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Review of the survey and analytical protocols used for estimating abundance indices of southern Gulf of St. Lawrence snow crab from 1988 to 2006

Revue du relevé au chalut et du protocole utilisé pour l'estimation des indices d'abondance de crabe des neiges dans le sud du golfe Saint-Laurent de 1988 à 2006

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ABSTRACT

In the past two decades of the survey history, some methodological adjustments and new equipment have been introduced to improve the procedure and accuracy of the net swept calculations but the sampling protocol has remained since the beginning of the survey. The addition of new and more performing technologies such as temperature-depth sensor, DGPS positioning system and the Netmind® net monitoring system has led to better estimate of the effective tow length and trawl width. Given the changes that have occurred during the snow crab trawl survey, a standard method is necessary in order to compare the time series data from 1988 to 2007. The comparative study amongst three different trawl boats used for the survey was not amenable. It is assumed that the catchability of the trawl has been equal to 100% for all years regardless of the boat used and that sensor measurements are true measurements of the trawl behavior. The 2006 survey served as the reference since most of the methodologies recommended during the recent Snow Crab Kriging Methodology Workshop were adapted. Therefore, the standardization of the survey data since 1988 was done using the KED technique along with the kriging polygon of 37,518 km^2 used during the latest years of the survey, and with the 3 year average variogram.

RÉSUMÉ

Durant les deux décennies de l'histoire du relevé au chalut, quelques ajustements méthodologiques et de nouveaux équipements ont été introduits afin d'améliorer la procédure et la précision du calcul de la surface balayée, mais le protocole d'échantillonnage est demeuré le même depuis le début du relevé. L'ajout de nouvelles technologies qui sont plus performantes tel que la sonde de température-profondeur, le système de positionnement (DGPS) et le système de suivi du comportement du chalut (Netmind®) a résulté en une estimation plus fiable de la longueur effective du trait et de l'ouverture du chalut. En tenant compte des changements qui sont parvenus au cours de l'histoire du relevé au chalut du crabe des neiges, une méthode standard était nécessaire pour que l'on puisse comparer la série des données historiques de 1988 à 2007. Une étude comparative entre les trois chalutiers utilisés pour le relevé n'a pu être réalisée. Il est donc assumé que la capturabilité du chalut était égale à 100% pour toutes les années indépendamment des bateaux utilisés, et que les mesures obtenues des sondes électroniques étaient les vraies mesures du comportement du chalut. Le relevé en 2006 a été considéré comme étant la référence puisque la majorité des recommandations faites durant le récent atelier sur la méthodologie de Krigiage sur le crabe des neiges y a été adoptée. Par conséquent, la standardisation des données du relevé depuis 1988 a été faite à l'aide de la technique KED en utilisant un polygone de Krigeage de 37,518 km^2 , ce qui a été utilisé durant les plus récentes années de l'histoire du chalutage, et avec un variogramme qui se base sur une moyenne de trois ans.

INTRODUCTION

The snow crab fishery in the southern Gulf of St. Lawrence (sGSL) (Fig. 1) began in the mid-1960s and entered into a development phase in the 1970s when initial landings by fishermen from the Maritime Provinces and Quebec were relatively low. However, record landings were reached during the early 1980s (Fig. 2). Throughout this time, the status of snow crab population in the area was poorly understood and was based mostly on fishery statistics. In 1989, the Area 12 fishery (Fig. 1) was closed prematurely due to a rapid decline in catch rates associated with an increasing incidence of soft-shelled crabs being captured. Consequently, new fishery management measures were introduced in 1990. One of these measures was to determine the total allowable catch (TAC) based on the biomass index of adult male crab ≥ 95 mm in carapace width (CW) to be estimated from a bottom trawl survey. The ratio between TAC and biomass index for a given year was labeled as a 'relative exploitation index' and has fluctuated since its inception in 1990 depending on management objectives. This annual snow crab bottom trawl survey is fishery independent and is the main assessment tool used by biologists for determine the status of the snow crab population, as it provides indices of recruitment several years before adult crabs enter the fishery. Female snow crabs, inherently smaller than males, are also caught in the trawl net, therefore enabling the calculation of an index of the stock's reproductive potential. Other indices such as sex ratios, natural mortality, molting probabilities and relative exploitation rates can also be estimated with the trawl survey data analyses. These indices are used in population dynamics models for short and long term abundance projections (Surette and Wade 2006).

During the 2007 Science Regional Advisory Process (RAP) meeting, the scientific committee expressed concerns relating to the modifications made in the methodology used for estimating the abundances of snow crab over the years (e.g., changes in survey vessels, adding and repositioning sampling stations and increasing the survey surface). Consequently, the scientific committee recommended a thorough investigation to describe all changes that might impact the time series. The goal of this paper is to document any changes in survey design and analytical protocol from 1988 to 2006 which might have had a quantifiable impact on the homogeneity of abundance or biomass estimates. This document describes the changes that have occurred in the snow crab trawl survey in the last nineteen years pertaining to the survey design, crab measurements, the estimation of the net swept area and the calculation of the abundance indices.

DESCRIPTION OF HISTORICAL CHANGES

Survey design and protocol

The snow crab trawl survey has been conducted since 1988 in Areas 12 and 25/26 (except for 1996), since 1990 in Area 19, since 1992 in Area 18 (except 1997 and 1998) and since 1997 in Areas E and F (Appendix 1). In Areas 12, 18, 25/26, E and F, the survey was conducted after the fishing season which usually opened in late April and finished by mid-July (Appendix 1). The annual trawl survey normally started early to mid-July and ended in September (Fig. 3). In Area 19, the fishing season was open for two periods (spring and summer) between 1990 and 1992, and thus the survey was conducted between the two seasons. Since 1993, the survey in Area 19 has been conducted after the summer fishing season. Since 2003, a pre-fishery trawl survey (late June) has been introduced in Area 19 in addition to the regular post- fishery survey in order to better estimate the effect of seasonal movement of crabs in the establishment of the TAC by fishery managers for this area (Biron et al. 2008).

A systematic random sampling design was used to determine the location of trawl stations in 1988 (Moriyasu et al. 1998). One or two locations were randomly chosen within each grid of 10 by 10 minutes latitude-longitude (Fig. 4). If a given station was deemed untrawlable by onboard biologist, an alternative location within the same 10 by 10 minute latitude-longitude grid was randomly chosen. Once the locations of trawl stations were determined, they remained fixed each year. In small areas such as Areas 18, 19, 25/26, E, F and in Chaleur Bay, two stations within a 10 by 10 latitude-longitude grid were randomly chosen to increase the precision of the estimates. The sampling protocol calls for the survey to be postponed in the event of adverse weather conditions; i.e. winds above 20-25 knots or sea conditions that hinder the maneuverability of the boat. Only good tows are considered in the analysis. Bad tows are defined as torn or damaged nets resulting in lost specimens and/or uncompleted tows due to the weather, sea conditions, abnormal net behavior or malfunction of the electronic net sensors. Table 1 shows the historical record in number and percentage of bad tows.

