al. 1998; Mello and Rose 2005; Voutier and Hanson 2007). Four size-classes were treated separately: two molts prefishery (50-59.9 mm CL); one molt pre-fishery (60-69.9 mm CL); canners (70-80.9 mm CL), and markets (\geq 81 mm CL). The distributions for 2000 were included for illustrative purposes (Figs 5-8). The area of abundance > 400 lobster per km² was determined using point kriging. Estimates were done separately for the west-central portion of the Strait and central Strait. An index of abundance, arithmetic mean number per standard tow (number per ha) was calculated for each stratum (the same four size classes). Strata 1, 2, and 3 constitute west-central Northumberland Strait (Fig. 4); stratum 5 constitutes central Northumberland Strait, while Stratum 6 represents the eastern Northumberland Strait.

For the 2001 to 2006 survey data combined, the cumulative distributions of numbers of lobsters captured (four size classes: 50-59.9, 60-69.9, 70-80.9, 81-plus mm CL) were determined as well as the number of tows that were performed to determine whether lobster of different sizes occupied the same depths. The number of lobsters captured in each size class and the number of tows performed were summed into one-m depth intervals (4 to 40-plus m) and the cumulative frequency distribution calculated (Hanson 1996; Hanson and Lanteigne 2000; Voutier and Hanson 2007). To test whether lobsters were evenly distributed between depth intervals, Kolmogorov-Smirnov tests were done between the numbers of lobsters captured in each size class and the numbers of tows performed for the depth intervals.

Additional samples were collected during July-August trawl surveys in 1999 (lobsters were captured with a 4.2 m beam trawl) and 2000 (the same bottom trawl used in 2001 to 2006 but with smaller doors). These two pilot surveys covered the same area and depths as in July-August 2001 to 2006 surveys but catch rates were not comparable because between-net calibration studies were not done. Animals captured during the 1999 and 2000 surveys were only used for diet analysis and to illustrate lobster distribution (2000 only).

2.1.2 Community diet analysis

Intact fish or crustaceans were retained for an arbitrary sub-set of stations within each block, then frozen and taken to the laboratory, for stomach contents examination. In the laboratory, the organism was thawed in cold water, the appropriate length or width recorded, and the stomach was excised. Stomach contents were identified to the lowest practical taxonomic level, the number of individuals recorded (when possible), and the weight of all organisms in a taxon taken to the nearest mg on an analytical balance (blotted wet weight). For the purpose of this document, the importance of the various prey diet of each fish or crustacean species was expressed as % by weight for all samples of a species combined. In the case of lobster, four size-classes (50-59.9, 60-69.9, 70-80.9, and 81-plus mm CL) were treated separately. Data were

expressed as percentage by weight because it is less subjective than visual estimation of volume or point estimate methods that are frequently used when reporting diets (e.g., Saint-Marie and Chabot 2001; Stehlik et al. 2004; Karani et al. 2005). Additional diet samples were collected during the 1999 (beam trawl) and 2000 trawl surveys in the same area and during the same period.

The diet similarity between the major fish species, crab species, and the four size-classes of lobster was evaluated by means of a dendrogram for hierarchical clustering, using group-average linking of Bray-Curtis similarities calculated on fourth-root transformed data, followed by Multi-Dimensional Scaling (Primer, Version 6.0; Primer-E Limited, 2001, Plymouth Marine Laboratory, Plymouth, UK).

The relative fullness index (Lilly 1991; Dempson et al. 2002; Darbyson et al. 2003) of each lobster stomach (stomach content weight in g and CL in mm) was estimated as follows:

Fullness index = ((Total weight of stomach contents) / (CL^3)) x 10⁶

The multiplier "10⁶" is only a convenient scaling factor. The fullness index was used to test for evidence of feeding periodicity. The advantage of this index over the traditional fullness index measure (fullness expressed as a percentage of body weight) is that it avoids the effects of variation (within and between seasons) in weight of animals of the same linear dimension (in this case, CL). For all summer surveys combined, the fullness values were grouped into one-hour intervals (06:00-06:59 to 19:00-19:59) and a Kruskal-Wallis one-way analysis of variance was used to test for significant differences among hourly mean fullness indices.

2.1.3 Results

2.1.3.1 Spatial distribution

Large commercial or market-size lobsters (81 mm CL and larger) were concentrated in the central zone in all seven years, less numerous on the PEI side of the northernmost part of the survey area, and sparse east of Cape Tormentine (Fig. 5). Substantial numbers of market-size lobster were present along the NB coast in 2001 and 2002; indeed, the northern-most distribution (and highest density patch) continued into Miramichi Bay of the adjacent LFA 23. In 2003 and 2004, relatively few market-size lobsters were present in the western zone just prior to the opening of the summer/fall fishery in LFA 25 while the distribution in 2006 resembled that of 2002. In all years, the sparse density of large lobster in the central zone of Northumberland Strait continued eastward to about Pictou Island, where densities were similar to those in the west-central zone of the Strait.

Small commercial or canner (Fig. 6) and the two sub-legal (Figs 7 and 8) size-classes of lobster had almost identical distributions. In 2002, lobsters of all three size classes were most abundant along the NB coast of the northern-most portion of the survey area and continuous into Miramichi Bay of the adjacent LFA 23. Canners were common in the central zone west of the Confederation Bridge, sparse in the central (muddy) zone, and again abundant in the Strait beginning at the eastern end of PEI. The lobsters in the two sub-legal size classes were

uncommon in the central Strait and largely restricted to near-shore habitat in this zone. Sub-legal size lobsters were again abundant in the Strait beginning at the eastern end of PEI. The highest densities consistently occurred along the NB coast of the western zone, centered on Kouchibouguac National Park, which may represent a discrete nursery area or may simply be due to small animals moving shorter distances compared to large animals (or both).

2.1.3.2. Lobster abundance indices: summer surveys

West-central (main) zone: The number of canners in the main zone (Strata 1, 2 and 3) declined about 67% between 2001 and 2005 (2004 for stratum 2) but rebounded to near-2002 levels in 2006 (Table 4). The number of markets declined by about 40% during the same period and was the highest ever estimated in strata 1 (NB shore) and 3 (central area east of Cape Tormentine) in 2006. The number of sub-legal lobster (will molt into canner group in 1 or 2 years or molted into the canner size class this year) decreased about 70% between 2001 and 2005 (2004 for stratum 2). Comparing Strata 1 and 2 (ignoring 2005 when coverage was incomplete in stratum 2), the NB side of Northumberland Strait had much higher concentrations than the PEI side for all sizeclasses of lobster: 2.8-fold for markets; 4.3-fold for canners; 7.3-fold for one-molt sub-legal; and 9.6-fold for two-molts sub-legal. If recruitment only occurred from within LFA 25, there should have been a strong signal predicting the high 2006 numbers from preceding years of the survey. Using markets as an example, there should have been a strong pulse evident in 2005 for canners, 2004 for one-molt sub-legal, and 2004 for two-molt sub-legal. Similarly, there should have been a large peak in canner landings in 2005 to account for the large increase in market abundance in 2006. None of these potential indicators of high abundance in 2006 were observed, emphasizing the current dependence of the LFA 25 stock on immigration - mainly from the adjacent LFA 23. The presence of very small (< 50 mm CL) lobsters during summer (and spring; J. M. Hanson, unpublished data), mainly along the NB shore, does suggest there is settlement and survival of larval lobster, but it does not seem to be a self-sufficient population or sub-population of lobster in west-central Northumberland Strait. Between 2001 and 2005, the spatial distribution of high densities (area with > 400 animals per km²) of all four size classes contracted within west-central Northumberland Strait with a rebound in 2006 (Fig. 9).

Central (muddy) zone: The abundance of market-size lobster in the central area (stratum 5) was always much less than in strata 1 and 3, but the pattern of decline and rebound was similar (Table 4). Canners were caught in very low numbers in all but 2002, while sub-legal sizes were all but absent (< 0.05 animals /ha). This does not seem to be a self-sustaining population of a sub-population of lobster. In this case, the animals present appear to originate from the part of the Strait east of a line from Pictou Island to the eastern end of PEI.

Eastern Zone: There were only three years with adequate coverage in the eastern end of the Strait (Stratum 6). During 2005 and 2006, the numbers of market-size lobster were similar to, or slightly higher than, those in Strata 1 and 3 while the abundance of canner-size and sub-legal sized lobster was intermediate. Estimates for all size classes were higher in 2006 compared to 2005. Because the survey occurred after the 2006 spring fishery and the annual molt, this could suggest relatively strong landings in 2007 (compared to 2006) in the part of LFA 26A covered by this survey if no emigration or mortality occurred (Table 4).

2.1.3.3 Lobster sizes and sex ratio

The length-frequency distribution for the pre-fishery surveys were remarkably similar between years and did not show evidence of a large influx of smaller individuals in any year (Fig. 10). The absence of a peak in small-sized individuals in the two years preceding 2006 suggests the large increase for all sizes of lobster seen in 2006 was due to an influx of animals from the Miramichi Bay area, possibly in combination with an earlier molt compared to earlier years.

There was a significant difference in sex ratio (number of males/number of females) between years in West-Central Northumberland Strait (Table 5). The ratio of males to females increased in the western survey area from 2001 to 2004, the opposite of what would be expected to occur if exploitation of females was less than that of males. In general, the fishery regulations only protect egg-bearing females. These regulations do not have much effect in the LFA 25 fishery because there are almost two full fishing seasons from time of mating in July (or early August when the molt is late) to new-egg extrusion the following September/October, compared with only one fishing season for females in spring-fisheries. To illustrate the consequences, at 70% annual exploitation rate it equates to only 9% of mated females surviving for LFA 25 vs. 30% surviving for all other sGSL LFAs. An alternate explanation for the male-dominated sex ratio is that there could be a difference in timing of migration between male and female lobster moving into the west central Strait, particularly for the canner-size class. These two possibilities are not mutually exclusive.

In the Central Strait, very few lobsters were captured and the sex ratio was not significantly different between years.

2.1.3.4 Depth distributions

Based on observations from the summer trawl survey (July-August), lobsters were not randomly distributed with relation to depth in Northumberland Strait (Fig. 11; Kolmogorov-Smirnov statistic, P < 0.001 for all four size classes *versus* number of tows per depth interval). All sizes of lobster were caught predominantly in the shallowest waters (< 5 m); the depth at 10% cumulative captures was 7 to 8 m for all four size classes. The depth of occurrence of the two larger size classes extended to slightly deeper waters. The depth of 50% cumulative catch was about 11 m for the 50-59.9 and 60-69.9 size classes compared to 13 and 14 m for canner and market size classes. The depth of 90% occurrence for the 50-59.9 and 60-69.9 mm CL lobster was 18 m deep compared with 21 m for the two largest size classes. Virtually no 50-59.9 mm CL lobsters and a small percentage (1.1% to 1.5%) of commercial sized lobster occurred in water > 30 m deep.

2.1.3.5 Lobster as predator

Feeding periodicity: During the July-August surveys, stomach fullness of lobster differed significantly with time of day (Kruskal-Wallis AOV, $F_{13, 1891} = 11.6$, P < 0.0001). The average fullness index (Fig. 12) was highest in early morning, relatively constant between 08:00 and 17:00 h, and declined significantly in late afternoon (18:00 and 19:00 h). In addition, the proportion of empty stomachs differed significantly between hourly intervals ($\chi^2 = 28.6$, df = 13,

P = 0.0074), averaging 6.2% between 06:00 and 14:00, increasing to 11.1% from 15:00 to 18:00, and declining to 3.2% at 19:00 (despite the very low average fullness index).

Ontogenetic diet patterns (July-August surveys): The incidence of empty stomachs was low (< 10%) for all size-classes of lobster (Table 6). Lobster was largely carnivorous - plant material (mainly fragments of *Zostera*) was never more than 2% of prey biomass for all four size classes. Decapod crustaceans were the principal prey of lobster in Northumberland Strait (57 to 84 % of prey biomass). Rock crab was the single most important principal prey of all size-classes of lobster in Northumberland Strait, comprising 45 to 78% of total prey biomass. About 70% of the rock crab consumed by lobster represented fresh prey (muscle or gills attached) and the remainder consisted of old carapaces. It was impossible to determine how much of the fresh prey represented active predation on intact crabs or the result of scavenging of animals that died or were damaged while molting or when discarded from the rock crab fishery. Lobster represented 7.5 to 12.6% of the prey biomass; however, a substantial portion (39 to 79%) of the lobster remains consisted of old carapaces. Lady crab and hermit crab were minor prey of lobster (2.5 to 3.7% of prey biomass, combined) while shrimp, mysids, and amphipods occurred only in trace amounts in the diet.

Non-crustacean animals were minor prey of all four size classes of lobster. The importance of sea stars in the diet varies by size from 11% of prey biomass for the smallest lobster to about 3% for the largest size-class. Molluscs, polychaetes, and fish did not comprise more than 7% of prey biomass for any size-class of lobster. Most of the fish remains consisted of bones and scales. The fish remains most often identified were cunner, three-spine sticklebacks, and herring (mainly scales). Detritus represented 10% and 2% of the diet for the smallest and largest size-class respectively.

2.1.3.6 Seasonal diets of lobster in Northumberland Strait

The comparison of spring, summer, and autumn diets was restricted to years when samples were collected seasonally (2001 to 2003) in west-central Northumberland Strait. We noted that relatively few canners or markets were captured during May, consistent with the hypothesis that they had not moved as yet into the west-central Strait, but suggesting the presence of a small resident population (Bowlby et al. 2007). The diets differed markedly between seasons (Table 7).

The diet of the smallest lobsters (50-59.9 mm CL) was dominated by rock crab regardless of the season. However, consumption of old carapaces was highest during summer months, presumably reflecting the seasonal peak in molting activity of rock crab. Consumption of polychaetes and sea stars was higher during spring compared to the other seasons, while consumption of molluscs and fishes was low. Old carapaces of lobster were consumed in trace amounts during spring and autumn reflecting reduced molting activity during these seasons compared with summer months.

The spring and summer diets of lobster 60-69.9 mm CL did not change as much as for the smaller size-class. Most of the differences were due to a slight reduction in the consumption of rock crab and "other" prey and the elimination of lobster from the diet. In contrast, consumption of fresh rock crab during autumn was substantially higher than during spring and summer, with

concurrent decrease in the consumption of old carapaces of rock crab and lobster as well as polychaetes.

Polychaetes and fresh rock crab were the principal prey of the canner lobsters (70-80.9 mm CL) captured during spring with no lobster detected and a low consumption of sea stars and fishes. Total consumption of rock crab was almost the same between summer and autumn months; however, the proportion clearly identifiable as old carapaces was much lower during autumn. Similar to spring, consumption of lobster (almost exclusively old carapaces) dropped to nil during autumn. Consumption of fish remains was at its highest level during autumn (12% of prey biomass) compared to the other seasons.

As with the other size classes, the greatest consumption of polychaetes by market lobsters (81plus mm CL) occurred during spring; however, the sample size was very small and may not be representative of the population. For the summer and autumn diets, rock crab was the principal prey with consumption of old carapaces greatly reduced during autumn. The consumption of lobster dropped to low levels during autumn, fresh remains were not detected and old carapaces dropped from 17 to 1% of prey biomass. There was also a slight increase in consumption of sea stars during autumn versus summer.

2.1.3.7 Lobster as prey

Stomachs of pelagic species were collected during July, August, and October – months when some lobster larvae would be present in the water column. Lobster larvae were rarely observed (trace amounts in terms of biomass) in diets of pelagic species (Table 8), suggesting consumption was passive or in proportion to availability in the water column while the fishes were filter feeding.

