Visual line-transect surveys using SCUBA divers on lobster habitat between 2000 and 2012 were done to assess the lobster density at various sites in the sGSL (Table 7).

The longest uninterrupted surveys have been carried out in Caraquet, located in sub-region 23BC, and Shediac (sub-region 25S) starting in 2003 and 2005, respectively.

Other sites were selected and added from Pointe-Verte to Pictou Island to cover LFAs 23, 25 and 26A located in central Northumberland Strait, Some sites in NB and NS were originally selected to create nearshore artificial reefs to compensate for declared harmful alteration, disruption and destruction of marine coastal habitats (DFO, 2012) and the *in situ* site selection process and monitoring were coordinated or carried out by DFO Lobster Section, Moncton.

Ultimately, several sites have been chosen as permanent sites (Table 7; Figure 101).

The main objective of the SCUBA survey design was to measure absolute lobster population density and sample length frequency. The survey design has three components. First, a selective design was used to draw a survey region, i.e., identifying lobster reefs, within the site. Then, line-transects within the survey region were placed using a haphazard design and, finally, a systematic design was used to survey the site on a yearly basis.

We used a two steps approach to draw the survey region that consisted of mapping and visual surveys. Mapping the location of lobster reefs was first done based on harvesters’ traditional fishing knowledge through interviews followed by mapping using the OLEX™ system. During the interviews, harvesters were asked to identify on a map their general fishing locations with rocky habitat characterized by gravel, cobbles and small boulders at depths ranging from 4.5 to 10.0 m. Also, some exclusion mapping was done where harvesters identified areas with soft sediments, i.e., undesirable survey locations. The actual seafloor mapping was done by remote sensing using an OLEX™ system. This system is connected to echosounders and analyze bottom echo, taking into account parameters such as pulse length, beam width and transducer type. A naturalized bottom backscatter is calculated and added to the internal chart where hardness is shown as adjustable colors for seafloor hardness. This system will allow for automatic seafloor mapping using bottom discrimination and hardness. This equipment is a high-speed plotter that used the echosounder depth data and GPS lat/long data to generate small scale topographic seafloor maps for large areas in real time. A single-beam (Simrad™ CM 60 and ES 60 complete system) was used between 2004 and 2007, and a multi-beam (WASP™ system) is now being used. The second step was groundthruting the mapping by carrying out visual surveys. These surveys were done on a flat bottom in water <10 m deep with gravel and cobble substrate either by an underwater camera deployed from the surface or SCUBA divers. During the visual survey, information was gathered on the abiotic (i.e., to corroborate the information from the remote technology) and biotic (i.e., density or presence of lobster, other benthic species and densities of the algae coverage) habitat characteristics for the final selection of the most appropriate survey region to set line-transects. Essentially, wide areas with dense algae cover (mainly kelp), large immovable boulders, stacked of smaller boulders, soft sediment bottom (i.e., mud and/or sand), or unbroken granite or sandstone sheet were avoided.

On selected survey regions (i.e., lobster reefs) within a site, leaded line-transects were placed haphazardly always parallel to the coastline to assist the diver movements (i.e., divers surveyed against the current to avoid low to nil visibility from disturbed silt while overturning small boulders). Start and finish positions of all line-transects were entered into the onboard GPS chart plotter and, if chosen for a given year, were systematically sampled. The number of line-transects per site was established based on the lobster reef size and the pre-approved diving time allowed for the site. Weather permitting, at least 3 line-transects per year on selected sites were sampled.

A 100-m leaded line-transect marked at 5-m intervals was used to survey all of the sites. Two divers descended and swam on either side of the line-transect. Each diver sampled on one side of the line-transect searching 2-m perpendicular to the line-transect along its entire length (100-m) 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: lobsters directly on the line will never be missed (i.e., they are seen with probability of 1); lobsters are fixed at the initial sighting position (i.e., they do not move before being detected and none are counted twice); distances are measured exactly, thus, neither measurement errors nor rounding errors occur; and finally sightings are independent events.

Divers attempted to capture every lobster observed within the line-transect. All captured lobsters were measured (CL) and the sex was determined. Beside lobster, divers also recorded the seafloor characteristics (i.e., size and aggregation of rocks and other substrate’s feature). The information from each diver was recorded on underwater sampling sheets for every 5-m interval, which is equivalent of sampling forty 10 m2 quadrats along the line-transect.

Information on the seafloor characteristics was used to gather knowledge on hard-bared or soft substrates (i.e., seafloor not considered as lobster habitat) and evaluate the sampling complexity within a line-transect. The sampling complexity refers to the ability of a diver to efficiently sample a 10 m2 quadrat. To standardize the information collected by divers, the basic sediment size classification developed by Wentworth (1922) and later modified by Pettijohn (1949) was used. Sampling complexity was identified as simple if a diver could sample a quadrat without missing or underestimating the presence of lobsters 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 macro-algae within the quadrat. Based on assumption 1, quadrats (10 m2) that were identified as complex by divers within each transect line were removed from the analysis. Also, quadrats with soft substrates (i.e., mud and sand) or solid sheet of sandstone and/or granite with no ledge (referred as hard-bared seafloor) were removed from the analysis because they were not considered lobster habitat. SCUBA data were analyzed to derive both abundance and production indicators.

**Model:**

The goal of the this analysis is to provide a synthesis of SCUBA data collected since 2000 in various sites in the sGSL, with special focus on spatial and temporal trends in abundance.

For each transect (*n* = 724),

A generalized linear mixed model (GLMM) was used for the analysis, with the aim of predicting length-frequencies by region and year, from which various length-based indices could be derived.

The response variable were counts with an assumed negative binomial distribution with dispersion parameter . Predictor variables were a carapace length random effect, a categorical variable indexed by , a region effect indexed by , a year effect indexed by , a transect effect indexed by , and a diver effect indexed by .

Interaction terms included in the analysis were : a length x region interaction , a length x year interaction , a region x year interaction , a transect x year interaction , a length x diver interaction , a year x diver interaction , and finally a three-way interaction term .

The log-linear mean of the model is given by:

The observed counts were assumed to follow a negative binomial distribution

where is a dispersion parameter.

The hierarchical structure of the model provides a way of pooling information between lobsters of different carapace length, between regions and years, as well as accounting for selectivity differences between divers.

Interaction terms allow for variation between temporal, spatial and cohort trends to be incorporated in the model. This combination of hierarchical pooling and model flexibility allows us to make reasonable inferences on missing data observations, all while taking uncertainty into account.