In 1988, the survey area covered the expected boundaries of the commercial fishery in Area 12 only, and has since expanded to cover a much larger area. The survey area used since 2006 covers all snow crab fishing zones in the sGSL and is bounded by the 20 fathom depth contour (Fig. 4). Also, the redefinition of Area 12 in the management plans, such as the creation of new zones (Areas E and F in 1995) and the integrations of Areas 25/26 into Area 12 in 1997 and Area 18 into Area 12 in 2003, have impacted the number of stations and the polygons used to estimate the commercial biomass in these particular management areas. Consequently, the number of stations have increased throughout the years (Table 2, Appendix 1).

Sampling Protocol

<u>Boats</u>

Three chartered vessels have been used since the first survey in 1988. The side trawler 'Emy-Serge' from 1988 to 1998, followed by two stern trawlers, the 'Den C Martin' from 1999 to 2002, and the 'Marco-Michel' from 2003 to present (Fig. 6). No catchability comparison was made during the transitions. The 'Emy-Serge' was 64 ft in length and had a 375 hp engine and its hull was made of wood. The 'Den C Martin' was also 64 ft in length but with a 402 hp diesel engine and had a steel hull, while the 'Marco-Michel' is 65 ft in length, has a 660 hp engine and has a fiberglass hull.

Since there have been no comparative studies done between the three vessels used during the time series, there are uncertainties on the relative behavior and the catchability parameters of the trawl between boats. It is assumed that the catchability of the trawl has been equal to 100% for all years, regardless of the boat used, and that the measurements of net width and distance by net sensor are true measurements of the trawl behavior.

<u>Trawl</u>

The trawl used is a Bigouden Nephrops trawl (Fig. 7) originally developed for the Norway lobster (*Nephrops norvegicus*) fishery in France. The particularity of this trawl is its ability to dig into the soft sediment to catch species that burrow themselves. As there was no detailed description of the trawl net published in the literature, we describe the net as follows.

The trawl opening is 20.8 m with a 28.2 m foot rope, on which a 18 m long by 8 mm in diameter galvanized chain is mounted. The plastic buoys (8 buoys 200 mm in diameter and 8 buoys 130 mm in diameter) are mounted on the upper combination of the trawl. The net is made of 2.5 mm diameter braided nylon twine and the mesh sizes are 80 mm in the wings, 60 mm in the belly and 40 mm in the cod-end. The wing cables are made of 15.88 mm in diameter wire and a length of 5.94 m with mechanical splice at each end (Fig. 8). The wing cables are attached to the ground cables, which are 15.88 mm in diameter and are 45.72 m in length with mechanical splice at each end. The transfer cables (15.88 mm in diameter and a length of 3.20 m with mechanical splice at each end) are used to attach and detach the doors from the ground and main cables. A pair of wooden doors (1.12 m in width, 0.65 m in height and 9 cm in thickness) weighting about 82 kg each is used. A 4 cm wide by 7 mm thick metal sheet covers the sides and the base of the door. In addition, a 2.5 cm thick metal plate reinforced the base (1.12 m) and the lower parts on the side of the door (20 cm in length on both side). Each door bears two triangles (50.6 cm at the base and 43 cm on each side) and 3 rings (12.5 cm in diameter) both made of 22 mm diameter metal rod.

The only modification on the trawl since the beginning of the survey is the chain mounted on the foot rope. From 1988 to 1990, the chain was attached to the foot rope as shown in Figure 9, but since 1991 the chain has been rolled up to the foot rope (Fig. 10). This change was suggested by experienced trawl fishermen to improve onboard handling safety and trawl digging behavior into the sediment. The possible change in catchability of crab was not determined and thus considered as unchanged.

Temperature and temperature-depth sensors

From 1988 to 1996, the bottom temperature was measured using a temperature probe with a delay timer. Only one reading was recorded once the trawl was on the bottom. From 1997 to 1999, a Minilog® temperature data logger that records temperature at each 10 second intervals was used. Since 2000, a Minilog® temperature-depth sensor, a complementary independent tool to the Netmind system, has been used.

The addition of this sensor, along with the Netmind® depth sensors introduced in 2001 has led to the better determination of the effective trawl touchdown and liftoff time.

Positioning systems (Loran C, GPS, DGPS)

There have been different systems used aboard the vessels to record the locations of the start and end positions of tows.

From 1988 to 1998, the captain used a Loran-C receiver to locate the trawl stations and record the various locations during the trawling. From 1991 to 1998, a Global Positioning System (GPS) was used by the DFO scientist onboard. A Differential Global Positioning System (DGPS) has been used by the captain since 1999.

Loran-C provided better than 400 m absolute accuracy for suitably equipped users within the published areas. Users of this system can return to previously determined positions with an accuracy of 50 meters or better in the time difference repeatable mode. The GPS, which used a satellite based navigation system, has a precision within 15 m. The DGPS is an enhancement to GPS that uses a network of fixed ground based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. The precision of the DGPS is usually within 3 m (www.navcen.uscg.gov/pubs/frp2001/FRP2001.pdf).

Scanmar® / Netmind®

The electronic net monitoring systems (Scanmar® and Netmind®) are acoustic, wireless, net monitoring systems that enable real-time information of the trawl as it is towed through the water and on the sea bottom. These net monitoring systems (active), along with the Minilog® depth-temperature (passive) and locations of the start and end of the tow are the main tools to evaluate the swept area of a given tow.

From 1988 to 1998, a Scanmar® system was used to monitor the net behavior. The Scanmar® system was made up of three components: a hydrophone, a receiver and the sensors. From 1988 to 1992, a towed hydrophone was used, and from 1993 to 1998, a hull mounted hydrophone was set-up on the chartered vessel (Emy-Serge). The hydrophone was mounted in a steel housing to protect it from ice and other hazards. From 1995, a receiver unit acted as an interface between the user's laptop and the hydrophone for easy logging of data collected and exporting to various spreadsheets and charting programs. Three types of sensors were used; the headline height sensor, the distance sensors and the depth sensor. The headline height sensor measures the distance from the headline to the footrope and from the footrope to the bottom. The distance sensors measure the distance between the wings of the net and the depth sensor measures the depth of the trawl. All sensors on the Scanmar® system recorded data at every 7 seconds.

Since 1999, a Netmind® system has been used on the chartered vessels (Den C. Martin and Marco-Michel) to monitor the net behavior. The Netmind® system is made up of the same components as of the Scanmar® system: hydrophone, receiver and sensors. A mounted hydrophone was set-up on the two chartered vessels. The depth sensor of the Netmind® system records data every 7 seconds while the height and distance sensors record data at every 3 seconds.

Operation during trawling

The captains and crew of the three chartered vessels used during the survey were all experienced fish harvesters with extensive trawling expertise. All stations were trawled during daylight time. The predetermined amount of warp was let out (3 times the distance of the depth) and winch drums were locked. The start time of a standard tow (trawling) was always determined after the winch drums were locked and when the trawl touched the bottom monitored by the hydro-acoustic net monitoring system (Scanmar® or Netmind®). The duration of each tow varied between 4 and 6 minutes at an average speed of approximately 2 knots depending on the depth, current speed and sediment type. The catch of each tow was sorted; species were identified and species other than snow crab were counted (when present in low number) or estimated (large quantities). All snow crabs were kept for morphometric measurements.