As found in a 1990-1996 study (Hanson and Lanteigne 2000), the only demersal fish to consume large amounts of intact lobster from 1999 to 2006 was shorthorn sculpin. Results from the September groundfish survey show that shorthorn sculpins are presently uncommon in all parts of the sGSL (about 0.03 kg/ha; Benoit and Swain 2003). The consumption of lobster by cod and hake from 1999 to 2006 was lower compared to the 1990-1996 study and consisted of one small individual found in a hake and one uropod in a cod, despite directed fishing for large individuals of white hake on lobster grounds (Davis et al. 2004). One lobster abdomen was found in a thorny skate stomach compared to none during 1990-1996 study. In all other species, the lobster remains consisted of legs, mostly legs of molting individuals in the case of cunner. Lobster did eat substantial quantities of lobster but most of the material consumed consisted of old carapaces. However, about 3% of the lobster prey mass during summer consisted of fresh lobster tissue, indicating cannibalism on molting individuals. Although lobster represented a large fraction (17-29%) of the prey biomass of shorthorn sculpin in the sGSL, the amount of lobster consumed by other lobster (2.7% of prey biomass) is likely much higher due to the large size of the lobster population compared with other potential predators. To place this consumption in context, the average CPUE of lobster (7.6 kg/ha) was 190-times that of shorthorn sculpin (0.04 kg/ha) in Northumberland Strait (this study).

Rock crab was the most important prey of lobster in the sGSL but crabs seldom eat lobster: none from the 1990s and 2000s (this study); trace amounts from 162 rock crabs collected during the 1980s (Hudon and Lamarche 1989); and none from 230 rock crabs examined during the 1960s (Scarratt and Lowe 1972). Likewise, studies conducted outside of the sGSL did not report lobster in rock crab diets (Drummond-Davis et al. 1987; Ojeda and Dearborn 1991; Stehlik 1993; Stehlik et al. 2004). Trace amounts of lobster were eaten by lady crab in Northumberland Strait (Voutier and Hanson 2007; additional samples in this study); however, lobster was not noted in other studies of lady crab diets outside of the sGSL (e.g., Ropes 1989; Stehlik 1993; Stehlik et al. 2004). Based on limited diet information (e.g., Hudon and Lamarche 1989; this study), there is the potential for moderate competition for food between lobster and rock crab, if food (or space) can be demonstrated to be in short supply (a prerequisite for competition).

2.1.3.8 Potential for competition (diet overlap)

While there is no evidence that food is in short supply for the fish and decapod crustacean community of Northumberland Strait, high diet overlap can be indicative of the potential for competition for food. Examination of the potential competition for space (either active or passive) is beyond the scope of this study. We based the current analysis on the > 28,000 stomachs that have been processed from May to October (1999-2006 data in Table 8).

There were clear groupings in types of prey eaten by the fish and decapod crustacean community of Northumberland Strait (Fig. 13). Four of the pelagic species preyed mainly on small copepods and crab larvae, although small fish comprised about 20% of the mackerel diet. Rainbow smelt are often classified as a pelagic species but their principal prey was *Crangon* shrimp, followed by polychaetes and a small amount of copepods and small fish. Atlantic cod, white hake, winter skate, and sea ravens were primarily piscivores. Fish consumption was very high in rock crab, but it is unclear whether this was active consumption or scavenging. The only species to eat substantial quantities of molluscs were the lady crab (almost exclusively buried bivalves) and cunner (a mixture of tiny gastropods and tiny bivalves). The diet of windowpane consisted almost exclusively *Crangon* shrimp. Rock crab was the principal prey of the four size-classes of lobster and shorthorn sculpin. The "other" prey that dominated the diet of winter flounder consisted of filamentous algae and infaunal tunicates.

Cluster analysis of diets and the MDS plot (Fig. 14) showed clear separation of windowpane, smelt, and the planktivore group (herring, shad, mackerel, and alewife) from all other groups (>70% level). The diets of the four size-classes of lobster formed a clearly separate group, largely due to the high proportion of rock crab in the diet, while rock crab and lady crab diets had about 50% of the prey in common. White hake and sea raven formed a separate group due to the very high proportion of fish in the diet. Atlantic cod, winter skate, longhorn sculpin, and thorny skate had a fairly broad diet (principally crabs, shrimp, and small fishes) and had about 50% diet similarity. Yellowtail flounder and American plaice occurred along the deep water edge of the survey area and their diets with about 50% prey similarity.

2.2 Recruitment Abundance Based on SCUBA Observations

2.2.1 Methods

To assess the recruitment abundance, visual line-transect surveys were done by divers using SCUBA between 2000 and 2006. Surveys were carried out in Baie des Chaleurs located in LFA 23BC for all the years except in 2002. Surveys were also carried out in 2005 and 2006 in Shediac (LFA 25S) and Fox Harbour (LFA 26AD). A 100-m transect line marked at 5-m intervals was used to survey all of the sites. Transects were randomly placed on the site to be sampled and surveyed by two divers, one each side of the line. Each diver sampled an area of 2 m wide perpendicular to the transect line along its entire length for a total swept area of 400 m².

Our SCUBA survey was designed to meet underlying assumptions identified by Burnham et al. (1980) to achieve reliable estimates of population abundance from the line transect sampling model. These four assumptions are:

- 1. Lobsters directly on the line will never be missed (i.e., they are seen with probability of 1).
- 2. Lobsters are fixed at the initial sighting position; they do not move before being detected and none are counted twice.
- 3. Distances are measured exactly; thus, neither measurement errors nor rounding errors occur.
- 4. Sightings are independent events.

Divers attempted to capture every lobster observed within the transect zone. All captured lobsters were measured (CL) and the sex was determined. Beside lobster, divers also recorded an array of habitat characteristics, including: other biota (i.e., other benthic species) and substrate features (i.e., size and aggregation of rocks and other substrates). The information from each diver was recorded for every 5 m interval, which is equivalent of sampling forty 10 m² quadrats along the transect line. The sampling complexity, referring to the ability of a diver to efficiently sample a 10 m² quadrat, was also noted. Sampling complexity was identified as simple if a diver could sample a quadrat without missing or underestimating the presence of lobsters (see assumption 1), and complex if unable to do so. The complexity of the habitat within a quadrat was assessed based of the assemblage of different type of rocks and macroalgae within the quadrat. Hence, a quadrat could be identified as complex based on the information related to the habitat, but simple based on the ability of a diver to efficiently sample the quadrat.

Based on assumption 1, quadrats (10 m^2) that were identified as complex by divers within each transect line were removed from the analysis. To assess the yearly abundance level of recruits, only lobsters with a CL of less than 40 mm were considered. At these sizes, lobsters are considered within the 1 and 2 age-classes (Hudon 1987) and represent the cryptic phase (i.e., lobsters that hide and stay within their burrows).

2.2.2 Results and discussion

Abundances observed in Baie des Chaleurs between 2000 and 2003 remained at values of approximately 1.3 lobster/ $100m^2$ before increasing to 6.2 lobster/ $100m^2$ in 2006 (Fig. 15). Abundances observed in both Shediac and Fox Harbour were lower than those in Baie des Chaleurs with values of 1 lobster/100m² observed in 2005 (Fig. 15). In 2006, the abundance in Shediac increased to 1.2 lobster/100m², while it remained low in Fox Harbour. It is possible that a change in oceanographic conditions between 2003 and 2006 could have been favorable to lobster recruitment (e.g., a high temperature regime in the fall; Paulin et al. 2005; Paulin and Gagnon 2008). However, it seems that these conditions were not homogeneous throughout the sGSL since there was little improvement in central Northumberland Strait (LFAs 25S and 26AD). Another possible reason for the increase in the abundance of recruits could be attributed to conservation measures put in place in the last 2 multi-year plans to protect females and favor an increase in egg production. Although it was strongly recommended in the last stock status report for LFA 25 (Comeau et al. 2004) to move the opening date to early September in order to avoid a conflict with female reproductive cycle and increase the egg production (see section 4 of this document), fishery managers never properly addressed that recommendation. Since the Northumberland Strait is essentially an isolated system (relying on itself for recruitment; see section 6 of this document), unlike the rest of the sGSL, and that the summer fishery makes it more difficult to achieve the management goal of increasing egg per recruit (based only on increases in MLS) low abundance levels continue to be observed in LFAs 25S and 26AD.

3. LOBSTER STOCK STATUS BASED ON FISHERY DATA

3.1 Data Sources and Analyses

Lobster size distributions, landings and effort data, needed to calculate the CPUE, can be used as indicators of stock status and possible changes in recruitment. Declines in recruitment should be a concern when a low proportion of first year recruits are observed in combination with a low CPUE. Numerous programs have been put in place to gather this fishery-based data. In this assessment, berried females were treated separately in the analysis as they could be above the MLS but are not retained by the commercial fishery.

The fishery-based data collected to establish the stock status for the sGSL were taken from 1) DFO official catch statistics, 2) at-sea sampling, 3) recruitment-index logbooks, and 4) index-harvesters logbooks.

3.1.1 Official catch statistics

Official lobster catch statistics were obtained from the Policy and Economics Branch of DFO. The database consists of a compilation of sale transactions conducted between official lobster buyers and harvesters. Although this information essentially documents monetary transactions, it is assumed that the volume sold to official lobster buyers closely tracks the quantity of lobster caught by commercial harvesters. Furthermore, because the actual fishing location is not available from this data source, it was decided that landings would be separated by statistical

district (SD), and assumed that the SD where lobsters were landed generally represents the geographical area in which lobsters were caught. These SD were then regrouped into nine sub-regions (Fig. 1) which will be used in the assessment. Landings from 1947 to 1968 are only available for the entire LFA (Williamson 1992).

3.1.2 At-sea sampling program

Lobster size structure and catch rate in commercial traps was obtained from the at-sea sampling program. This program has been in place since 1982 and went through numerous changes over the years (Mallet et al. 2006). The sampling was conducted by scientific staff onboard commercial fishing vessels during the fishing season. One sea sample was defined as one day at sea with one harvester from a given port. In general, sampling technicians onboard the vessel recorded information on lobster size (CL to the lowest mm), sex and condition (egg stage of berried females), in addition to trap types and characteristics. Other information recorded include the trap position on the line of trap (where applicable), geographic position of the line of traps and water depth. Water temperatures were occasionally recorded. In earlier years, geographic positions were merely descriptive but, in recent years, many technicians were equipped with handheld GPS.

For both LFAs 25N and 25S (summer fishery), only at-sea sampling data collected in August were used for the analyses since almost 60% of all catches occur in the first 3 weeks of the fishery. For all other LFAs, at-sea sampling data for the entire fishing season were used. Data were grouped in the nine identified LFA sub-regions 23BC, 23G, 24, 25N, 25S, 26AD, 26APEI, 26ANS and 26B.

Two sex groups were considered: 1) berried female lobsters hereafter identified as B and 2) male and non berried female lobsters, identified as M&F. For each sub-region, years with less than 41 measured lobsters were not considered. At-sea samplings considered for this assessment are listed in Table 9.

Size distributions and CPUE at size were based on 2-mm size groups:

 $CPUE_{id} = \frac{\text{total number of lobsters in size class } i \text{ and zone } d}{\text{Number of traps sampled in zone } d}$

For exploitable lobsters only (males and non berried females of MLS), yearly catches per molt group was also plotted. Four molt groups were identified:

- 1) from MLS up to but not including (MLS + 10 mm),
- 2) (MLS + 10 mm) up to but not including (MLS + 20 mm),
- 3) (MLS + 20 mm) up to but not including (MLS + 30 mm),
- 4) (MLS + 30 mm) and above.

For years when MLS was not a round number, the highest millimeter was used.

3.1.3 Recruitment-index program

Lobster size structure, catch and effort data were also obtained from the recruitment-index program. This experimental trap program was put in place in 1999 to monitor the relative abundance of pre-recruits and its relative CPUE. In addition to filling a daily logbook of their daily catch and number of trap hauled, harvesters participating in this voluntary program recorded size and sex of all lobsters caught in 6 identified traps, 3 of which had the escape vent blocked. It was thought that traps not equipped with an escape vent would retain more animals below the MLS. The lobster CL was measured with a gauge graduated in 13 size classes (Fig. 16). Class size 1 represented lobsters at least 20 mm smaller than the MLS and class size 13 referred to lobsters 50 mm above the MLS. Except for size classes 2, 11 and 12, which are 10-mm group size, all other size classes are in 5-mm groupings. Lobsters of group size 4 and below were sub-legal lobsters and, when the MLS was changed, the gauge was adjusted each year such that group sizes 5 and 6 represented animals from the first molting group (FMG) into the fishery.

The number of participating harvesters has varied from year to year (Table 10) and was often affected by changes in fishery management plans. For the analyses, yearly information collected in the 6 traps was grouped according to the nine sub-regions of the participating harvesters and the trap types (regular or modified traps with the escape vent blocked). The number of lobsters per traps at-size, CPUE_n, was calculated using the gauge's bin sizes and the equation given in the at-sea sampling program section (CPUE_{id}).

3.1.4 Index-harvesters program

An effort control fishery requires information on the actual effort deployed by the fleet to properly manage the fishery. Daily landings and effort information are needed to estimate CPUE. Since 1993, DFO's Science Branch (Lobster Section) in Moncton established a voluntary logbook program because DFO has no mandatory requirement for harvesters to report their fishing activities (i.e., daily landings and effort). The program relies on volunteer harvesters recording their fishing activities on a daily basis. Data collected included daily catches of lobster by category (i.e., canners and markets), the number of traps hauled, and the number of soak days. Although the number of participants has fluctuated slightly over the years, the program provided the daily catch and effort information for approximately 5% of the number of lobster fishing licences in the sGSL. Since index-harvesters were located throughout sGSL, it was assumed that annual changes in the catch and CPUE from our index-harvesters reflected the fishery as a whole.

For each of the 9 sub-regions, landing information was used to calculate weekly CPUE per lobster category (canner, market, and total catch) as:

$$CPUE_{w} = \frac{\text{total weight of commercial lobsters in week } w}{\text{Number of traps hauled in week } w}$$

The daily average number of traps hauled (Weektrap) by harvesters per week was used as a measure of fishing effort and calculated by sub-region as follows:

 $Weektrap_{wr} = \frac{\text{total number of traps hauled in week wand region } r}{\text{Number of logbook entries in week wand region } r}$

By comparing the actual trap haul to the nominal trap haul (based on the fishery regulations) another indicator (effective) could be estimated to assess effort.

*Nominal effort*_r = Maximum number of traps allowed per region r *Total number of days the fishery is open in region r

 $Effective_r = \frac{\text{total traps hauled in region } r}{\text{Number of harvesters in region } r}$

Data used to estimate that last indicator were from harvesters who fished the entire season or spent similar amounts of time on the water compared to their peers for each sub-region. The reason is to avoid underestimating the total amount of traps hauled by some harvesters who, for various reasons, did not fish lobster throughout the season.

3.2 Landings

3.2.1 LFA 23

Commercial lobster catches in LFA 23 showed small fluctuations with a median landing of 1,175 t between 1947 and 1974, followed by a sharp increase from 759 t in 1974 to the highest recorded landing of 4,528 t in 1989 and 1990, representing approximately a six-fold increase in 16 years (Fig. 3). Since 1993 landings in LFA 23 have been declining. In 2005, 2,907 t were landed, representing a 35% reduction from the peak landings observed in 1989, but still 79% above the long-term median landing (1,626 t) observed between 1947 and 2004.

Within LFA 23, the landing trends were somewhat different between fisheries operating inside Baie des Chaleurs (LFA 23BC) and the Gulf-side (LFA 23G). In LFA 23BC, an increase in landings was observed in the 1970s going from 169 t in 1971 to 639 t in 1980 (Fig. 17), followed by a small drop in landings in 1983 (466 t). Landings increased 2.3-fold and peaked at 1,070 t in 1989. Following relatively high landings between 1988 and 1994 with a median of 1,015 t, a slow decrease in landings was observed. Landings in 2005 were 561 t, which represents a 45% decrease from peak years, but were comparable to landings observed in the early 1980s (Fig. 17). The latter decrease in landings is more pronounced in LFA 23BC compared to LFA 23G.

A two-step increase was not observed in LFA 23G as it was seen in LFA 23BC (Fig. 17). A 6.5-fold increase from the lowest landings recorded in 1973 (542 t) to the 1990 peak landings of 3,493 t was observed. Following this peak, landings remained at a high level, but are slowly declining in recent years. Landings in 2005 were 2,346 t, a 30% reduction in 15 years (average of 2% per year) from the 1990 peak, but are still 3.6-fold higher than the median landing (637 t) observed from 1968 to 1974.

3.2.2 LFA 24

Commercial lobster catches in LFA 24 showed a steady increase from 1947 to 2004 with few minor fluctuations (Fig. 3). Overall, a 12.7-fold increase was observed from the lowest landings recorded in 1947 (497 t) to the peak in 2004 (6,336 t). Landings in 2005 were 5,697 t, which is 2.6 times the long-term median landing (2,195 t) observed between 1947 and 2004. To compare with other LFAs, we also compared this latest increase to the lowest value of 1,396 t observed in 1974. Thus, landings in LFA 24 have increased 4.5-fold from the mid-1970s. Contrary to the other LFAs, LFA 24 is still recording record-high landings based on information dating to 1947 (Fig. 3). Furthermore, based on anecdotal information, it is expected that landings in 2006 have increased compared to 2004.

3.2.3 LFA 26B

Commercial lobster catches in LFA 26B showed a relatively stable trend between 1947 and 1977 with a median at 495 t (Fig. 3). A 3.8-fold increase in landings was observed between 1974 (408 t) and 1991 (1,543 t). Landings then dropped 28% in four years to 1,110 t in 1994. However, this sharp decline was followed by stable landings (Fig. 3). A median landing of 1,111 t has been observed for the past 12 years that represent a 2.2-fold increase from the previous median observed between 1947 and 1977 (i.e., prior to the large increase in landings in the 1980s). The fishery in LFA 26B is stable with a recorded landings in 2005 of 1,118 t, which is 78% above the long-term median landing (629 t) observed between 1947 and 2004.

3.2.4 LFA 25

The landing trend in LFA 25 is characterized by wide fluctuations with no stable period since 1947 (Fig. 3). Commercial lobster catches in LFA 25 showed a sharp increase from 1,622 t in 1973 to the highest recorded landing of 6,323 t in 1985, representing an almost four-fold increase in 12 years (Fig. 3). Within the sGSL, LFA 25 was the first one to reach its record high landings (Fig. 3). Since 1985, however, landings in LFA 25 have been steadily declining. In 2005, 2,419 t were landed, which represents a 62% reduction from the peak landings observed in 1985, and a 21% reduction from the long-term median landing (3,106 t) observed between 1947 and 2004. Landings in 2005 for LFA 25 were still higher than those observed in 1947, 1954 and between 1967 and 1974. However, this 20-year decline is the largest one observed in the sGSL. Also, since 1947, three major increases were observed, the first (1947 to 1950) was 2.4-fold, the second (1954 to 1960) was 3.3-fold and the last one (1973 to 1984) was 3.9-fold. These large fluctuations (in terms of amplitude) were not observed in the other LFAs (Fig. 3).

Within LFA 25, the landing trends were different between LFA 25N and LFA 25S. The landing trend for LFA 25N is more similar to those from LFAs 23BC and 23G than the one from LFA 25S (Fig. 17). Between 1968 and 1989, two distinct increasing phases were observed. Landings first increased from 1968 (1,182 t) to 1980 (2,186 t), then to 3,762 t in 1989. A steady decline was then observed from 1989 to 2005 (1,846 t) at a rate of an average of 3% decrease per year (Fig. 17). Landings in LFA 25N observed in 2005 were still higher than the median landing of 1,508 t observed between 1968 and 1984 (Fig. 17).

LFA 25S is the area within the sGSL with the widest landings fluctuations. From 1968 to 1985, a five-fold increase was observed with some small fluctuations (Fig. 17). Following the historical highest peak recorded in 1985 (3,509 t), a steady decline was observed until 2004 (533 t) representing a decrease of 85%. The 2005 landings were 573 t. From the ten lowest recorded landings since 1968, six are from 1968 to 1976 (median of 725 t) and four are from 2002 to 2005 (median of 633 t). Besides being the period with the lowest landings since 1968, the lowest recorded annual landings were observed in 2004 and 2005.

3.2.5 LFA 26A

Commercial lobster catches in LFA 26A showed a median of 2,484 t between 1947 and 1974 (Fig. 3). After the lowest recorded landings of 1,372 t in 1974, there was a sharp increase to the highest recorded landing of 6,691 t in 1988, representing a four-fold increase (Fig. 3). Following this peak, a rapid decline to 3,480 t in 1994 was observed. Since then, landings are somewhat stable at a median of 3,637 t. In 2005, 3,172 t were landed which is still 13% above the long-term median landing (2,816 t) observed between 1947 and 2004.

Landing trends in LFA 26A were remarkably different between the three sub-regions (LFAs 26AD, 26ANS, 26APEI). Landing trends in LFA26AD were divided into three phases. The first is from 1968 to 1982 where landings declined from 784 t to the lowest recorded landings between 1968 and 2005 at 205 t (Fig. 17). The median for that period was 427 t. The second phase was the increase from 1982 (539 t) to 1987 (2,067 t) followed by an equally rapid decline to 710 t in 1994 (Fig. 17). The final phase was the 1994-2005 period where landings increase to 995 t in 2000 to decline to 599 t by 2005. The median landing for that period was 750 t. Thus, landings observed in the last period (1994-2005) were in general higher than those observed during the initial period (1968-1982). However, landings observed in 2005 were quite similar to the median landings observed during the initial period.

Similar to the trends observed for LFA 26AD, the landing trends in LFA 26APEI were also divided into three phases. The first was from 1968 to 1985 when landings declined from 1,383 t to the lowest landings recorded between 1968 and 2005 at 857 t, before increasing again until 1983 (Fig. 17). The median landing for the 1968-1985 period was 1,346 t. The second phase was the increase from 1985 (1,728 t) to 1988 (3,597 t) followed by a decline to 1,834 t in 1994 (Fig. 17). The final phase was the 1994-2005 period with a median landing of 1,781 t. Hence, landings observed during the last period (1994-2005) were generally higher (32%) than those of the initial period (1968-1985). Landings observed in 2005, at 1,125 t, were also higher (12%) compared to the median landing observed in the initial period.

Landing trends for LFA 26ANS were quite different from those of the other 2 sub-regions located in LFA 26A. After a slight declining trend from 1968 (513 t) to 1974 (325 t), the lowest recorded landings between 1968 and 2005, a 3.8-fold increase was observed until 1991 (1,221 t) (Fig. 17). Landings since the peak landings of 1991 are somewhat stable (Fig. 17). The median landing from the first peak was 1,125 t, which was quite similar to the 2005 landings of 1,170 t.

3.2.6 Landing indicators

The 2005 landings have been compared to the median landings of the long- (55 years), mid- (35 years), short- (10 years) term trends, and to the previous year. Landing indicators were defined as followed: if the 2005 landings were within $\pm 15\%$ of the median landings, then they were not different (i.e., stable \clubsuit); if the 2005 landings were higher than 15% or lower than 15%, it indicates that they were higher (\clubsuit) or lower (\clubsuit) respectively. Based on the long-term median landing (1950-2004), LFAs 23, 24 and 26B were higher and LFA 25 was lower, while the 2005 landings in LFA 26A were stable (Table 11). The long-term trend cannot be done for sub-regions because landings prior to 1968 were not tabulated by SD. Comparison of the 2005 landings to the mid-term medians show that LFAs 24 and 26ANS were the only sub-regions higher, while sub-regions located closer to the Northumberland Strait (25N, 25S, 26AD and 26APEI) were lower (Table 12). The 2005 landings in LFAs 23BC, 23G and 26B were stable (i.e., not different from the mid-term median values). The short-term indicator does not show any sub-region with higher landings. As per the mid-term indicator, LFAs 25N, 25S, 26AD and 26APEI were lower with the addition of LFA 23BC (Table 12). The other LFAs were stable. Results from the 2004 indicator show that all LFA sub-regions were stable (Table 12).

Another indicator is to assess annual landing trends within a specified ranking system. Based on an ascending ranking approach, landings were ranked compared to the 1968-2005 landing median for each statistical district. For this indicators, landings were ranked as 1 for values greater than 75%, 2 for values ranging between 26% and 75%, 3 for values ranging between - 25% and 25% (values within the median value), 4 for values ranging between -26% and -75%, and 5 for values lower than -75%. The landing trends ranking approach show that the 2005 landings were among the best landings of the past 38 years for LFA 24, and part of sub-regions 26ANS and 23G, while it ranks within the average for 23BC, 26APEI, 26B, and part of 23G and 26ANS (Fig. 18). As per the mid- and short-term indicators (Table 12), sub-regions located within the Northumberland Strait (25N, 25S and 26AD) ranked the lowest (Fig. 18).

Official catch statistics can be used as crude indicators of the overall status and annual fluctuations of the stock abundance. However, compiling the catch information from sale transactions should not be considered a reliable indicator of the size or reproductive health of the lobster population. Increased fishing power or changes in fishing strategies and socio-economic factors may give the impression that stock levels are increasing or being maintained. Nonetheless, the large increase in lobster catches since the mid-1970s cannot be explained entirely by an increase in fishing power or changes in fishing strategies. This increase was observed for the entire range of the lobster distribution in areas with different management regimes, fishing fleet characteristics and fishing traditions. Therefore, the increase and recent decrease in lobster catches in some LFAs are assumed to represent real changes in lobster stock biomass. Accurately measuring the magnitude of these changes is difficult with the data presently available.

3.3 Catch Characteristics and Size Structures

3.3.1 At-sea sampling

Many factors independent from the lobster biomass will affect the results from an at-sea sampling analysis (e. g. gradual implementation of escape vents, increase in MLS or decrease in the number of traps allowed). The CPUE distributions based on at-sea sampling data showed different patterns for all areas, but there were distinct differences between data collected inside (LFAs 25N, 25S and 26AD) and outside the Northumberland Strait (Fig. 19). Patterns were also different for the two groups considered: berried females (B) and male and non berried female lobsters (M&F).

The general trend for B was a gradual increase in CPUE ranging from a 2-fold increase in LFAs 23G, 26APEI and 26ANS, to a 4- to 5-fold in LFAs 24 and 26B (Fig. 19). However, the CPUE decreased in LFAs 25N, 25S and 26AD. In LFA 23BC, the berried female CPUE had increased from 1983 to 2002, but seems to be on a declining trend since 2003.

For M&F, the CPUE magnitudes and trends vary between LFAs. In some cases, these variations are closely linked to MLS increases. For the spring fisheries, there was a general decrease in CPUE in the 1990s. In most cases, the CPUE level dropped half from what it was in the previous years (Fig. 19). This decrease was also observed in LFA 25S but after a drop in 1988-1990, the CPUE increased temporarily in 1991-93. Both LFAs 25N and 25S experienced a decline in the CPUE of M&F starting in 1996. In LFA 25S, the CPUE decreased again in 2003, dropping from 0.4 lobster/trap (recruitment size) in 1985 to 0.1 lobster/trap in 1996, and finally to 0.01 in 2006 (Fig. 19). The CPUE in LFA 26AD has also followed a continuous declining trend since 1996, from 0.06 lobster/trap in 1994 to 0.04 lobster/trap in 1997 to 0.02 lobster/trap in 2006 (Fig. 19).

The CPUE size distribution is spread mostly over the pre-recruit size of 5-10 mm below the MLS to about a CL of 90-100 mm (i.e., 3 molt groups above MLS) (Fig. 19). However in LFAs 25S and 26AD, the size distribution has distinctly shifted to the 60-125 mm size range since 2003. This spread of the size distribution is probably due to the declining number of lobsters in smaller sizes and not due to either the increase in large-sized lobsters or the implementation of the management measure protecting large lobsters. This pattern becomes more evident based on the size distribution of the M&F in terms of molt groups (Fig. 20). The total catches are composed of about 80% of animals in the FMG into the fishery but the pattern of catches is changing considerably in LFAs 25N, 25S and 26AD.

Gradual implementation of escape vents in traps starting in 1985 can explain the decrease of sublegal size lobsters in the catch the following years (CPUE distributions; Fig. 19). However escape vents only became mandatory in 1996 and prior to that period, multiple at-sea samplings within a same year could have been carried out both with harvesters using traps equipped with escape vent and harvesters not using such traps. The presence or type of escape vent was not recorded during at-sea sampling.

The CPUE distribution is a reasonable indicator of stock abundance. A declining trend can clearly be observed in the capture of both sub-legal and canner size lobsters for LFA 25S (Fig.

19), likely indicating a reduction in stock abundance. The CPUE gave a good index of the lobster abundance because the size structure was standardized to effort.

Finally, the increase in the CPUE of larger lobsters (>120 mm) in LFAs 25N and 25S may be an artifact and not evidence of the positive effect of the management measure aiming at protecting large lobsters via a window-size exclusion. Indeed, the overall CPUE were extremely low and the increase in the CPUE of large animals could be due to large lobsters being returned at sea are being recaptured and thus recorded several times through the season. Indeed, there is strong evidence from the banding study that large lobsters are recaptured several times during the fishery (MacMillan et al. in press).

3.3.2 Recruitment-index program

The recruitment-index program is an extensive at-sea sampling collecting information on lobster size and CPUE throughout the fishing season, and contrasts with the information gathered during the tradition at-sea sampling that is more intensive but of a short duration. Advantages of the recruitment-index program over the traditional at-sea sampling program are an improved temporal coverage and harvesters' involvement. Hence, a temporal coverage can address issues/biases that occur throughout the fishing season including variability in events (i.e., biological and meteorological) and fishing strategies that can be missed by pre-determined intensive sampling. Information recorded in the three modified traps (blocked escape vent) allows for the verification of the level of the pre-recruit CPUE observed in the at-sea sampling program.

In LFA 24, where there is a longer time series, the CPUE of recruits is increasing (Fig. 21). In LFAs 23G, 25N, 26APEI and 26B, the pre-recruit index of M&F seems to indicate stability in the population (Fig. 21). However, LFAs 25S and 26AD show constant decline of the CPUE of recruits and the catches in the modified and regular traps are almost identical, indicating a lack of pre-recruits (Fig. 21). For B, CPUE in both trap types are almost identical. This is to be expected since only a small percentage of females are sexually mature below 70 mm CL, which is equivalent to the escape vent efficiency (Fig. 21). Note that for LFA 26B where the MLS went from 70 mm to 74 mm, similar CPUE between regular and modified traps is a sign of an inefficient escape vent and not of recruitment failure (Fig. 21). Finally, there is no apparent increase in larger lobsters in LFAs 25N and 25S following the implementation of management measure aiming at protecting large lobsters via a window-size exclusion (Fig. 21).

Although this time series is shorter than the at-sea sampling program, the same declining trends have been observed for pre-recruit, canner and market size lobsters in all LFAs.