There were differences in the deployment of the trawl between side and stern trawlers. When using a side trawler (1988-1998), the procedure necessitates a turn while releasing the trawl and then going forward during the trawling (Fig. 11A). The trawling duration was approximately 5 minutes and start of the tow was determined by the DFO scientist when the winch drums were locked and when the trawl effectively touched the bottom based on Scanmar® data. The captain's start time location from 1988 to 1998 (except for 1989 and 1992) was recorded when the trawl was thrown into the water at the pre-determined station position independently to the start time position taken by the DFO scientist. The mean tow lengths calculated from the captain's recorded start and end coordinates were very different in 1989 and 1992 compared to 1988, 1990 and 1991 and from 1993 to 1998. In 1989 and 1992, the start time position was set by the captain according to the signal from the DFO scientist, who made the decision based on the time when the winches were locked and an assessment of the Scanmar® data (Fig. 12). There was no significant difference in the end time position between the captain and the DFO scientist from 1988 to 1998.

Since 1999, the methodology used in deploying the trawl changed with the stern trawlers which simply unfurl the trawl as it moves forward (Fig 11B). Also, a Netmind® hydro-acoustic system replaced the Scanmar® system for monitoring the trawl net parameters. The start and end time positions based on the touchdown of the trawl provided by the DFO scientist (Fig. 12).

Crab measurements

Morphometric measurements

The main morphometric measurements used in snow crab stock assessments are the chelae height in males, the abdomen width for females, and the carapace width for both sexes. These measurements have been recorded for all captured crabs since 1988 and taken by using modified vernier calipers. The precision of the measurements were to the nearest millimeter up to 1997 and then to the nearest hundredth of a millimeter with the introduction of the digital version of the caliper in 1998. The carapace width measurements are used to derive size-frequency histograms and form the basis of any size-based classification, the most important being separating the sub-legal and legal-sized males when estimating commercial categories.

Morphometric relationships between the carapace width and the secondary sexual characters (here measured by the chelae height and abdomen widths) are classified using a linear discriminant function, which separates the morphometrically mature individuals from the immature and adolescent ones. This discriminant function (Conan and Comeau 1986) has been in use since 1988 and has remained unchanged; it has been tested throughout the years without showing any significant difference. Size-weight relationships for newly molted males (shell conditions 1 & 2) and hard-shelled males (shell conditions 3, 4 and 5) were derived from an experimental sample, and have been used since 1988 (Hébert et al. 1992).

Shell condition

The relative age of a snow crab's carapace since its previous moult, called carapace or shell condition, has been initially ranked and then modified through the years according to Sainte-Marie (1993), Anonymous (1994), Sainte-Marie et al. (1995), Hébert et al. (1997), and Moriyasu et al. (1998). From a biological and stock assessment perspective, we are mainly interested in separating newly molted crab (crab having molted within the previous molting season), from older crab, in order to construct an index of future recruitment to the fishery for the following year and/or available biomass for the coming fishing season. Very old shelled crabs are associated with a higher mortality rate and a resulting decrease in catchability, as well as reproductive capacity.

A set of practical criteria are required for proper identification of shell condition. Among these, shell hardness (soft to hard), shell color (white to yellow to brown), opacity, degree of iridescence (lesser for older-shelled crab) and epibiontic growth (an index of cleanliness) are all used to identify the shell condition of a given specimen. These criteria are further described in Table 3. The number of shell condition categories has increased since the inception of the trawl survey in order to address industry demands or reach new research goals (A detailed diagram showing the evolution of the trawl survey shell condition classification system is presented in Figure 13).

From 1988 to 1991, there were three shell condition categories, corresponding to newly molted crab (shell condition 1), hard-shelled intermediate crab (shell condition 2) and old-shelled crab (shell condition 3). In 1992, the newly molted crab category was split into two sub-groups; i.e. soft-shelled (relabeled shelled condition 1) and relatively hard-shelled (relabeled shell condition 2). Both categories are colloquially referred to as ‘white’ crab (referring to the shell color) while the term ‘soft’ crab specifically refers to the shell condition 1 category. Categories previously labeled shell conditions 2 and 3 were subsequently relabeled as 3 (intermediate) and 4 (older shelled crabs), respectively.

In 2002, the shell condition 3 (intermediate) category was split into two sub-categories according to whether iridescence was detectable or not, and relabeled as shell conditions 3 and 3M, respectively. The shell condition 4 was relabeled as shell conditions 4 (old shelled) and 5 (very old shelled). This five-category system forms the basis of scale in use today, although some sub-categories with an ‘M’ suffix (3M from 2002 onward and 2M between 2005 and 2006 only) were added, mainly to address industry demands by indicating the light presence of epibionts (i.e. moss) on the carapaces. However, the M suffix was disregarded in all stock assessment analyses and summary statistics (i.e. 2M and 3M were considered as 2 and 3, respectively).

In spite of the progressive ramification of the category of shell conditions over years, the most important categories for stock assessment, i.e. newly molted and hard-shelled crabs, were not affected.

Estimation of the net swept area

The global snow crab abundance index depends on our ability to estimate local abundance indices at each sample location. These local abundance indices may be simply based on tabulated frequency counts for a given demographic category (i.e. commercial crab, mature females) or may be standardized by an auxiliary variable. In this case, the observed frequency counts are divided by the auxiliary variable which is an estimate of the surface area covered by the trawl net during sampling. We call this surface the swept area. The resulting value is a local density index, which may be either averaged or interpolated over a given study area (e.g. fishing zone) assuming homogeneity of suitable habitat for snow crab to obtain abundance indices. The estimation of the swept area for each tow may be complicated by the variable behavior of the trawl net from one tow to the next, which in turn may depend on the type of bottom being sampled, the speed of the vessel, the water depth or the accumulation of debris (e.g. mud, rocks, and benthic organisms). Thus, the swept area for each tow must be estimated separately.

Acoustic sensor data

Since 1988, the survey protocol included acoustic trawl monitoring systems to relay real-time information on the height and the width of the trawl net, which was either manually (1988-1994) or electronically (1995-2006) recorded, and then used to estimate the swept area. Acoustic sensor information for estimating the swept area is also used by the DFO scientist to detect at which point the trawl initially touches down on the ocean bottom sediment.

The acoustic sensor data go through several validation steps to ensure proper results because the acoustic sensor data could be error prone or missing. The rough bottom topography, water depth and signal strength may all contribute to the variable levels of noise in a data series. An automatic system first filter the data to remove outliers, followed by manual filtering to 'weed-out' tows where there is not enough information available to make a proper estimate of the swept-area. In the event where estimates of swept-area cannot be calculated, the average of ten (10) nearest calculated swept areas was used.

General swept area model

Some of the general assumptions that are common among the several swept area estimation methods used during the time-series include:

- Analytical assumptions:
    - Trawl width data which may have required a priori filtering are valid data.
    - The width of the trawl net $w(t)$ is known at all times t.
    - Touchdown time and liftoff times are known or can be calculated.
    - The speed of the trawl net $v(t)$ is known at all times t within a specified interval $t_0 \le t \le t_1$.
    - Uncertainties associated with the above quantities are negligible.
- Experimental assumptions:
    - Boat speed is equal to trawl speed.
    - Boat location is equal to trawl location.
    - Overall catchability of the trawl is independent of the vessel used, boat speed, and bottom type.