3.3.3 Index-harvesters program

Assuming that lobsters will be in the canner size category (at a MLS of 70 mm) for approximately one molt before molting into market size (Comeau and Savoie 2001), the ratio of canner: market can be used as an indicator of lobsters surviving beyond the first year in the fishery. Since the MLS for LFA 26B is now at 76 mm CL, this LFA was excluded from the analysis because the canner group only represents half of the animals considered in their first

year into the fishery. An obvious declining pattern in the canner: market ratio yearly trends can be observed for LFAs 23BC, 23G, 26APEI, 26ANS and 25S (Fig. 22). In LFAs 24 and 25N, no trend was observed, but LFA 24 has the highest values (Fig. 22). A decline in ratio can be explained by either a recruitment pulse moving through the population (large number of canner size lobsters that entered the fishery and now are growing to larger sizes) or, conversely, by a decrease in abundance of canner size lobsters (no new canners size lobsters entering the fishery so that only market size lobsters are left). Since landings in most areas have been declining, it is safe to assume that the yearly decline in the ratio is due to a decline in abundance. Furthermore, this assumption is also supported by the lack of trend, especially in LFA 24 and to a certain extend in the first week of LFA 25N, indicative of a fishery that relies primarily on canner lobsters (i.e., recruitment fishery). LFA 24 has the highest canner: market ratio among all regions (Fig. 22). In weight, LFA 24 lands from 2- to 4-fold the amount of canners compared to heavier and bigger market lobsters. The canner: market ratio in region LFA 26AD is the only one being lower than 1 (more market than canner lobsters in weight). Those results might be explained by either a very low abundance of canner lobster in that region or fishing strategies targeting market size lobsters. The trawl survey indicates that canner-size lobsters are seldom captured in much of 26AD.

3.4 Fishing Effort

Information from the index-harvesters program can also be used as an indicator of fishery effort or fishing strategies. Generally, a sharp decrease in weekly CPUE early in the fishing season without a subsequent increase could be a sign that the stock cannot sustain the current level of fishing effort. This depletion pattern is observed in LFAs 25N and 25S, while trends with slowly declining CPUE were observed in the other LFAs (Fig. 23). Environmental conditions could affect lobster catchability. For example, water temperature in the spring of 2006 was warmer than normal (Paulin and Gagnon 2008) and CPUE for the first weeks of the fishing season were higher. LFAs 23BC and 23G can be described as stable with very little variation between years.

Volunteer logbook information indicates that in LFAs 24, 26APEI and 26ANS, almost every harvester hauls the maximum trap allocation throughout the season (Fig. 24), but the fishing effort (between 68 and 82%) indicates that they do not fish every possible day of the season (Fig. 25). This reflects the "no Sunday" fishing in those areas. In LFA 23, trap allocation was 375 prior to 1998. In 1998, the management plan called for a reduction in the number of traps from 375 to 300 in 3 years (i.e., 25 traps per year; as illustrated in Figure 24). In the two sub-regions of central Northumberland Strait (LFAs 25S and 26D), several harvesters do not haul their entire fishing gear (250 and 300 traps respectively) on a daily basis even at the start of the fishery (Fig. 24). In LFA 26AD, the average effort since 1994 is 66% while it is only 50% for LFA 25S (Fig. 25).

Another indicator of the fishing effort in relation to the lobster abundance is the proportion of empty traps during the season (Fig. 26). Patterns observed vary between LFAs. LFAs 23BC, 23G and 26B show a slow increase in the proportion of traps not catching any commercial size lobsters (berried females excluded), with averages of 36%, 30% and 42% in the 1980s and 54%, 39% and 53% in the 2000s respectively (Table 13). In LFA 25N the proportion of traps without commercial catches has increased 3-fold while proportions in LFA 26APEI increase from 23%

to 47%. LFAs 25S and 26AD have seen similar increases in the proportion of traps not catching commercial lobsters with proportions rising from a 1980s average of 13-17% to 57-61% respectively in the 2000s. Conversely, the proportion of traps without commercial catches in LFAs 26ANS and 24 is stable. Finally, a much higher percentage of empty traps in the fishery would be expected in LFA 25 (both 25N and 25S), if data from September and October were included. In this assessment, only at-sea sampling data from August were considered. With proportions of empty traps around or over 50% in five of the nine sub-regions, it could indicate that fishing effort is too high.

4. FEMALE LOBSTER REPRODUCTIVE STATUS IN LFA 25

4.1 Background

In the sGSL, lobster mating and spawning occur between July and September. Comeau and Savoie (2002a) reported that the majority of female lobsters follow a two-year reproductive cycle with females molting and mating during the same summer, extruding the eggs the following year, and carrying them attached on pleopods under the abdomen for nearly another year. However, up to 20% of the females in the sGSL could spawn in successive years and some could even molt and spawn in the same summer. Comeau and Savoie (2002a) also indicated that the length of the reproductive cycle is related to water temperature. Based on this information, females with a one-year reproductive cycle are fully protected in a spring fishing season since they will spawn and be legally protected during the summer period and be berried (thereby protected from the fishery) the following fishing season. However, in LFA 25 (fishing season from early August to early October) harvesters can catch females with a one-year reproductive cycle in early postmolt, but before they extrude their eggs (i.e., in the same year before they become primiparous females). They could also catch multiparous females that have the ability to spawn in successive years before they can release another clutch of eggs. Hence, nearly all of the potential egg-producing females would be vulnerable to the fishery before they have the opportunity to extrude their eggs and get "legal protection". Based on this scenario, significant numbers of mature females in their egg-extrusion year (hereafter referred to as EEY females) should be observed in the commercial catch during the early part of the fishing season in LFA 25. In order to verify this hypothesis, a study to investigate the reproductive condition of females caught during the summer lobster fishery was carried out.

4.2 Methods

The reproductive potential of the stock and the female maturity condition in LFA 25 was investigated between 2002 and 2006, both in LFA 25N (Loggiecroft) and LFA 25S (Aboiteau). A total of 100 canner size females were randomly collected every week at the beginning of the fishing season. In Loggiecroft, females were collected for the first three weeks every year except 2004 as the season was delayed one week and females were only sampled in the first two weeks. In Aboiteau, females were collected every week in August. Additional samples were collected in the first week of September in 2003 and 2005 because the percentage of EEY females was still higher than 10% at the end of August. All females were transported to the laboratory to be examined according to the technique described by Comeau and Savoie (2002a). Their

reproductive condition (readiness to spawn) was based on ovary condition and pleopod staging techniques. Although the ovary condition technique is very accurate, it requires dissection and is quite labor-intensive. Hence, to investigate the reproductive condition of females until the end of the fishing season, the fast and nondestructive pleopod staging technique was used. Pleopods were sampled using a stratified sampling technique that consists of collecting five pleopods per 2-mm size group starting at the MLS for the canner size females. The number of pleopod collected was increased to ten per 2-mm size group in 2005. The ovary condition technique was used to validate the fast and nondestructive pleopod staging technique.

4.3 Results and Discussion

Females during their EEY were present in the commercial catch of both sub-areas. The weekly level of EEY females in the catch was different between LFA 25N and LFA 25S, being higher in the south (Fig. 27). However, the absence of EEY females in the catch was observed simultaneously in both areas (Fig. 27).

4.3.1 Loggiecroft

The weekly percentage of EEY females varied between 19% and 44% (Fig. 27). Based on the ovary condition, the highest percentage of EEY females during the first week of the fishery in Loggiecroft was 44% in 2005. EEY females were nearly absent in the catch before the last week in August, except in 2005 with 6% of EEY females during the week of August. The weekly percentage of primiparous females with a one-year reproductive cycle, which are fully protected in a spring fishery, remained low (<3%), except in 2005 when it ranged between 2% and 14%. Multiparous females with a one-year reproductive cycle were predominant in the samples. These females are mature females that were either molting earlier in summer or had just released their larvae. Low percentages of that type of mature females were present in 2000 (1%) and 2004 (2%-3%), but much higher (2%-16%) in 2003, 2005 and 2006. Both primiparous and multiparous EEY females with a two-year reproductive cycle were frequently observed in the catch reaching as high as 20%. These females were already exposed to the fishery the previous year.

4.3.2 Aboiteau

The weekly percentage of EEY females ranged between 33% and 54% during the first weeks of the fishery (Fig. 27). The highest percentage observed was in 2005 with 54%, and remained high for the following three weeks (47%-54%; Fig. 27). Based on the ovary condition, the weekly percentage of EEY females in Aboiteau remained high in the month of August and dropped to low values in the first week of September (Fig. 27) in every year. The only exception was in 2003 when 6% of EEY females were still observed on 9 September. The weekly percentage of primiparous and multiparous females with a one-year reproductive cycle was low between 2002 and 2004, and higher in 2005 and 2006. Both primiparous (0%-23%) and multiparous (0%-29%) EEY females with a two-year reproductive cycle were observed in the catch. Their percentages reached 25% and 35% for both primiparous and multiparous EEY females respectively.

4.4 Conclusion

As mentioned in a 2004 report (Comeau et al. 2004), it is imperative that the reproductive potential of the lobster stock in LFA 25 be fully protected under a high exploitation level (i.e., EEY females should be totally absent from the commercial catch). For lobster fisheries operating during the critical period of the life cycle (summer season), the reproductive potential is not fully protected even if the landings of berried females are prohibited. The fishing season LFA 25 should not be open in August to protect the reproduction potential of the stock and to avoid an increase of the exploitation rate of EEY females. The "double-dipping" by the fishery of the mature female population in LFA 25 is not observed in a spring fishery. A summer fishery makes it more difficult to achieve the management goal of increasing egg per recruit based only on increases in MLS and is contradictory to the FRCC's (FRCC 1995) recommendations for lobster conservation.

5. SELECTIVITY AND CATCHABILITY BASED ON ESCAPE VENT AND ENTRANCE RING DIAMETER

5.1 Background

Fishing effort has changed over the years due to modification of the fishing gear and technology. Information on effort needs to be updated to reflect these changes. Lobster traps are equipped with vents to facilitate the escape of sub-legal animals. There is a regulation on the size of the escape vent height that did not change although an increase in MLS occurred in the sGSL fisheries and therefore needs to be reviewed. Studies currently available have tested escape heights of 38.1 mm (Maynard et al. 1987), which is still the legal size in 2006, and escape heights of 50.8 mm, 52.45 mm, 53.98mm and 55.56mm (Estrella and Glenn 2006). Entrance ring diameter is regulated in some LFAs but no study had been done to measure the effect of such a regulation, more specifically, there is a lack of information concerning the ability of smaller diameter entrance ring to reduce large lobsters' catchability.

The objectives of this project were to 1) develop new selectivity curves for various escape vent height, 2) gather information on the escape vent length, and 3) establish the lobster catchability in relation to the entrance ring diameter.

5.2 Methods

The escape height study was carried out from 8-17 September 2004 and the entrance diameter width study from 22 September to 1 October 2004 in Cribbon's Point, NS, after the yearly commercial fishery season (1 May to 30 June), and the July-August lobsters' biological activities of molting, mating, and/or spawning. For both studies, traps were set by harvesters familiar with the Cribbon's Point area and information was collected on board the fishing vessel. Lobster CL and the largest cheliped width were measured to the nearest tenth of a mm using an electronic caliper. The sex (male, female no-egg, berried females), carapace condition (soft, hard), missing or rejuvenating cheliped (crusher or pincer) were also recorded, as well as the trap specificity in which the lobster was caught. Line positions in Lat/Long and water depth were also recorded.

5.2.1 Escape vent study

Baited rectangular wire traps with two compartments were used. The height of five escape vents were tested (Table 14), all escapes had a length of 152 mm. A ventless trap was also used for comparison and selection estimation. Two of the escape vent sizes had to be custom-made by using the Type 2 escape size and filing the width until the required size was obtained. Traps were set in lines of 6 traps, one of each escape type. There were 60 traps for a total of 10 lines. The orders in which traps were positioned on a line followed a Latin square design. Traps were hauled daily on weekdays, except when weather conditions did not permit, and were not fished during the weekend.

At the same time, underwater camera observation was carried out to identify any specific lobster behavior once caught in the trap. All activities were recorded and the trap content was measured daily by SCUBA divers.

The SELECT method was used to analyze the collected data (Treble et al. 1998; Millar and Fryer 1999). Information collected during the 8 sampling days were pooled on the basis that setting 60 traps over 8 days was equivalent to setting $8 \times 60 = 480$ traps on one day. Selectivity curves were not separated by sex as there were too few lobsters of each sex and size. SELECT model computations are done by pairing successively each of the escape vent size information with the blocked trap data. Based on the observed number of lobsters in the ventless and one of the vented traps, one can calculate the proportion of the total catch caught in the vented trap, $\psi(l)$, as:

$$\psi(l) = \frac{p \cdot r(l)}{p \cdot r(l) + (1-p)}$$

The size selectivity function r(l) describes the probability of retention of lobsters of length l in the vented trap given that they encountered this gear, and p is the relative fishing intensity of the vented trap and ventless trap. Data was fitted with both p as a random variable and p fixed at 0.5 which assumes that both traps have equivalent fishing intensity. We set the r(l) to equal the logistic selectivity function:

$$r(l) = \frac{\exp(a+bl)}{1+\exp(a+bl)}$$

where a and *b* are parameters of the logistic curve. The length at 50% retention, l_{50} , and the interquartile range SR (SR = $l_{75} - l_{25}$) were calculated as -a/b and 2ln(3)/b respectively. The model was fitted to the observed data using maximum likelihood estimation. See Millar and Fryer (1999) for further details on the model description and fitting.

Conservative 95% confidence intervals were calculated for the observed proportions *s* using the approach of Millar (1995). It consists of replacing the term s(1-s) in the normal approximation equation by its maximum 0.25 so to yield the equation

$$s \pm \frac{z_{0.025} \cdot \sqrt{0.25}}{n}$$

where *n* is the number of observation at size, *s* the observed proportion at size and $z_{0.025}$ the 0.025 percentage point of the normal distribution.

5.2.2 Entrance diameter study

Five entrance ring diameters were selected (Table 15) to represent both those that were used in the past (11.4 cm) and those which are presently in use in the sGSL (12.7-15.2 cm) by the majority of the harvesters (M. Comeau unpublished data). A ring size of 20.3 mm, used by some harvesters to catch larger lobster, was also tested. To avoid the accumulating catch of small lobsters, wire lobster traps equipped with escape vents height of 41.8 mm were used. Five traps equipped with different entrance ring diameter were set on a string for a total of 12 strings. The order of trap types on line followed a Latin square design. Traps were hauled daily on weekdays, except when weather conditions did not permit, and were not fished during the weekend.

The 8 days of data collection were combined to obtain a contingency table of the lobster catches above 114.9 mm, between 105.0 and 114.9 mm and between 95.0 and 104.9 mm, inclusively. A permutation test was performed to test whether the ring diameter influenced the number of large lobsters caught (i.e., CL greater than 114.9 mm). If N lobsters are caught, assuming that they are randomly assigned, one should expect to catch N/5 lobsters per trap type. A *chi-square* test was calculated with expected value equal to N/5 for all trap types, that is:

$$X^{2} = \frac{\sum_{i=1}^{5} O^{2}_{i}}{(N/5)} - N$$

Since the number of observation was low, permutations were used to obtain the level of confidence instead of comparing the test value to a *chi-square* distribution with 4 degrees of freedom. Assuming that setting 12 lines of traps over 8 days is equivalent to setting 480 lines on one day, permutations of the observations were made on each line of 5 traps. A trap ring diameter was assigned randomly among the 5 traps and a new permutated table of observations per ring diameter was obtained. *Chi-square* tests were calculated for each of the 1,200 permutations. The high occurrence of large lobsters in ring diameter 20.3 mm, the largest entrance ring, was also measured by the number of permutations with large lobster catches greater than what was observed.

5.3 Results and Discussion

A total of 3,901 lobsters were measured over the 8 sampling days with sizes ranging from 27.3 to 156.1 mm CL. Only lobsters between 55 and 110 mm CL were considered for the selectivity analysis because very small lobster may escape through the mesh of traps and since very large lobsters are very scarce. This restriction reduced the number of available lobsters to 3,766.

Akaike's Information Criterion (AIC) (Burnham and Anderson 1992) was used to choose between SELECT models assuming equal fishing intensity (p = 0.5) and models estimating the fishing intensity. In all cases, models assuming equal fishing intensity were more parsimonious (Table 16). The fit of each select model to the observed proportion of lobsters in 1-mm CL increment are shown in Figure 28. There is a sharp change in size-selectivity for a small change of escape height. For each increase of approximately 1.5 mm in the escape height, the l_{50} (i.e., 50% retention) increased between 1 and 6.9 mm for larger and smaller animals, respectively (Table 17). Similarly, l_{95} (i.e., indicating the lobster CL at which the escape vent is no longer efficient) increase less for a height increase for vents larger than 39.6 mm (Table 17). Hence, the efficiency of a 152 mm escape vent in length to allow smaller lobsters to exit the trap seems to diminish for an increase of the escape height.

Video observations of trapped lobsters trying to escape through the escape vent show that lobsters have particular behavioral patterns when exiting the trap. In general, the claws go out first and the rest of the body follows; often sideways, and, thus, the lobster pass lengthwise through the escape instead of simply front to back. This indicates that escape length might be a limiting factor when exiting the trap and explain the reduced efficiency of the 152 mm in length escape vent when its height is increased. However, the largest cheliped width was not a limiting factor for going through the escape vent for all lobsters measured. The smallest escape height was 38.1 mm and the smallest lobster CL with cheliped width greater than 38 mm was 92 mm, a CL much greater than 1_{50} .

The analysis of the ring diameter study is based on the information from lobsters larger than 95 mm CL as escape vents have no effect at that size. Also, three lines of traps were not recorded on one of the sampling days because of bad weather reducing the number of hauls from 480 to 465. Hence, 303 lobsters were measured (Table 18). There seemed to be an increasing number of large lobsters (115-146 mm CL) captured as the ring diameter increases (Table 18) although it is not clear for lobsters in the 105-114 mm size range. Testing for large lobsters (115-146 mm CL), under equal catchability, one should expect an average of 6 lobsters per trap type (30 lobsters $\div 5$ traps types = 6 lobsters per trap). The *chi-square* randomness test for equal catchability was equal to 10.33. Only 47 of the 1,200 permutations yield a *chi-square* larger than 10.33, hence giving an observed *p-value* of 3.9% (Fig. 29). Furthermore, from the 1,200 permutations, only 14 cases had number of large lobsters equal or above 12, the observed number in the largest ring diameter traps (Fig. 30). This indicates that traps equipped with larger ring diameter will tend to catch larger lobsters if large lobsters are available.

Since the implementation of the escape vent regulation in 1996, the height has been set at 38.1 mm. Since then, the MLS has gone from 63.5 to 75 mm in some areas (Table 1). Results indicate that escape height should be modified. Furthermore, underwater camera observations indicate that escape length could eventually be an important limiting factor for the escape vent efficiency. Further studies are required.

The results also show that ring diameter could influence the catchability of larger lobsters. Hence, limiting the ring diameter could be an indirect method for reducing catchability of the large egg-producing lobsters. Future studies in areas with large quantities of large lobsters are needed to fully understand the effect of ring diameter. The ring entrance angle on the trap, distance from bait pins and use of offset entrances are other factors that could influence catches of large lobsters. Further studies on the effect of entrance ring on lobster catchability should be considered.

6. ECOSYSTEM CONSIDERATIONS

Environmental factors, such as water temperature, can influence the distribution of lobster as well as their catches (Drinkwater et al. 2006). Chassé et al. (2006) reported that the bottom temperatures over most of the sGSL are typically less than 3 °C, which is not considered a suitable thermal habitat for lobster. This constrains the distribution and movement of lobster to the coastal water of the s GSL (Comeau and Savoie 2002b) where bottom temperature can reach over 20 °C (e.g., central Northumberland Strait) during the summer.

Air temperatures can have a strong effect on the water masses properties, especially in coastal water. Time series of air temperature recorded at the Magdalen Islands (Quebec), Charlottetown (PEI), and Miramichi (NB) show similar trends indicating wide-spread changes over the sGSL. Based on the longest time series (which began in 1873 in Charlottetown; Fig. 31), the annual mean air temperatures prior to 1930 typically were below the 1971-2000 average. The 1950s showed warmer than average conditions, and oscillations with about a 15-year period can be seen until the late 1990s. Recent temperatures have been above normal, with 1999 having the highest temperature on record at all three sites.

An analysis of bottom temperature time series gives an indication of the average seasonal cycle between 1997 and 2004 for each LFA (Fig. 32). LFA 25N shows the highest amplitude with temperatures averaging over 18 °C during the month of August while LFA 23BC has the smallest amplitude. In all cases, minimum temperatures are reached during the winter months (January –March).

Overall, environmental conditions have been warming up in the sGSL over the last decade. In particular, sea surface temperatures (SST) have been rising in all LFAs, especially during the last 4-5 years (Fig. 33 shows SST anomaly for LFA 25S as an example). This is consistent with the observation of less ice coverage than normal over the last 6-7 years, except for 2003 when the ice volume and extent was well above average.

A volume index of the cold intermediate layer (CIL) was developed for the month of September using the information from the multi-species survey. It consists of calculating the volume of water that has a temperature below 1 °C in the sGSL (Fig. 34). The index has been decreasing since 2003, when it was above the long term mean. The 1999 value represented the first year since the mid-1980s that the volume index was below normal, suggesting warmer conditions in the sGSL. Since then, there have been five years with a below average quantity of cold water. This may favor an expansion of the lobster distribution to deeper waters.

There is ongoing research aiming at better understanding lobster larval drift and survival in the sGSL. Ocean-current observations, hydrodynamic models, and Individual Based Models (IBMs) of lobster larvae indicate that the Northumberland Strait is an isolated system (relying on itself

for recruitment), unlike the rest of the sGSL. The recent warmer conditions have lead the models to predict a better relative survival of lobster larvae, as their growth rates are temperature dependent in the presence of sufficient food resources.

7. SOURCES OF UNCERTAINTY

Landings and information gathered from recruitment-index program and at-sea sampling program 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, indicators derived from these sources would not necessarily reflect changes in abundance, fishing pressure, or production.

Data on landings from the Statistical Branch (DFO) correspond to compilation of sale transactions (purchase slips) between official lobster buyers and harvesters. This information takes 18 to 24 months to be available. There are also uncertainties on the amount of non-recorded lobster catches corresponding to other sales, personal consumption and poaching. In addition, there is no direct data on the spatial distribution of landings and effort. This information is needed to monitor the extent and changes in the distribution of fishing effort and to map the overlap of fishing gear. Information on catch, effort and fishing location from all the users is imperative to properly assess lobster stocks. A pilot project conducted by DFO Science Gulf Region in collaboration with harvesters in LFA 26B started in 2006 to electronically collect accurate landings with effort and location information in a timely fashion.

Changes in fishing efficiency (or "effective effort") are not accounted for. If fishing efficiency has increased in the last five years due to larger vessels, better navigation or improved fishing strategies, then the catch rate index may not be indicative of abundance in recent years.

8. CONCLUSION

The stock status of the five LFAs located in the Gulf Region has been assessed using a suite of indicators from trawl survey and SCUBA-count data, DFO official catch statistics, at-sea sampling, index-harvesters logbooks, recruitment-index logbooks, and biological sampling. Lobsters in the sGSL as a whole continue to be in high abundance with landings above long-term means. The only area with strong negative trends is the Northumberland Strait (i.e., LFAs 25 and 26AD). Fishing pressure, measured by the percentage of FMG into the fishery coupled with the 38-yr landings trend, indicated that it is high for the five LFAs within the DFO Gulf Region except for the sub-region 26ANS. The lobster fishery in the sGSL continues to have high exploitation rates and to be heavily dependent on new recruits, making this fishery directly dependent on the level of recruitment. The increase in the percentage of empty traps during the fishery in several areas corroborates the interpretation that the fishing pressure on the lobster stock is too high. Exploitation rates were not evaluated but based on previous evaluation are still considered high.

The two multi-year management plans aimed at increasing egg production seem to have had a positive effect on lobster production in the five LFAs within the DFO Gulf Region as a whole. Once again, the only area that systematically shows negative indicators for the level of 1- and 2- yr old lobsters, pre-recruits into the fishery and berried females is central Northumberland Strait. Furthermore, the female condition monitoring program in LFA 25 clearly shows that the time of the fishery is detrimental to the reproductive potential of the stock (i.e., increase in the egg production).

The trends of the lobster stock from different indicators are presented in more detail in Table 19.

8.1 Abundance Indicators

Abundance indicators based on landings for legal size lobster from all LFAs are close to or above the long-term median except for LFA 25. While landings have generally increased since 1947, the timing of the peaks differed as did the pattern of decline of landings following the peaks. This reflects the heterogeneity of the spatial distribution and the temporal variability of the lobster resource in the sGSL. The exception is LFA 24 where landings show a steady increase since 1977.

For all LFAs, very little change was observed in landings between 2004 and 2005. For the longterm trends, it seems that declining trends have been less pronounced in the spring fisheries and those outside of central Northumberland Strait, with landings in 2005 still above the long-term median. In LFA 23, the 2005 landings (2,907 t) were 79% above the long-term median (1,626 t) but landings have been declining since 1993. Within LFA 23, the decline in landings was more pronounced in Baie des Chaleurs. Landings in LFA 26B have varied little for the last 12 years. In LFA 26A, the 2005 landings of 3,172 t were 13% above the long-term median. However, landing trends within LFA 26A varied with location. Landings in the Northumberland Strait portion of the LFA (LFA 26AD) dropped more than 76% from the highest peak landings, while they dropped more that 58% in LFA 26APEI. Conversely, landings have been somewhat stable for the last 18 years for fisheries operating in mainland NS east of Pictou (LFA 26ANS).

The landing trends in LFA 25 were characterized by wide fluctuations with no stable period since 1948. In 2005, 2,419 t were landed, which represent a 21% reduction from the long-term median. The 20-year decline is the largest one observed in the sGSL. Although a declining trend was observed for the entire LFA, the one observed in LFA 25N is similar to LFA 23. LFA 25S is the area within the sGSL with the most alarming trend.

Landing trends in both LFAs 25S and 26AD are typical of a boom and bust fishery (Acheson and Steneck 1997). All indicators suggest that we are presently in a "bust" situation and that, based on historical landings information, the area located in the central Northumberland Strait might still experience further declines in the future.

The total lack of reliable catch, effort and fishing location information from harvesters is making it difficult to understand and analyze landing fluctuations. This situation is symptomatic for most of the Canadian lobster fishery, and has been raised by every biologist assessing lobster stocks in eastern Canada (see research documents and the stock status reports at http://www.dfo-
mpo.gc.ca/csas/Csas/Home-Accueil_e.htm). Although harvesters in communities within the sGSL are indicating important changes in their catches, it is impossible to clearly determine where they are occurring, to quantify these changes and to determine if they are the result of shift in effort. These issues can only be fully understood with timely accurate temporal and spatial data supplied directly from the users, i.e. harvesters.

Similar trends in abundance were observed in the fishery-independent trawl survey. The numbers of canners in LFA 25N declined about 67% between 2001 and 2005 but rebounded to near-2002 levels in 2006. The number of canners remained low for LFAs 25S and 26AD. The number of market size lobsters declined by about 40% during the same period and was the highest ever estimated for the entire LFA 25 and LFA 26AD in 2006. The highest lobster abundance was observed in LFA 26ANS. The spatial extent of high density areas (area with >400 animals per km²) contracted within west-central Northumberland Strait between 2001 and 2005 (Comeau et al. 2004) and rebounded in 2006.

8.2 Fishing Pressure Indicators

The percentage of FMG into the fishery landings could be a good indicator of the fishing pressure because, under the assumption of a low exploitation rate, there should be a good representation of multi-molt groups in the catch (i.e., low FMG) and more stability in landings. Based on at-sea sampling data from the 2000s, the FMG were higher than 70% for LFAs 23G and 24, between 60% and 70% for LFAs 23BC, 25N, 26APEI, and 26B, and were lower than 60% for LFAs 25S, 26AD and 26ANS. However, the FMG alone will only give a partial indication of the situation if it is not coupled with landing trends. Hence, a decline of the FMG could be viewed as positive, but coupled with a declining trend in landings, could be indicative of a high fishing pressure (not allowing FMG to survive the fishery and growth to bigger sizes). By comparing the FMG to the 38-yr landings trend (in terms of a risk analysis given the most severe situation), a high fishing pressure is observed in several sub-regions, except in LFAs 23BC and 26B where the indicator is neutral, and in LFA 26ANS where the indicator is positive. The high incidence of the FMG coupled with declining landings trends indicates that the fishing pressure or the exploitation rates are still high except in LFA 26ANS. Based on estimates from previous stock status reports (Lanteigne et al. 1998, 2004), the exploitation rates of LFA from the Gulf Region could vary from 63% to 87%.

In general in the sGSL, the high portion of FMG and the low abundance of market size lobsters provide further support to the statement brought forward by the FRCC (1995) and previous assessments in the sGSL (Lanteigne et al. 1998, 2004; Comeau et al. 2004) that the lobster fishery is defined as a recruitment fishery. In the last two management plans, changes in conservation measures were implemented in terms of increasing the MLS, but no actual progress was made on reducing the fishing effort and the exploitation rate. The increases in MLS began in the 1980s, and as part of the last two multiyear management plans, were primarily designed to increase the egg production of the lobster population, not to tackle the issue of the heavy dependence of the fishery on annual recruitment. Abundance and fishing pressure indicators from both fishery-based and independent data still corroborate this situation for 2006. A sustainable lobster fishery cannot be achieved in the sGSL as long as the overall commercial catch relies heavily on the annual contribution of new recruits into the fishery. Recruitment

fisheries are seldom stable and a reduction in the effective effort is needed to change this situation.

Further evidence that the fishing pressure is too high in four of the five LFAs is based on the estimates that 50% of traps are empty over the season. The only exception is LFA 24 with 24% empty traps. An increase of more than 10% between the 1980s and 2000s was observed in LFAs 23, 25 and 26AD, while it remained constant (neutral) in LFAs 26APEI, 26ANS, and 26B. The increase in the percentage of empty traps is unexpected for LFA 23 since the number of allowable traps went down by 75 traps. The biggest increase was observed in central Northumberland Strait (LFAs 25S and 26AD) averaging 13-17% in the 1980s to 57-61% in the 2000s. Finally, since LFA 25 at-sea sampling data only include August, an even higher percentage of empty traps in the fishery would be obtained if data from September and October were included.