Ideally, the basis of the analytical model used to calculate the swept area is given by the following method:

- Given the speed *v(t)* and width of the trawl net *w(t)*, we may calculate the rate at which the area at bottom is being swept in an infinitesimally small time dt. The resulting quantity $v(t)w(t)dt$ is referred to as the instantaneous swept area and we obtain the swept area estimate (A) of this quantity by its integration between suitable time bounds t_0 and t_1:

(1) $$A = \int_{t_0}^{t_1} v(t)w(t)dt$$

The time values t_0 and t_1 are referred to as the *touchdown* time and *liftoff* time, respectively. Similarly, the coordinates associated with these times are referred to as the *start* and *end* positions of the sample tow.

History of the swept area estimation

The availability of the relevant information regarding the various components of this model has greatly improved throughout the history of the trawl survey. A number of simplifying assumptions were made depending on the availability of information from various time periods.

Early Scanmar® utilization (1988-1994):

From 1988 to 1994, trawl width measurements were manually recorded by on-board scientist from real-time output from the Scanmar® acoustic monitoring system (Appendix 2). However, these width measurements represent a set of ordered values rather than a time series, since times were not noted with each observation. The number of observations recorded varied from tow to tow with anywhere from 3 -12 observations. Given that no time data are provided and that only the order of the observations is known, the tow was assumed to have laid along a straight line, and adjacent trawl width observations were assumed to be at equal distances from each other.

The tow length was calculated as follows: 1) on the captain's recorded start and end coordinates using the onboard Loran C, which was the main positioning device on the 'Emy-Serge'; and 2) starting in 1991 by the DFO onboard scientist recorded start and end locations of the sampling according to the outputs of the Scanmar® system using a GPS (Appendix 3). The timing of the trawling (5 minutes) was always based on cues from the scientist. For each tow, the swept area was obtained using the sum of the trapezoids outlined by the recorded values for trawl width and the trawl length (Fig 14).

Late Scanmar® utilization 1995-1998:

Starting in 1995, an electronic file containing all Scanmar® measurement was obtained for each tow, showing data from various instruments or sensors every seven (7) seconds. The files include the location of the boat, the date and time, the trawl width, height, and depth and the boat speed. The last field of the electronic file contained a coded flag that highlighted the location and time of the DFO scientist's tow start (coded as '1') and end (coded as '2') time based on the Scanmar® monitoring system. A sample file is presented in Appendix 4.

The swept area based on the DFO scientist's start and end positions was calculated as the sum of the trapezoids formed by each adjacent pair of filtered trawl width observations. The filter consisted of the elimination of all records that contained trawl widths greater than 20 m (i.e. stretched net width) and all records prior to the start code (1) and after the end code (2).

The total area, the sum of all trapezoids, was calculated assuming they were separated by equal distance Δd and a set of trawl width observations $w_1, \ldots, w_n$, is given by

$$A = \sum_{i=1}^{n} \frac{\Delta d}{2} \left(w_i + w_{i+1} \right)$$

where A is the swept area estimate, and n is the number of trawl width observations (Fig. 14).

Netmind® utilization (1999-2006):

Starting in 1999, an electronic data file was generated by the Netmind® system which contains trawl parameters such as the door spread, depth and time (Appendix 5). Latitude and longitude were gathered from onboard DGPS data. In 2000 a Minilog® sensor was added which recorded the water temperature, depth and time every 3 seconds. The time of both the Minilog® sensor and the Netmind® system were synchronized prior to each sampling day. During the analysis, the depth profiles of both the Minilog® sensor and the Netmind® depth sensor were plotted (Fig. 15). The onboard scientist estimated the time and position of the touchdown and liftoff electronically as indicated on the chart (blue vertical lines on Fig. 15A). An analysis was made to automatically detect the inflection points of the Minilog® depth, (red vertical lines on Fig. 15 A, C, D, E) thereby deducing the touchdown and liftoff. Charts of the boat locations, boat speed and door spread were also presented as standard outputs of the Netmind® file analysis.

In the event that signals from the door spread sensors were not available for several seconds, an interpolation of the missing door spread measurements was made. Given the high autocorrelation of these datasets, a variogram analysis was used to determine the parameters of a spherical variogram model to be used for this interpolation (Fig. 15 E, F). A two dimensional kriging algorithm was used as the interpolation method. The total area swept was then estimated using various combinations of observed and experimental touchdown and liftoff times. The area swept using the observer's touchdown and liftoff estimates were labeled as (Obs-Obs) on the sample output in Figure 15E. The area swept estimate using the calculated touchdown and the observers estimate of liftoff were labeled as (Exp-Obs). The corresponding area based on the observer's touchdown and the calculated liftoff was labeled as (Obs-Exp) and finally, the estimates based purely on the calculated estimates of swept area were labeled as (Exp-Exp). A printout was then scrutinized in order to obtain the most likely area swept based on the information presented. In the event that the information was deemed insufficient to determine the swept area for a particular tow, an average of the swept area of the 10 nearest points (stations) was used.

In both the Scanmar ®and Netmind® data, the touchdown and liftoff locations were indicated by the DFO scientist onboard using codes entered in the electronic log. However, additional information linked to the Netmind file since 1999, such as Minilog® temperature and depth information, made it possible to obtain a complementary analytical procedure to evaluate the liftoff and touchdown locations.

Regarding trawl net spread, the real time acoustic trawl monitoring systems gave the width of the trawl net (Fig. 16) which was either manually (1988-1994) or electronically (1995-2006) recorded, and then used to estimate the swept area

Calculation of the abundance indices

A geostatistical approach, an ordinary kriging (OK) technique (Conan et al. 1988; Armstrong et al. 1992; and Rivoirard et al. 2000), was used in the sGSL snow crab assessment from 1988 to 2005. In 2005, a Snow Crab Methodology Workshop took place in order to review some of the issues pertaining to the types of analysis performed during the snow crab assessment (DFO 2006). One of the recommendations related specifically to the kriging analysis, in which it was suggested that a secondary variable, such as temperature or depth, should be considered during the analysis and the results compared with the other techniques. The 'kriging with external drift' (KED) method was used to better estimate a primary variable using information from a secondary variable related to the first and for which the structure is better known (Wackernagel et al. 1994, McBratney et al. 2000). In the analysis of the sGSL snow crab stock assessment, Surette et al. (2007) showed by using cross validation that the kriging with external drift (KED) with depths as a secondary variable performed better overall than the ordinary kriging or ordinary kriging with pseudo zeros.

Pseudo-zeros

During the 1993 and 1994 surveys, when crab populations were expanding, an 'edge-effect' was observed, whereby samples at the edge of the survey near Shediac Valley and Magdelen Islands areas showed very high crab density. Since 1995, a collection of 'outer zeros' was used to designate the assumed limits of snow crab habitat in the sGSL. These zeros (also called 'pseudo-zeros') were placed starting at 20 fathoms depths or less and at 150 fathoms depths or more (Fig. 17), and were considered to be outside the favorable temperature range of the habitat. Some effort was made recently to trawl in 'pseudo-zeros' areas to confirm the absence of snow crab. For example During the 2005 survey, approximately 10 'pseudo-zero' stations were sampled, mostly in the Chaleurs Bay, and no snow crabs were observed at these locations.