The effective effort based on the actual trap haul, compared to the nominal trap haul (allowed by fishery management regulation) could also be used as a fishing pressure indicator. In all LFAs, the maximum trap allocation was fished the majority of the time with a noticeable decline at the end of the season. In a situation where the resource is diminished, harvesters would try to be more cost effective and might adopt different fishing strategies. Furthermore, the actual effort deployed to capture lobster is much below the effort allowed by the fishery management regulation. Results corroborate the fishing practices in central Northumberland Strait, which change their fishing practices by doing trap hauling rotations, i.e. they will either fish every two to three days or alternate from hauling half the traps one day and the other half the next day (Comeau et al. 2004). In either scenario, trap soak time will increase to compensate for low lobster abundance. Thus, one can assume that the total number of traps per harvester could be reduced by half in some areas without any reduction in lobster landings or exploitation rate and the landings would still decline.

8.3 Stock Production Indicators

The abundance of 1 and 2 year old lobsters was assessed by SCUBA diving surveys in LFAs 23, 25S, and 26AD. Abundances observed in LFA 23 increased from 1.3 to 6.2 lobster/100m² between 2000 and 2006. Abundances observed in both LFAs 25S and 26AD were much lower than in LFA 23BC. They were below 1 lobster/100m² for 2005 and 2006 with no increase. There was a large increase in cryptic lobster abundance in the LFA 23 for the last three years indicative of very good recruitment. These large increases of cryptic lobsters were not observed in central Northumberland Strait where the estimated abundances were the lowest. It seems that recruitment is still lacking in the Northumberland Strait area.

The production indicators using the pre-recruit logbook program and the trawl survey are negative in the Northumberland Strait and positive elsewhere in the sGSL. The trawl survey indicates that the level of pre-recruits into the fishery is low in LFAs 25S and 26AD, corroborating the information from fishery-based surveys. Moreover, the number of pre-recruits has decreased by about 70% between 2001 and 2005. Using three modified traps with the escape vent blocked during the recruitment-index program allows assessing pre-recruits into the fishery. High levels of pre-recruits were observed in LFAs 24 and 25N, while levels were very low and

on a constant decline in LFAs 25S and 26AD. In LFAs 23, 26APEI, 26ANS and 26B, the levels were high and stable.

A gradual increase of berried females catch rates was observed in several spring fisheries in the sGSL, while a decline was observed in the summer-fall fishery and the Northumberland Strait. Increases ranging from a 2-fold increase in LFAs 23G, 26APEI and 26ANS, to a 4- to 5-fold increase in LFAs 24 and 26B were observed. However, the berried females catch rate declined in LFAs 25 and 26AD. In LFA 23BC, berried females catch rates had increased from 1983 to 2002, but seems to be declining since 2003.

During sampling of the fishery in LFA 25, a high percentage (up to 54%) of mature females in their EEY (exposed to the fishery a second time) was observed in the commercial catch, indicating that the reproduction of the stock is not fully protected due to the timing of the fishery. Under the current LFA 25 summer fishery management regulation, this "double-dipping" of mature EEY females larger than the MLS severely reduces the egg production compared to a spring fishery (Comeau et al. 2004). It could also explain the low catch rate of berried females. Furthermore, since the general water movement in the central Northumberland Strait is influenced by the tide (central Northumberland Strait could be considered a closed area) with a slight movement toward the east, the low egg production in LFA 25S could also explain the overall poor performance in LFA 26AD. It is more difficult to achieve the management goal of increased egg production based only on increases in MLS during a summer fishery than a spring fishery.

Abundance, fishing pressure and production indicators all suggest that the declining landing trends observed in central Northumberland Strait are probably caused by a severe reduction in annual recruitment and very high fishing capacity. Any corrective measures to reduce the fishing effort and enhance the egg production that would be put in place now would take at least seven years to have some effect (i.e., the time it takes a lobster to develop from egg to canner size).

8.4 Ecosystem Indicators

The ecosystem indicators show that climatic conditions for the sGSL are warming, and temperature has been rising in all areas. In terms of larval drift and survival, current observations and models suggest that the Northumberland Strait is essentially an isolated system, relying on itself for recruitment, unlike the rest of the sGSL.

Lobster diet and predator-prey relationships were established based on samples collected during the May, July, August and October trawl surveys carried out in LFAs 25 and 26A. Lobster was largely carnivorous and decapods were the principal prey (57-84% of prey biomass), with rock crab being the single most important species (45-78%). About 70% of the rock crab consumed by lobster represented fresh prey and the remainder consisted of old carapaces. Lobster represented 8% to 13% of the prey biomass; however, a substantial portion (39-79%) of the lobster remains consisted of old carapaces. The only demersal fish to consume large amounts of intact lobster was the shorthorn sculpin, but their abundance in lobster habitat was very low. Cannibalism during the molt may be an important source of natural mortality for lobster and should be investigated further.

9. MANAGEMENT CONSIDERATIONS

The lobster fishery in the sGSL continues to be heavily dependent on new recruits making it susceptible to changes in the level of recruitment. The increase in the percentage of empty traps during the fishery in several areas also corroborates the interpretation that the fishing pressure on the lobster stock is high. Based on previous assessments, the exploitation rates are considered high. A reduction in exploitation rate could be achieved by reducing the effort. Options for this include diminishing the number of participants, the number of traps per participant or the number of days in the season. For a reduction in the number of traps to be an effective measure, consideration should also be made to the efficiency of the trap (fishing power) and changes to these.

Information on catch, effort and fishing location from all the users is imperative to properly assess lobster stocks. At present there is no direct data on the spatial distribution of landings and effort. This information would permit a monitoring of the extent and changes in the distribution of fishing effort and to map the overlap of fishing gear. Reliance on volunteer programs to provide this level of information has been inadequate to date.

The female condition monitoring program in LFA 25 clearly shows that the time of this fishery is detrimental to the reproductive potential of the stock (i.e., increase in the egg production). The opening of this fishery in August overlaps with the spawning period of lobster and it is difficult to protect the mature females which have not yet extruded the eggs.

Egg production in all areas could also be enhanced by further increasing the MLS. An increase of the MLS will allow more females to spawn at least once and protect a larger number of multiparous females. This could reduce the risk of recruitment variation or decline, as has been presently observed for years in central Northumberland Strait.

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Table 1. Management measures to control fishing effort, size and type of lobster (Homarus *americanus*) that can be legally retained by harvesters and measures to minimize indirect fishing mortality in the southern Gulf of St. Lawrence in 2006 managed by the Gulf Region.

Management measures			Description	l	
Lobster Fishing Areas (LFA)	LFA 23	LFA 24	LFA 25	LFA 26A	LFA 26B
	May 1 to	May 1 to	Aug. 10 to	May 1 to	May 1 to
Fishing season	June 30	June 30	Oct. 10	June 30 ¹	June 30
Number of licence $(Type A and B)^2$	718-42	635-4	848-6	756-11	243-4
Number of traps/license holder	300	300	250	300	300
Restriction on gear type	Traps (no re	estriction on i	internal desig	gn)	
Trap overall dimension (cm)	Length = 12	5, Width = 9	0, Height =	50	
Rectangular escape mechanism height in					
parlor section of trap (mm) (width					
common to all LFA = 127 mm)	40	40	40	40^{-3}	38.1
Biodegradable mechanism in the parlor	Dimension of	of unobstucte	ed opening no	ot less than 8	39 mm in
section of the trap	height and 1	52 mm in wi	dth		
Maximum size of entrances (mm)	152		152		
Minimum legal carapace size (mm)	70	70	70	70 4	75
			Greater		
			than		
Female size restriction (mm)	115-129	115-129	114mm	115-129	115-129
Landing of egg-berring females is		-	-	-	-
prohibited	Common to	all LFAs			
	Possession of	of lobster and	l fishing gear	r is prohibite	d between
Time restriction	9PM and su	nrise in LFA	25 only		

Regions between Pointe Prim and Victoria have their season from May 6 to July 7

²Type A represent fishermen with a full set of gear and Type B with 30% ³Western and Eastern Nova Scotian side of 26A is at 41 mm

⁴Western Nova Scotia of 26A is at 76 mm and Eastern Nova Scotia at 71.5 mm

	Lobster Fishing Area												
Year	23	24	25	26A	26A West	26A Eastern	26B						
1957	63.5	63.5	63.5	63.5			63.5						
1987	63.5	63.5	63.5	63.5			65.1						
1988	63.5	63.5	63.5	63.5			66.7						
1989	63.5	63.5	63.5	63.5			68.3						
1990	65.1	63.5	65.1	63.5			70.0						
1991	66.7	63.5	66.7	65.1			70.0						
1997	66.7	63.5	66.7	65.1	70.0	66.7	70.0						
1998	67.5	65.1	67.5	65.9	70.0	68.3	70.0						
1999	67.5	65.9	67.5	65.9	70.0	70.0	70.0						
2000	67.5	66.7	67.5	66.7	70.0	70.0	70.0						
2001	67.5	67.5	67.5	67.5	70.0	70.0	70.0						
2002	67.5	67.5	67.5	67.5	70.0	70.0	70.0						
2003	68.5	68.5	68.5	68.5	70.0	70.0	72.0						
2004	70.0	69.5	70.0	69.5	70.0	71.5	73.0						
2005	70.0	70.0	70.0	70.0	73.0	71.5	74.0						
2006	70.0	70.0	70.0	70.0	76.0	71.5	75.0						

Table 2. Lobster (*Homarus americanus*) minimum legal size (mm) observed since 1957 in five lobster fishing areas located in the southern Gulf of St. Lawrence.

Table 3. Size at the onset of 50% sexual maturity (SOM 50%) and the percentage of first spawners being protected by the minimum legal size (MLS) observed in the 2006 lobster (*Homarus americanus*) fishery for each Lobster Fishing Area (LFA) located in the southern Gulf of St. Lawrence managed by the Gulf Region.

LFA	MLS	SOM 50%	% of Mature Females
23	70	72	35%
24	70	72	35%
25	70	72	35%
26A	70	72	35%
26AW	76	72	74%
26AE	71.5	73	34%
26B	76*	75	56%

* LFA 26B will reach 76 mm in 2007 at the end of the latest multiyear management plan

Table 4. Catch per unit effort of selected size-classes of lobster (*Homarus americanus*), by stratum, in summer trawl surveys in Northumberland Strait, 2001 to 2006. Abundance is expressed as mean \pm standard error number per standard tow (1.0 ha). The number of tows is in parentheses.

Stratum	2001	2002	2003	2004	2005	2006
1	20.7 ± 5.9 (28)	5.8 ± 1.3 (37)	3.8 ± 0.9 (32)	4.4 ± 1.1 (31)	4.2 ± 1.3 (25)	9.1 ± 2.1 (37)
2	1.4 ± 0.6 (24)	$0.7 \pm 0.3 (25)$	0.7 ± 0.3 (26)	0.7 ± 0.4 (29)	0.0 ± 0.0 (5)	0.7 ± 0.4 (30)
3	1.6 ± 0.3 (69)	1.4 ± 0.3 (56)	0.7 ± 0.3 (63)	0.5 ± 0.1 (76)	0.4 ± 0.1 (62)	1.5 ± 0.3 (71)
5	0.0 ± 0.0 (46)	0.0 ± 0.0 (21)	0.0 ± 0.0 (46)	0.0 ± 0.0 (49)	0.0 ± 0.0 (48)	0.0 ± 0.0 (52)
6	N/A	N/A	$0.3 \pm 0.2 (34)$	N/A	0.6 ± 0.3 (32)	2.9 ± 0.9 (48)

50-59.9 mm CL (minus two molts)

60-69.9 mm CL (minus one molt)

Stratum	2001	2002	2003	2004	2005	2006
1	42.4 ± 15.6 (28)	12.9 ± 2.9 (37)	6.9 ± 1.5 (32)	$10.9 \pm 3.3 (31)$	9.1 ± 3.8 (25)	$17.8 \pm 4.2 (37)$
2	4.1 ± 1.3 (24)	2.7 ± 1.0 (25)	1.6 ± 1.0 (26)	1.3 ± 0.5 (29)	0.4 ± 0.2 (5)	2.0 ± 1.0 (30)
3	2.7 ± 0.4 (69)	2.5 ± 0.3 (56)	1.6 ± 0.4 (63)	1.2 ± 0.2 (76)	0.6 ± 0.1 (62)	2.6 ± 0.4 (71)
5	0.2 ± 0.1 (46)	0.0 ± 0.0 (21)	0.0 ± 0.0 (46)	0.0 ± 0.0 (49)	0.0 ± 0.0 (48)	0.0 ± 0.0 (52)
6	N/A	N/A	0.6 ± 0.4 (34)	N/A	1.6 ± 0.7 (32)	5.3 ± 1.2 (48)

70-80.9 mm CL (canner)

Stratum	2001	2002	2003	2004	2005	2006
1	33.0 ± 11.7 (28)	$13.5 \pm 2.9 (37)$	$4.3 \pm 1.1 (32)$	8.5 ± 2.9 (31)	8.8 ± 3.4 (25)	$19.7 \pm 5.0 (37)$
2	7.0 ± 2.2 (24)	3.3 ± 1.4 (25)	1.6 ± 0.8 (26)	1.9 ± 0.6 (29)	2.6 ± 1.2 (5)	3.7 ± 1.9 (30)
3	5.1 ± 0.6 (69)	3.7 ± 0.53 (56)	3.2 ± 0.5 (63)	1.9 ± 0.3 (76)	1.8 ± 0.3 (62)	4.1 ± 0.5 (71)
5	0.7 ± 0.2 (46)	0.0 ± 0.0 (21)	0.2 ± 0.1 (46)	0.1 ± 0.1 (49)	0.1 ± 0.0 (48)	0.1 ± 0.0 (52)
6	N/A	N/A	$1.7 \pm 0.6 (34)$	N/A	4.1 ± 1.3 (32)	9.7 ± 1.5 (48)

81-plus mm CL (markets)

Stratum	2001	2002	2003	2004	2005	2006
1	4.4 ± 1.2 (28)	2.5 ± 0.5 (37)	1.4 ± 0.4 (32)	$2.3 \pm 0.8 (31)$	2.8 ± 0.90 (25)	$6.2 \pm 1.7 (37)$
2	2.0 ± 0.7 (24)	1.0 ± 0.3 (25)	0.8 ± 0.3 (26)	0.7 ± 0.2 (29)	$1.8 \pm 0.7 (5)$	1.4 ± 0.7 (30)
3	6.0 ± 0.6 (69)	3.2 ± 0.4 (56)	3.9 ± 0.4 (63)	4.0 ± 0.5 (76)	2.9 ± 0.3 (62)	6.7 ± 0.6 (71)
5	2.1 ± 0.52 (46)	$1.1 \pm 0.5 (21)$	1.3 ± 0.3 (46)	0.7 ± 0.1 (49)	0.8 ± 0.1 (48)	1.6 ± 0.4 (52)
6	N/A	N/A	2.5 ± 0.7 (34)	N/A	2.9 ± 0.8 (32)	9.4 ± 1.2 (48)

Year	Males	Females	M:F						
2001	2276	2545	0.894						
2002	1114	1145	0.972						
2003	657	677	0.970						
2004	991	662	1.497						
2005	598	475	1.259						
2006	1805	1680	1.074						
		$\chi^2 = 95.31$, df = 5, $P < 0.001$							
2001	63	84	0.750						
2002	10	17	0.588						
2003	44	38	1.158						
2004	19	25	0.760						
2005	21	19	1.105						
2006	39	44	0.886						
		$\chi^2 = 4.22, df = 5,$	<i>P</i> = 0.518						

Table 5. July-August (pre-fishery) sex ratio for lobsters (*Homarus americanus*) captured in West-central (upper) and Central (lower) Northumberland Strait.