Variogram averaging

It was also decided at the Snow Crab Kriging Methodology Workshop (DFO 2006) that an average over three years of the empirical variogram may be better suited for modeling the autocorrelation between the samples. It was further recommended that during the local kriging analysis of the sGSL snow crab stocks, the neighborhood search should include at least 32 neighboring points.

Kriging polygons

One of the critical factors in the geostatistical method is the determination of the area selected for the population estimation process. Since the area covered during the snow crab survey only dealt with the main fishing grounds, the population estimation was limited to the selected area. Although the area selection is arbitrary, the process included the mapping of the standard errors generated from the 1988 analysis, so that only those regions where the standard deviation was lower than a certain level were selected. This reference area or 'kriging polygon' was used from 1988 to 1997, with a slight change made in 1998 to include a small area adjacent to areas 25/26 (Fig. 18). In 1999, this area was increased and in 2003, with the amalgamation of Area 18 into Area 12, the kriging polygon in Area 12 was adjusted accordingly (Fig. 18). The areas selected for the population estimates for Areas 18, 19, 25/26, E and F have been constant since the first population estimates were made in the respective zones. Specifically, the kriging polygons used for these zones are defined by their management lines, as well as by shallow depths near the coastline (for Areas 18, 19 and 25/26) or by very deep water in the case of Areas E and F.

Software

From 1988 to 1991, the software used to perform the sGSL snow crab ordinary kriging analysis consisted of a series of independent custom made applications programmed using the HPBASIC language. The results from one analysis made by one program were then passed on to the following analysis phase via either file transformations or manual input of the information at each step.

Starting in 1992, a MATLAB script, termed COKRI (Marcotte 1991), was used to perform the same ordinary kriging method. Specifically, the software performed point kriging, block kriging and co-kriging, using any number of variables. All the basic variogram models could also be used as well as different geometric anisotropies, thus allowing modeling flexibility. However, data transformation, variogram analysis and mapping functions were done separately using commercially available software.

In 1999, an integrated MATLAB toolbox (MPOGEOS) was developed by the Ecole Polytechnique de Montréal, in which all the functions required to perform a geostatistical analysis were incorporated into one program. A menu driven application permits the user to perform the data transformations, variogram analysis, ordinary kriging interpolation and mapping functions. Improvements and modifications to the software program have been made several times since then. The latest improvement in 2006 included a provision to include KED using depth, as a covariate as well as the kriged size frequency histograms.

STANDARDIZATION OF TIME SERIES

In the past two decades of snow crab survey history, some methodological adjustments and new equipment have been introduced to improve the procedure and accuracy of the net swept area calculations, but the sampling protocol has remained unchanged. The addition of new and more performing technologies such as the temperature-depth sensor, the DGPS positioning system and the Netmind® net monitoring system has led to better estimate of the effective tow length and trawl width.

Given the changes that have occurred since 1988, a method was needed to standardize the time series data. The 2006 survey served as the reference for the standardization since most of the methodologies recommended during the methodology workshop (DFO 2006) were adopted. Therefore, the standardization of the survey data starting in 1988 was done using the KED technique, along with a kriging polygon of 37,518 km^2 used during the recent years of the survey, and with a 3-year average variogram.

From 1999 to 2007, the standardization of the estimates was fairly straightforward since the area swept was already determined based solely on the analysis of electronic files generated from the Netmind® system and the results properly analyzed and scrutinized (Table 4). Standardization of the estimates from 1995 to 1998 was done using the area swept as determined by the analysis of data generated from the Scanmar® system. The start and end locations of the sampling were taken exclusively from the DFO scientist’s logbook. The area swept estimates from 1991 to 1994 were generated using the observed trawl widths recorded manually and the start and end locations from the DFO scientist’s logbook. Finally, the standardization of the estimates from 1988 to 1990 was calculated using the mean area swept from the ‘Emy-Serge’ boat as described above (Fig. 19). Table 4 shows both the adjusted and unadjusted Area 12 biomass estimates as they were calculated using the various standards of the time.

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Chiasson and his crew, Captain Joey Desveaux and his crew). The authors also thank Amélie Rondeau and Claude LeBlanc for their review of the manuscript.

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Table 1. Number and percentage of rejected tows during the snow crab trawl survey in the southern Gulf of St. Lawrence.

Year	***Bad Tows***	***Good Tows***	***Percentage Bad Tows***
1988	21	155	13.6 %
1989	16	155	10.3 %
1990	43	212	20.3 %
1991	19	215	8.8 %
1992	9	233	3.9 %
1993	11	208	5.3 %
1994	23	262	8.8 %
1995	38	262	14.5 %
1996	3	72	4.2 %
1997	18	259	7.0 %
1998	16	278	5.8 %
1999	26	278	9.4 %
2000	26	278	9.4 %
2001	26	292	8.9 %
2002	24	321	7.5 %
2003	44	317	13.9 %
2004	27	348	7.8 %
2005	51	355	14.4 %
2006	37	355	10.4 %

Table 2. Number of stations, area of survey polygons and crab fishing area (CFA) covered by the snow crab trawl survey in the southern Gulf of St. Lawrence.

year	***Number of stations***	***Survey Polygon (km^2)***	***Covered CFAs***
1988	155	29,336	12, 25/26
1989	155	29,345	12, 25/26
1990	212	29,250	12, 19, 25/26
1991	215	29,254	12, 19, 25/26
1992	233	29,254	12, 18, 19, 25/26
1993	208	29,254	12, 18, 19, 25/26
1994	262	29,254	12, 18, 19, 25/26
1995	262	29,254	12, 18, 19, 25/26
1996	72	NA	18, 19
1997	259	29,254	12, 19, E, F
1998	278	31,696	12, 19, E, F
1999	278	35,748	12, 18, 19, E, F
2000	278	35,748	12, 18, 19, E, F
2001	292	35,748	12, 18, 19, E, F
2002	321	35,748	12, 18, 19, E, F
2003	317	35,748	12, 19, E, F
2004	348	37,518	12, 19, E, F
2005	355	37,518	12, 19, E, F
2006	355	37,518	12, 19, E, F

Table 3. Summary of main criteria used to identify the condition of snow crab carapaces.

Criterion	Description
Colour	Newly moulted crabs are whiter in colour than older shelled individuals. Carapaces progress from white to yellow and from yellow to brown as they age. This property is closely associated with opacity.
Opacity	A newly moulted crab's carapace is less calcified and the endoskeletal muscle and connective tissue layers have not expanded to fill the interstitial space within the carapace. As a result, claws and appendages are more or less translucent. These become more opaque and yellow with time.
Senility	Very old shelled individuals are characterized by heavy epibiontic deposition, shell degradation and deformation, which may result in soft carapaces. This criterion is in fact a composite of multiple criteria.
Hardness	Refers to carapace hardness, specifically chelae hardness, determined either manually (from 1988-1992) or by a durometer value larger than 68 (from 1993 onwards).
Iridescence	Multicoloured light diffraction pattern observed within a snow crab's carapace. This phenomenon is analogous to that observed in soap bubbles or thin oil films on water. The visibility of this trait is dependent on the both opacity and colour of the carapace as well as the epibiontic coverage.
Epibionts	The presence of epibionts refers to the growth of various sessile organisms on the carapace. Colloquially referred to as 'moss'.

Table 4. Area 12 biomass estimates adjusted to the 2006 standards using a 37,518 km^2 polygon, tech start and end point, KED and a 3yr averaging of the variogram compared to the non-standardized biomass estimate used at the time.

Year	*Biomass (adjusted)*	*Biomass (unadjusted)*	*unadjusted method*
1988	14.2	8.7	29,336km^2 polygon, captain start and end, OK, 1yr variogram
1989	25.2	21.7	29,345 km^2 polygon, captain start and end, OK, 1yr variogram
1990	42.4	23.4	29,250 km^2 polygon, captain start and end, OK, 1yr variogram
1991	50.8	29.4	29,254 km^2 polygon, captain start and end, OK, 1yr variogram
1992	82.7	37.8	29,254 km^2 polygon, captain start and end, OK-pz, 1yr variogram
1993	126.7	61.9	29,254 km^2 polygon, captain start and end, OK-pz, 1yr variogram
1994	121.9	56.7	29,254 km^2 polygon, captain start and end, OK-pz, 1yr variogram
1995	90.2	49.5	29,254 km^2 polygon, captain start and end, OK-pz, 1yr variogram
1996	N/A	N/A	No survey in Zone 12, 25/26
1997	49.3	33.1	29,254 km^2 polygon, captain start and end, OK-pz, 1yr variogram
1998	44.6	28.2	31,696 km^2 polygon, captain start and end, OK-pz, 1yr variogram
1999	41.5	33.5	35,748 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2000	34.2	28.8	35,748 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2001	40.6	36.1	35,748 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2002	48.4	43.8	35,748 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2003	59.4	53.3	35,748 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2004	77.3	71.9	37,518 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2005	63.0	62.9	37,518 km^2 polygon, tech start and end, OK-pz, 1yr variogram
2006	61.9	61.8	37,518 km^2 polygon, tech start and end, KED, 3yr variogram

Unit of biomass is thousand ton (x 1000 t)

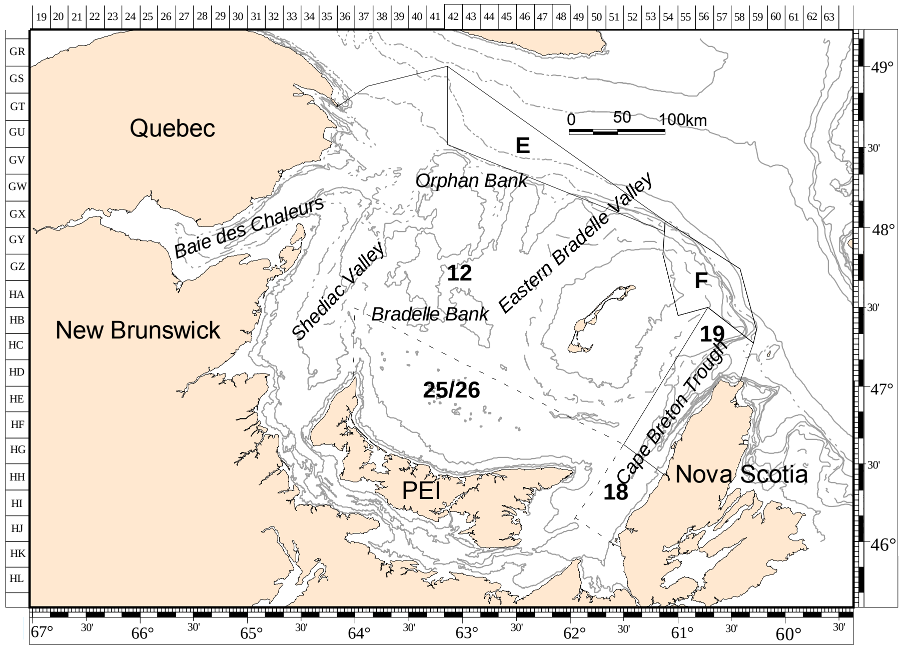


Figure 1. Map of the Southern Gulf of St. Lawrence and snow crab fishing areas (CFA).

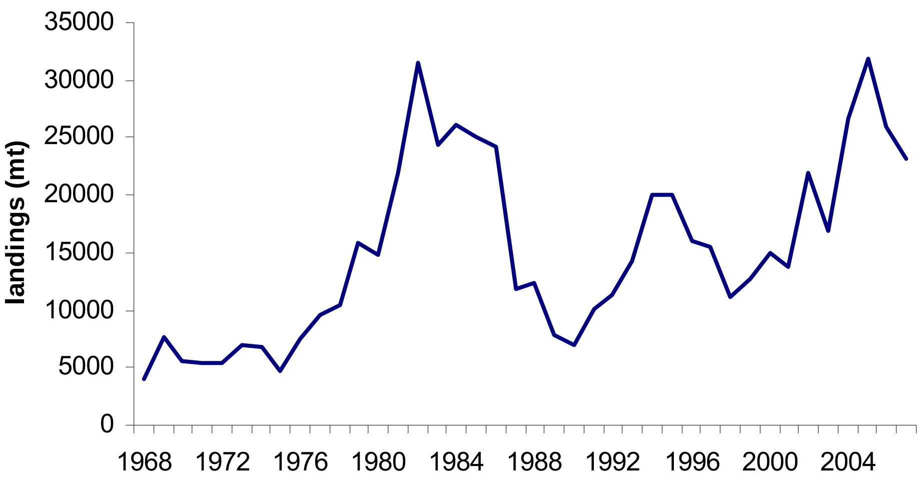


Figure 2. Historical annual landings of snow crab in Area 12.