Prey Taxon	Size	-Classes (mm	in carapace le	ength)
	50-59.9	60 -69.9	70-80.9	81-plus
Crangon	0.8	1.2	0.3	0.1
Hermit crab	0.9	1.2	1.4	0.3
Rock crab carapace	19.1	16.0	18.3	15.7
Rock crab remains	25.2	43.0	40.2	52.5
Lady Crab	2.8	2.4	1.1	3.2
Lobster old carapace	3.0	3.8	8.6	10.0
Lobster remains	4.8	3.7	3.3	2.6
Polychaetes	5.8	4.0	2.4	1.4
Bivalves	3.9	0.7	1.3	1.3
Gastropods	0.7	0.3	0.7	0.7
Mollusc shell	2.1	3.4	2.2	1.4
Sea star	11.5	7.3	6.9	3.3
Tunicates	0.8	1.2	1.0	0.1
Sponges	0.6	1.0	0.7	0.2
All fishes	6.1	2.7	5.5	3.6
Other animal prey	0.2	2.9	0.7	0.2
Detritus	9.9	3.7	3.9	2.2
Plant material	1.8	1.5	1.7	1.4
Number of stomachs	281	540	715	331
% empty	9.3	8.0	5.3	6.3

Table 6. Average diets (as % biomass) of lobsters (*Homarus americanus*) in LFA 25 observed in July-August from 1999 to 2006.

Taxon	May	JulAug.	October	М	ay	JulAug.	October
		50 - 59.9				60-69.9	
Rock crab	31.1	23.8	59.1	41	.4	45.4	63.3
Carapace – r. crab	9.9	22.3	5.8	17	'.9	19.3	5.4
Lobster	0	0.7	0	()	0.4	0
Carapace – Lobster	0	2.8	0.1	()	3.8	0.6
Polychaetes	30.2	9.0	2.3	13	.8	7.0	3.5
Molluscs	2.1	6.7	10.2	10	.2	4.2	6.8
Sea Stars	20.8	13.0	12.2	12	.8	7.1	12.5
Fish	0	7.6	0.4	2	.8	1.9	2.9
Other	5.9	14.1	9.6	1	.1	9.9	5.0
Ν	26	140	91	4	0	276	137
-							
-		70-80.9				81-plus	
Rock crab	39.5	43.6	64.9	24	.1	51.6	83.1
Carapace – r. crab	2.3	24.0	4.6	0	.1	17.2	1.6
Lobster	0	0.8	0	()	1.3	0
Carapace – Lobster	0	8.3	0	5	.6	16.9	1.1
Polychaetes	44.5	3.1	0.1	57	.2	2.2	0.7
Molluscs	0.4	1.6	2.9	9	.2	0.3	1.2
Sea Stars	1.4	9.7	13.6	3	.7	4.3	8.6
Fish	0.1	1.8	12.0	()	4.4	0.8
Other	11.8	7.1	1.9	0	.1	1.8	2.9
Ν	20	281	62		7	109	42

Table 7. Seasonal diets of selected size-classes of lobsters (*Homarus americanus*) captured in the Northumberland Strait between 2001and 2003.

Table 8. Numbers (N) of fish and large crustacean stomachs analyzed for diets, 1999-2006 compared to 1990-1996 (Hanson and Lanteigne 2000; J. M. Hanson, unpublished data). Numbers in parentheses represent % occurrence of lobster (Homarus americanus) in the diet except for lobster where % prey biomass as old carapaces is in square brackets.

Species	1990-1996	Lobster in Diet	1999-2006	Lobster in Diet
	Ν	%weight	Ν	% weight
Planktivores				
Atlantic Herring	0	N/A	1090	(0.18) < 0.01 ^b
Alewife	0	N/A	510	0.0
American Shad	0	N/A	402	(0.5) 0.06 ^b
Atlantic Mackerel	0	N/A	855	0.0
Mixed Diet				
Rainbow Smelt	0	N/A	2357	(0.04) < 0.01 ^b
"Pelagic" Fishes	0		5,214	
Demersal Fishes				
Longhorn Sculpin	0	N/A	1296	$(0.08) \ 0.05^{\mathrm{a}}$
Shorthorn Sculpin	322	(5.28) 16.7	151	(2.6) 28.94
Sea Raven	0	N/A	264	0.0
Cunner	57	(3.60^{a})	751	(0.5) 1.19^a
Ocean Pout	0	N/A	29	0.0
Atlantic Cod	12,008	(0.05) <0.01	10436	(0.01) < 0.01 ^a
Greenland Cod	467	0	18	0
White Hake	2305	(0.13)	3583	(0.03) 0.01
Winter Skate	0	N/A	604	0.0
Thorny Skate	306	0.0	187	$(0.5) 2.53^{\mathrm{a}}$
American Plaice	1645	0.0	571	0.0
Windowpane Flounder	0	N/A	369	0.0
Yellowtail Flounder	147	0.0	241	0.0
Winter Flounder	982	0.0	861	0.0
Demersal Fishes	18,239		24,575	
Large Invertebrates				
Lady Crab	0	N/A	1003	0.01
Rock Crab	369	0.0	279	0.0
American Lobster	27	(7.4) 0.3	2390	2.72 [6.53 ^c]
Decapods	396		3,672	
Grand Total	18,239		28,247	

^a legs only ^b larvae

^c % by weight as old carapaces

LFA 2	23BC					LFA 2	LFA 23G			LFA 24					
Year	В	M&F	Wharf	Sample	Trap	В	M&F	Wharf	Sample	Trap	В	M&F	Wharf	Sample	Trap
1983	11	504	1	1	171	47	1008	3	5	609	85	1602	3	5	471
1984	5	253	2	3	158	104	4801	3	26	3056	76	4276	2	15	1031
1985	139	2402	3	35	985	133	3658	2	20	2364	134	10145	3	29	2764
1986	10	233	1	4	93	46	825	2	5	383	358	8954	6	28	3055
1987	48	1255	1	3	573	21	551	1	4	311	61	1209	3	6	391
1988	126	2476	2	6	1423	7	409	1	4	517	14	1532	3	7	570
1989	29	790	1	3	643	65	1409	1	3	951	341	10026	3	26	3518
1990	210	3031	3	9	1877	45	1925	2	6	889	97	2819	3	10	846
1991	227	5463	3	11	2624	93	3549	2	8	1747	266	6760	5	15	1770
1992	405	3680	3	8	2089	127	1540	2	4	1041	428	11627	9	23	3295
1993	200	2658	3	6	1759	94	1640	2	4	1418	465	12105	9	24	3052
1994	91	951	3	6	669	14	730	2	4	388	154	3316	4	4	989
1995	209	1581	3	7	1244	42	713	2	4	661	254	5330	4	8	1218
1996	119	1267	3	6	925	36	1215	2	4	1086	422	6256	5	10	2472
1997	339	1859	4	10	1262	33	710	2	4	672	331	2520	4	8	1616
1998	205	977	3	6	938	76	986	2	4	960	3540	22413	13	85	12364
1999	1034	5454	3	24	3926	892	12252	3	37	9609	2597	42148	13	126	18226
2000	3273	16593	5	50	11455	233	2693	1	7	1633	4240	39934	14	115	15273
2001	994	4255	2	18	4055	1074	23827	1	36	10524	2034	31876	7	64	9135
2002	450	2189	1	10	2934	25	378	1	1	293	1496	17090	8	34	6495
2003	532	2463	2	7	2037	102	1491	1	4	1167	1697	17374	12	30	5865
2004	36	207	1	1	297						1603	16295	10	25	5093
2005											1624	18116	11	30	6861
2006											2987	23523	10	30	7321

Table 9. Number of male and non-berried female (M&F) lobsters (*Homarus americanus*) and berried female (B) lobsters measured, different wharves visited, at-sea sample and traps sampled between 1983 and 2006 during the at-sea sampling in each Lobster Fishing Area (LFA) divided into nine sub-regions.

Table 9. cont.

LFA 2	26APEI	[LFA 2	26ANS				LFA 2	26B			
Year	В	M&F	Wharf	Sample	Trap	В	M&F	Wharf	Sample	Trap	В	M&F	Wharf	Sample	Trap
1983	60	1300	2	4	429	199	1557	1	10	1080	270	5723	4	15	3399
1984	125	1999	4	14	1294	452	4558	6	20	2865	15	889	1	2	580
1985	167	7091	5	32	3456	33	738	3	5	499	194	7254	5	23	3259
1986	87	1475	3	5	553	107	1033	3	3	552	455	10021	6	27	3869
1987	96	920	2	6	309	63	662	1	3	567	215	3673	3	18	1937
1988	28	1647	3	6	316	28	1332	1	3	639	205	4869	3	18	1489
1989	218	3698	2	6	1262	9	636	1	2	426	331	6313	5	16	1844
1990	267	3811	2	6	1467	103	1269	1	3	671	913	15592	4	46	5124
1991	590	8531	5	15	2331	69	1411	1	3	481	1010	9634	5	25	2903
1992	518	7543	6	19	3213	179	1877	1	3	826	598	6987	5	23	3230
1993	414	5045	4	13	1927	119	1277	1	2	470	780	8875	4	24	4689
1994	57	284	1	1	294	39	382	1	2	187	668	7219	5	50	4251
1995	66	1906	2	4	855	17	369	1	3	387	351	3367	4	18	2019
1996	89	1457	2	4	1088	24	272	1	2	154	181	1155	3	6	672
1997	35	838	2	4	635	36	378	1	1	141	184	162	3	6	748
1998	2590	12739	8	58	10811	136	910	1	2	440	279	1577	3	6	1027
1999	2201	19507	8	75	20142	738	5295	2	12	3202	1099	6831	4	24	5601
2000	3381	18951	8	71	14170	1621	7437	1	13	3687	1834	8192	4	27	6710
2001	1207	11751	3	44	10774						2324	12511	1	28	8047
2002	2061	12342	4	39	9975						922	3742	1	11	3013
2003	1361	9668	6	27	6392	1916	10926	3	22	595	596	2385	2	11	2231
2004	613	5068	5	14	3488										
2005	649	6340	5	17	4525										
2006	1082	6117	5	20	5126										

Table 9. cont.

LFA 2	LFA 25N					LFA 25S				LFA 26AD					
Year	В	M&F	Wharf	Sample	Trap	В	M&F	Wharf	Sample	Trap	В	M&F	Wharf	Sample	Trap
1982	29	918	3	3	237	14	573	2	2	147					
1983	57	1185	4	5	265	60	1851	2	3	310	202	2023	1	6	390
1984	76	3806	3	10	999	132	6312	4	9	934	683	5673	8	19	3277
1985	289	3637	2	9	602	417	4896	5	14	1011	353	4010	11	20	2127
1986	22	704	2	2	120	5	826	2	3	143	250	2614	5	7	1000
1987	40	582	2	2	136	133	1981	3	4	587	224	1390	1	3	660
1988	19	549	1	1	105	124	1193	3	3	429	772	4566	2	14	1862
1989	114	1209	1	1	177	375	1479	3	3	535	1068	3430	2	14	1873
1990	401	3478	4	4	689	319	1950	4	4	803	510	2704	2	8	1249
1991	190	3203	6	6	537	189	2884	5	5	964	817	3494	4	12	2703
1992	189	5510	5	8	1145	504	4848	5	7	1607	802	4350	4	23	4905
1993	256	3403	6	7	598	154	222	4	4	714	173	1094	3	7	1457
1994	76	709	2	2	150	26	225	2	2	131	132	216	1	2	282
1995	166	1570	2	2	271	332	1495	4	4	681	58	408	2	4	470
1996	153	954	2	2	396	220	500	4	4	705	85	299	2	4	457
1997	10	656	2	2	298	152	721	4	4	590	134	256	2	4	468
1998	335	3044	5	9	1213	747	3091	8	18	2793	1062	4779	5	25	4263
1999	656	3920	5	10	1553	942	2997	8	16	3029	1694	8180	5	46	7441
2000	1018	5942	6	17	3207	467	1738	7	16	2216	2507	6871	5	34	6401
2001						502	2767	4	13	2583	181	283	2	3	379
2002	157	1504	2	3	609	57	446	2	2	497	733	1538	2	10	2716
2003	364	2389	5	7	1619	192	1380	4	8	1641	1681	3678	10	27	7172
2004	252	2314	4	4	852	38	259	2	2	428	464	1571	5	16	3581
2005	299	1459	3	4	899	152	831	3	5	1148	281	1155	5	12	2716
2006	284	1714	4	4	916	127	258	3	3	610	560	1575	4	14	3250

Sub-Region	Year	Number of Participants	Number of Lobsters	Number of Modified Traps	Number of Regular Traps
		1 an or of partice	Measured	Sampled	Sampled
LFA 23BC	1999	8	5597	1002	1002
	2000	7	3806	846	809
LFA 23G	1999	16	9473	2298	2298
	2000	15	9864	2157	2157
	2001	10	8061	1556	1557
	2002	10	6425	1536	1536
	2003	10	6422	1395	1395
	2004	9	7158	1389	1385
LFA 24	1999	19	14241	1717	1719
	2000	35	42893	4639	4654
	2001	57	68529	7597	7600
	2002	56	63934	7712	7786
	2003	57	71193	8044	8042
	2004	53	77414	7373	7379
	2005	53	72932	7161	7159
LEA 25N	1999	10	7548	944	849
	2000	13	11406	1701	1701
	2000	14	12247	1807	1687
	2002	15	10502	1917	1806
	2003	14	8943	1801	1800
	2004	9	6867	996	1103
	2005	8	7703	1044	1044
1 6 1 258	1000	14	5047	11/2	1144
LI'A 255	2000	13	5496	1269	1269
	2000	13	4353	1209	1209
	2001	12	3747	1161	1176
	2002	13	3205	1075	1075
	2004	10	2299	821	833
	2005	3	996	342	342
LFA 26D	1999	15	5572	1699	1699
2111200	2000	21	7128	2349	2386
	2000	9	2442	851	581
	2002	8	2614	920	930
	2003	8	2237	896	896
	2004	8	3163	878	878
	2005	7	1821	767	767

Table 10. Number of lobster (*Homarus americanus*) harvesters per Lobster Fishing Area (LFA) divided into nine sub-regions participating in the recruitment-index program between 1999 and 2005. The number of lobsters measured and traps sampled are indicated.

Table	10	cont
1 4010	10.	cont.

Sub-Region	Year	Number of Participants	Number of Lobsters Measured	Number of Modified Traps Sampled	Number of Regular Traps Sampled
LFA 26PEI	1999	10	3842	881	881
	2000	14	8397	1845	1845
	2001	23	13046	3185	3115
	2002	21	14222	2968	2962
	2003	20	14050	2907	2907
	2004	20	13027	2811	2812
	2005	20	12845	2799	2802
LFA 26ANS	1999	4	2639	587	588
	2000	9	4768	1114	1113
	1999	14	8549	1622	1619
LFA 26B	2000	12	7560	1459	1463
	2001	10	6411	1215	1215
	2002	10	6225	1176	1175
	2003	10	5990	1242	1241
	2004	9	5037	1029	1028

Table 11. Long-term lobster (*Homarus americanus*) landings (median of the last 55 years) compared to the 2005 landings as an abundance indicator for the five Lobster Fishing Areas (LFA) located in the southern Gulf of St. Lawrence.

	LFA 23	LFA 24	LFA 25	LFA 26A	LFA 26B
Long-term (55-yr)	1665	2266	3155	2853	632
2005	2907	5697	2419	3172	1118
Indicator	\checkmark	↑	\checkmark	→	↑

Table 12. Mid-term lobster (*Homarus americanus*) landings (median of the last 35 years), short-term landings (median of the last 10 years) and the 2004 landings compared to the 2005 landings as an abundance indicator for the five Lobster Fishing Areas (LFA) located in the southern Gulf of St. Lawrence divided into nine sub-regions.