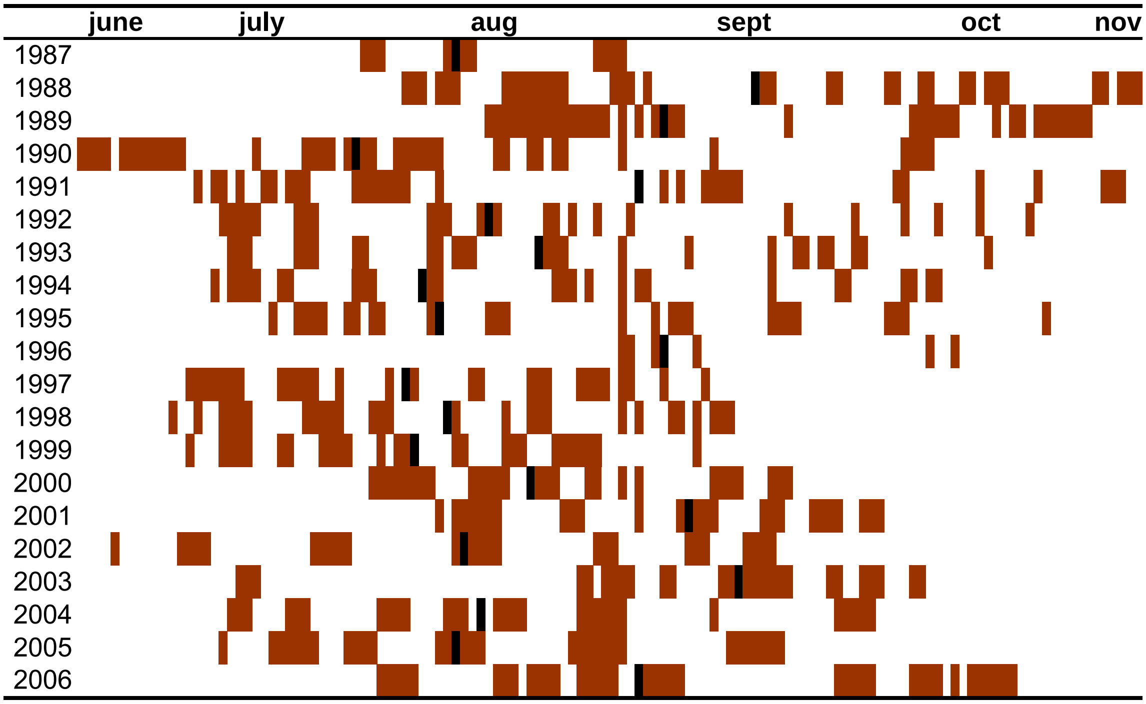


Figure 3. Timing of snow crab trawl survey. Brown marking indicate the trawl survey activity. Black marking indicates the mid point of sampling for the season.

Figure 4. Locations of samples during the snow crab surveys from 1988 to 2006.

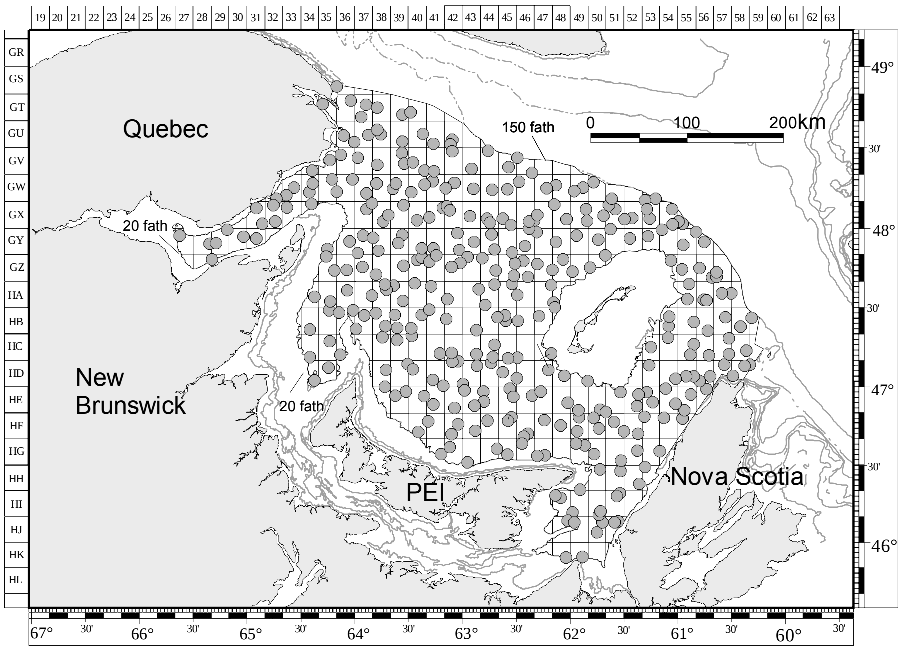


Figure 5. Sample locations (dots) and 10 minute by 10 minute grid used during the 2006 snow crab survey.

A

B

C

Figure 6. Fishing vessels used during the sGSL snow crab survey since 1988: Emy-Serge (A), Den C. Martin (B) and the Marco-Michel (C)

Figure 7. Trawl net in operation showing the upper portion of the net with buoys, Scanmar® sensors.

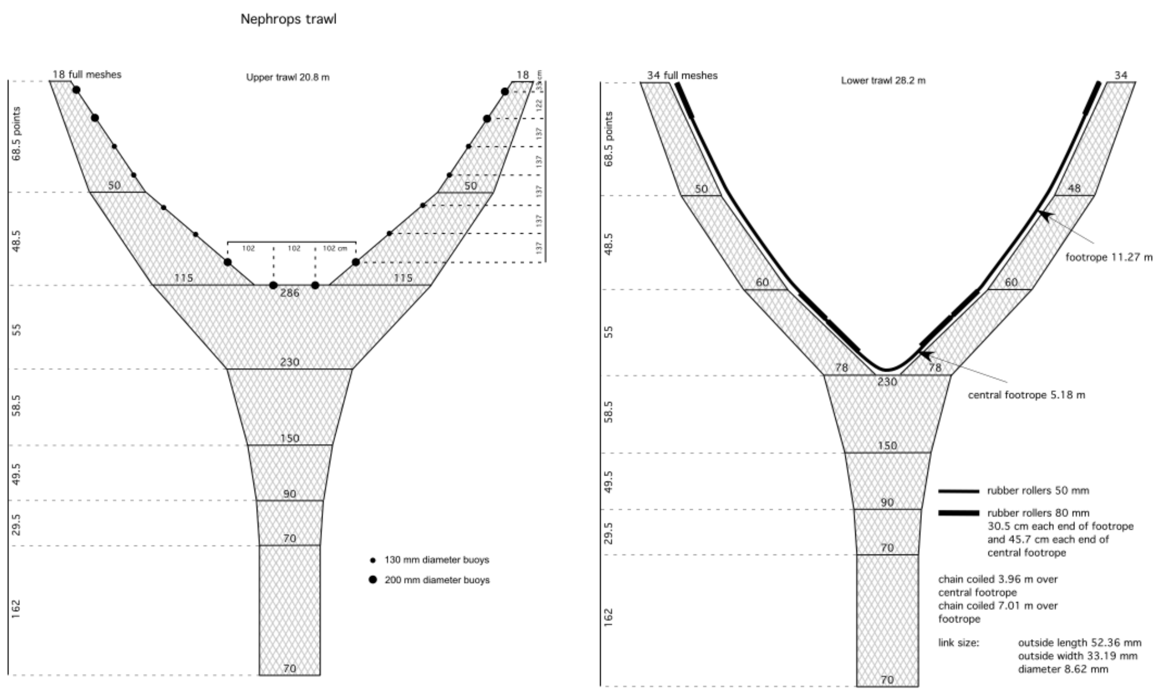


Figure 8. Nephrops trawl net diagram.

Figure 9. Trawl net showing the arrangement of chain attached to the foot rope from 1998 to 1990.

Figure 10. Trawl net showing the arrangement of chains rolled up to the foot rope since 1991.