	LFA	LFA	LFA	LFA	LFA	LFA	LFA	LFA	LFA
	23BC	23G	24	25N	25S	26AD	26APEI	26ANS	26B
2005	561	2346	5697	1846	573	499	1503	1170	1118
Mid-Term Indicator	639 ➡	2090 ➡	3278 ↑	2514 ♥	1280 ♥	729 ♥	1706 ♥	913 个	1068 ➡
Short-Term Indicator	675 ✔	2921 ➡	5154 ➡	2606 ♥	1042 ♥	789 ♥	1781 ¥	1119 ➡	1111 ➡
2004 Indicator	574 ➡	2454 ➡	6336	1890 ➡	533 ➡	578 ➡	1678 ➡	1125 ➡	1093 ➡

Table 13. Average percentage of traps without commercial-size lobster (*Homarus americanus*) based on data from the at-sea sampling program. Lobster Fishing Areas (LFA) located in the southern Gulf of St. Lawrence were divided into nine sub-regions. Sub-regions of LFA 25 (25N and 25S) only include the data from the August at-sea samplings.

LFA	1980s	1990s	2000s
23BC	36%	44%	54%
23G	30%	50%	39%
24	24%	28%	24%
25N	12%	18%	34%
25S	13%	33%	57%
26AD	17%	47%	61%
26APEI	23%	44%	47%
26ANS	38%	26%	27%
26B	42%	41%	53%

Table 14. Escape vent height tested during the lobster (*Homarus americanus*) trap selectivity study.

Escape	Туре	Mean Height (mm)	Standard Deviation (mm)
Type 1	Manufactured	38.1	0.11
Type 2	Manufactured	39.6	0.11
Type 3	Custom made	41.8	0.35
Type 4	Custom made	43.4	0.27
Type 5	Manufactured	44.5	0.11
Type 6	No escape	-	-

Table 15. Entrance ring diameters tested during the lobster (*Homarus americanus*) trap selectivity study. Entrance rings are manufactured in inches (their equivalent sizes in centimeter are indicated).

Ring Diameter	Size in Inches (cm)
1	4 ½ (11.4 cm)
2	5 (12.7 cm)
3	$5 \frac{1}{2}$ (14.0 cm)
4	6 (15.2 cm)
5	8 (20.3 cm)

Escape Height	Pa	rameter Es	timates		Likelihood	df	AIC	Rank
_	р	а	b	р	_			
1 (38.1mm)	Estimated	-13.88	0.23	0.52	-114.67	56	235.34	2
	0.5	-15.49	0.26	-	-115.32	57	234.63	1
2 (39.6mm)	Estimated	-15.77	0.24	0.50	-111.57	56	229.14	2
、 <i>,</i>	0.5	-15.77	0.24	-	-111.57	57	227.14	1
3(41.8mm)	Estimated	-20.03	0.29	0.51	-104.46	56	214.92	2
	0.5	-20.79	0.30	-	-104.75	57	213.50	1
4 (43.4mm)	Estimated	-15.35	0.21	0.53	-114.23	56	234.46	2
	0.5	-16.33	0.23	-	-114.94	57	233.89	1
5 (44.5mm)	Estimated	-14.44	0.20	0.49	-115.39	56	236.77	2
· · ·	0.5	-14.06	.19	-	-115.46	57	234.92	1

Table 16. Parameter estimates based on the SELECT modeling and the Akaike's information criterion method (AIC) to rank the different models in order of parsimonious fit for the five escape vent types.

Table 17. Lobster (*Homarus americanus*) carapace length based on the most parsimonious model assuming p = 0.5 for 50% retention rate l_{50} , and the interquartile range SR. Retention rate l_{95} is also indicated. Note that 733 lobsters were caught in the ventless traps.

Escape Height	$l_{50}(mm)$	SR (mm)	l ₉₅ (mm)	Number of Lobsters
1 (38.1mm)	58.5	8.3	69.3	739
2 (39.6mm)	65.4	9.1	77.3	634
3(41.8mm)	69.4	7.3	78.9	607
4 (43.4mm)	70.4	9.5	82.8	581
5 (44.5mm)	73.5	11.5	88.4	472

	Carapace Length (mm)								
Ring Diameter	95-104	105-114	115-146						
4 ½" (11.4 cm)	39	5	2						
5" (12.7 cm)	50	9	3						
$5\frac{1}{2}$ " (14.0 cm)	50	10	6						
6" (15.2 cm)	52	12	7						
8" (20.3 cm)	42	4	12						
Total	233	40	30						

Table 18. Observed frequencies of lobster (*Homarus americanus*) by size range and entrance diameter. Entrance rings are manufactured in inches (their equivalent sizes in centimeter are indicated).

Table 19. Summary of trends for different indicators used to assess the 2005 lobster (*Homarus americanus*) stock status for the Lobster Fishing Area 23, 24, 25, 26A. 26B located in the southern Gulf of St. Lawrence. \uparrow positive trend; \rightarrow indicates that there is no trend (variable) or not detected (uncertainty); Ψ negative trend. Lobster Fishing Areas were divided into nine sub-regions.

Indicator	23 BC	23 G	24	25 N	25 S	26A D	26A PEI	26A NS	26 B
Abundance								- 110	
Landings									
55-yr median vs. 2005	1	↑	↑	$\mathbf{\Lambda}$	$\mathbf{\Lambda}$	→	→	→	↑
38-yr median vs. 2005	→	→	↑	$\mathbf{\Lambda}$	$\mathbf{\Lambda}$	$\mathbf{+}$	$\mathbf{\Lambda}$	♠	→
10-yr median vs. 2005	$\mathbf{+}$	→	→	$\mathbf{\Lambda}$	$\mathbf{\Lambda}$	$\mathbf{\Lambda}$	$\mathbf{\Lambda}$	→	→
2004 vs. 2005	→	→	→	→	→	→	→	→	→
Trawl Survey 2005									
Canner				$\mathbf{\Psi}$	$\mathbf{\Psi}$	$\mathbf{\Psi}$			
Market				$\mathbf{\Lambda}$	$\mathbf{\Lambda}$	$\mathbf{\Psi}$			
Fishing Pressure									
At-Sea Sampling Program		_	_						
First Molt Group (FMG)	→	1	1	→	1	1	→	↑	→
FMG vs. 38-yr Landings Trend	→	1	1	1	$\mathbf{\Lambda}$	1	1	↑	1
Index-Harvester program									
Empty traps 1980s vs. 2000s*	1	↑	→	↑	↑	↑	→	→	→
Weekly CPUE	→	→	→	1	1	→	→	→	→
Seasonal Trap Haul	→	↑	↑	→	1	1	↑	↑	→
Production									
SCUBA					_	_			
1- and 2-yr Old Abundance	1	↑			$\mathbf{\Psi}$	$\mathbf{+}$			
Pre-Recruit Index Program					_	_			
Pre-Recruits Catch Rate	→	→	↑	♠	$\mathbf{\Lambda}$	1	→	→	→
Trawl Survey 2005					_	_			
Pre-Recruit Abundance				→	$\mathbf{\Lambda}$	1		↑	
At-Sea Sampling Program									
Berried Females in the Catch	→	↑	↑	$\mathbf{\Psi}$	$\mathbf{\Psi}$	$\mathbf{\Psi}$	↑	↑	↑
Biological									
Female Reproductive Condition				1	$\mathbf{\Lambda}$				
Ecosystem									
Predator-Prey				→	→	→			
Temperature	↑	↑	↑	↑	↑	↑	↑	↑	↑

* a positive indicator for empty trap is considered negative for the lobster stock



Figure 1. Lobster Fishing Areas (LFA) and the nine sub-regions in the southern Gulf of St. Lawrence managed by the Gulf Region.



Figure 2. Historical lobster (*Homarus americanus*) landings in the southern Gulf of St. Lawrence (DFO, Gulf Region) from 1892 to 2005.





Figure 3. Historical lobster (*Homarus americanus*) landings in Lobster Fishing Areas 23, 24, 26A and 26B between 1947 and 2005.





Figure 3. cont.



Figure 3. cont.



Figure 4. Map of stations fished in 2003. The solid lines show boundaries (left to right) of westcentral (strata 1, 2, and 3), central (stratum 5), and eastern (stratum 6) zones of Northumberland Strait.



Figure 5. Distribution of market-size (81-plus mm CL) lobster for 2000 to 2006.



Figure 6. Distribution of canner (70 to 80.9 mm CL) size American lobster, 2000 to 2006.



Figure 7. Distribution of one-molt sublegal (60-69.9 mm CL) American lobster in 2000 to 2006.



Figure 8. Distribution of two-molts sublegal (50-59.9 mm CL) American lobster, 2000 to 2006.



Figure. 9. Area (km^2) of abundance > 400 lobsters per km^2 for 2001 to 2006 in west-central Northumberland Strait.



Figure 10. Length distribution of lobster during summer surveys in west-central Northumberland Strait (most of LFA 25).



Figure 11. Depth distribution of four size classes of lobster and number of tows (N), 2001 to 2006.



Figure 12. Mean and 95% confidence intervals of stomach fullness of American lobster by time of day during summer 1999 to 2006.


Figure 13. Principal pelagic and demersal fishes, and large crustaceans prey items in lobster from Northumberland Strait, 1999 to 2006.

Group average



Figure 14. Cluster-analysis of average diets of fishes and large crustaceans from Northumberland Strait (1999 to 2006). The upper panel is a dendrogram derived using the Bray-Curtis Similarity measure. The lower panel shows the same information using Multi-Dimensional Scaling.



Figure 15. Abundance of cryptic stage lobster (<40 mm carapace length) in Lobster Fishing Areas (LFA) 23BC, 25S and 26AD observed during SCUBA surveys.



Figure 16. Gauge used by harvesters participating in the recruitment-index program. Size class 5 was adjusted to the minimum legal size each year. Size classes 3 to 10 are 5-mm size intervals while size classes 2, 11 and 12 are 10-mm wide intervals.



Figure 17. Lobster (*Homarus americanus*) landings by sub-region of Lobster Fishing Areas (LFA) 23, 24, 26A and 26B between 1968 and 2005.



Figure. 17. cont.



Figure 17. cont.



Figure 18. Lobster (*Homarus americanus*) abundance indicator based on a ranking system using the 1968-2005 landing median for each statistical district (SD) located in Lobster Fishing Areas (LFA) 23, 24, 25, 26A, 26B.



Figure 19a. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 24 in the southern Gulf of St. Lawrence, 1983 to 2006.



Figure 19b. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 23BC in the southern Gulf of St. Lawrence, 1985 to 2004.



Figure 19c. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 23G in the southern Gulf of St. Lawrence, 1983 to 2003.



Figure 19d. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 26AD in the southern Gulf of St. Lawrence, 1986 to 2006.



Figure 19e. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 26ANS in the southern Gulf of St. Lawrence, 1983 to 2005.



Figure 19f. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 26APEI in the southern Gulf of St. Lawrence, 1983 to 2006.



Figure 19g. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 26B in the southern Gulf of St. Lawrence, 1983 to 2006.



Figure 19h. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 25N in the southern Gulf of St. Lawrence, 1983 to 2006.



Figure 19i. Catch (number of lobster) per unit effort (CPUE) for berried female lobsters (left panels) and combined male and non-berried-female lobsters (right panels) by 2 mm size interval based on data from the at-sea sampling program for LFA 25S in the southern Gulf of St. Lawrence, 1983 to 2006.



Figure 20. Catch (number of lobster) per unit effort (trap) (CPUE) of combined males and non berried female lobsters (*Homarus americanus*) categorized as one to four molt groups (M+1 to M+4) larger than the minimum legal size, by lobster fishing subarea.



Figure 20. cont.



Figure 20. cont.



Figure 20. cont.



Figure 20. cont.



Figure 21. Annual catch (number) per unit effort (trap) (CPUE) by size bin for berried females (upper panel), and combined male and non-berried-female (lower panel) lobsters (*Homarus americanus*) reported in regular (Reg) and modified (Mod) traps from the recruitment-index program, by sub-region. Size bins are shown in Figure 16.



Figure 21. cont.



Figure 21. cont.



- Mod - Reg (berried $\stackrel{\bigcirc}{+}$)

Figure 21. cont.



 \longrightarrow Mod \longrightarrow Reg (berried $\stackrel{\bigcirc}{\rightarrow}$)

Figure 21. cont.



Figure 21. cont.



Figure 21. cont.



Figure 21. cont.



Figure 21. cont.



Figure 22. Weekly ratio (by weight) of canner to market lobster (*Homarus americanus*) reported in catches by sub-region from the index-harvesters and recruitment logbook programs, 2001 to 2006. Week 18 corresponds to May 1 and week 32 corresponds to August 10.



Figure 23. Weekly catch (kg) per unit effort (trap) (CPUE) of lobster (*Homarus americanus*) by sub-region based on the index-harvesters and recruitment logbook programs, 2001 to 2006. Week 18 corresponds to May 1 and week 32 corresponds to August 10.



Figure 24. Average number of traps hauled daily during the lobster (*Homarus americanus*) fisheries by sub-region of the southern Gulf of St. Lawrence as reported in the index-harvesters and recruitment logbook programs, 1996 to 2006. Week 18 corresponds to May 1 and week 32 corresponds to August 10.



Figure 25. Percentage of effort deployed compared to the nominal effort authorized during the lobster (*Homarus americanus*) fisheries by sub-region of the southern Gulf of St. Lawrence as reported in the index-harvesters and recruitment logbook programs, 1993 to 2006.



Figure 26. Annual proportion of traps with no commercial lobsters (*Homarus americanus*) based on data from the at-sea sampling program by sub-region of the southern Gulf of St. Lawrence, 1983 to 2006.



Figure 27. Weekly percentages of mature female lobsters (*Homarus americanus*) in their eggextrusion year in the commercial catch of in two sub-regions of Lobster Fishing Area (LFA) 25 in 2002 and 2006. The upper graph represents LFA 25N (Loggiecroft) and the lower graph represents LFA 25S (Aboiteau). Week 1 corresponds to August 10.
(a) escape vent of 38.1 mm



(b) escape vent of 39.6 mm



Figure 28. Observed proportions in vented lobster (*Homarus americanus*) traps (\blacklozenge) and size selectivity curves (r(l)) for the 5 escape heights studied: (a) 38.1 mm, (b) 39.6 mm, (c) 41.8 mm, (d) 43.4 mm and (e) 44.5 mm. The error bars around the observed proportions show the approximate 95% confidence intervals for the expected proportions.

(c) escape vent of 41.8 mm



(d) escape vent of 43.4 mm



Figure 28. cont.

(e) escape vent of 44.5 mm



Figure 28. cont.



Figure 29. Results of 1,200 permutations on lobster (*Homarus americanus*) trap diameter entrance within a line of traps for the chi-square test. Observed value is 10.33.



Figure 30. Results of 1,200 permutations on lobster (*Homarus americanus*) trap diameter entrance within a line of traps for the number of large lobsters observed in traps equipped with ring entrance of 20.3 cm. Observed value is 12.



Figure 31. The time series of the 5-year running mean of air temperature anomalies at Charlottetown (PEI) in the southern Gulf of St. Lawrence. The anomalies are calculated relative to the 1971-2000 average.



Figure 32. Mean seasonal cycle of bottom temperature in all Lobster Fishing Areas.



Figure 33. Sea surface temperature anomaly for Lobster Fishing Area 25S.



Figure 34. Volume of the Cold Intermediate Layer (CIL) over the southern Gulf of St. Lawrence. The horizontal line is the 1971-2000 average.