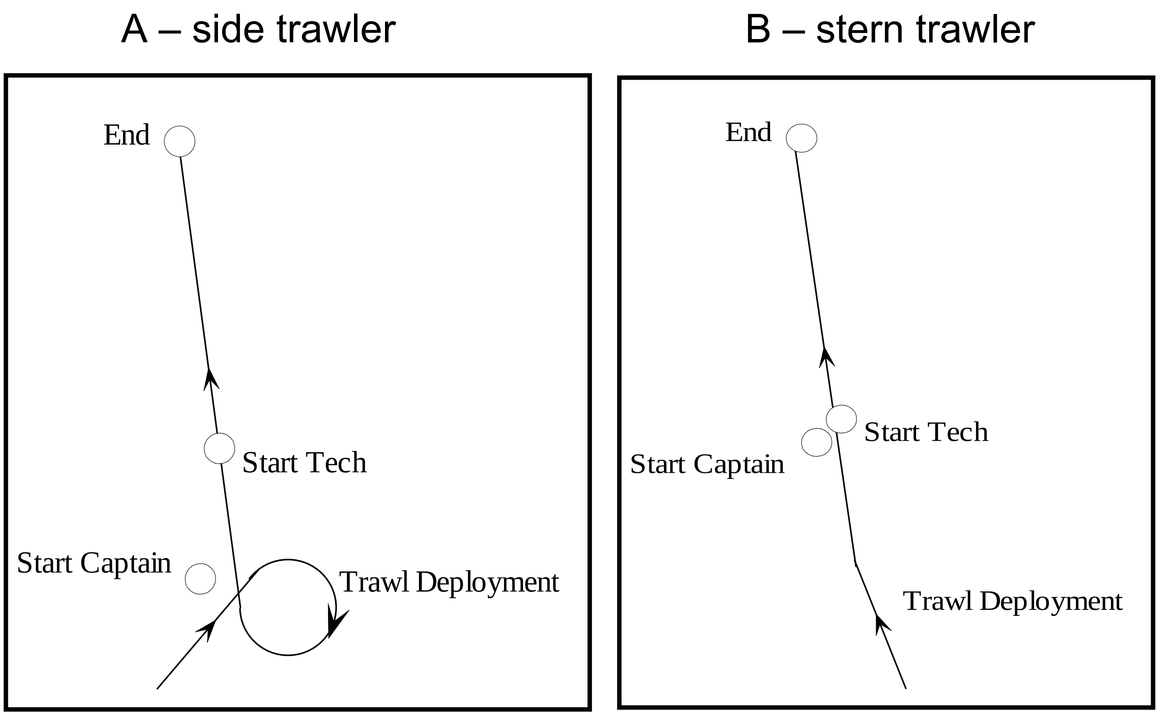


Figure 11. Diagram showing the different methodologies used in deploying the trawl net and determining the start and end time with : A, the side trawler (Emy-Serge) and B, the stern trawlers (Den C. Martin and Marco-Michel).

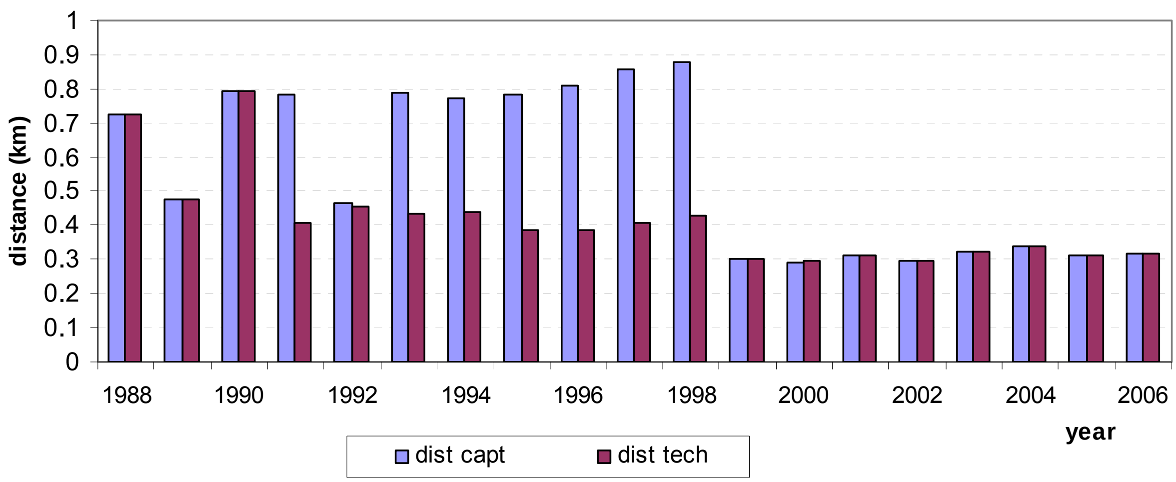


Figure 12. Average distance trawled using the two references – captain's logbook data (dist capt) and onboard scientist's data (dis tech).

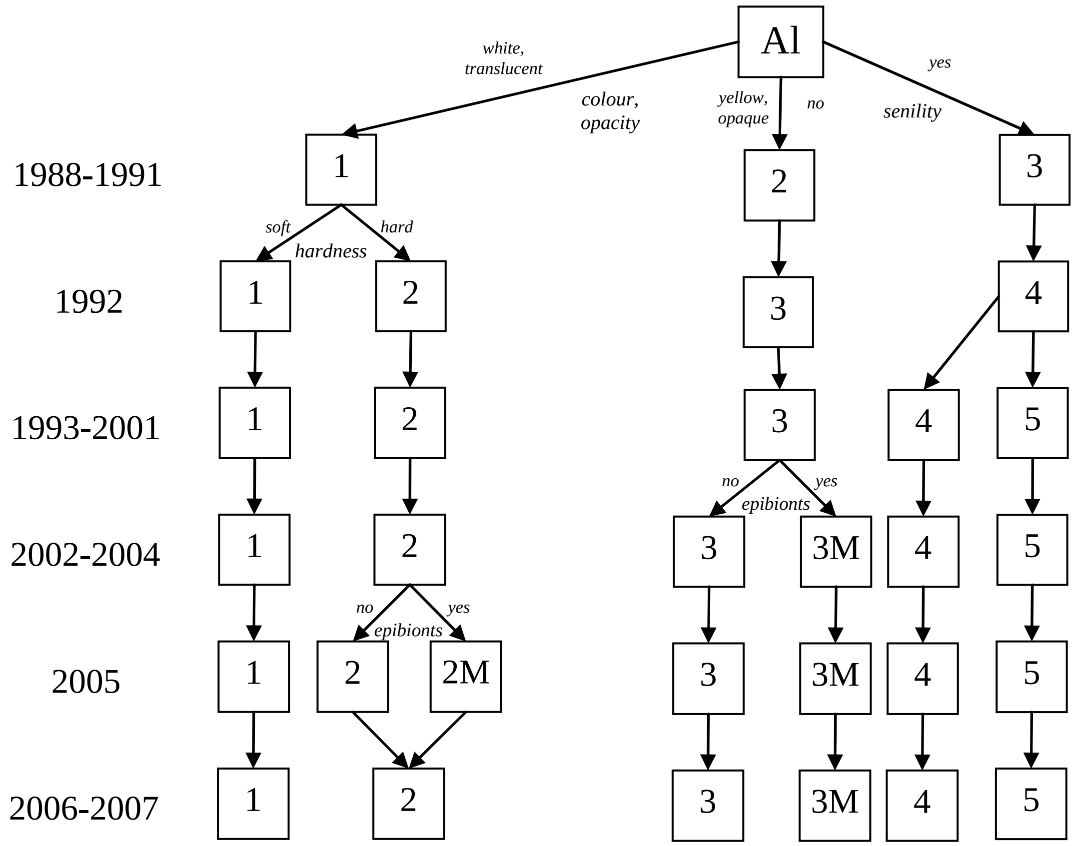


Figure 13. Diagram illustrating the evolution of the trawl survey shell condition classification system as well as the relationships between categories and the criteria used to define them.

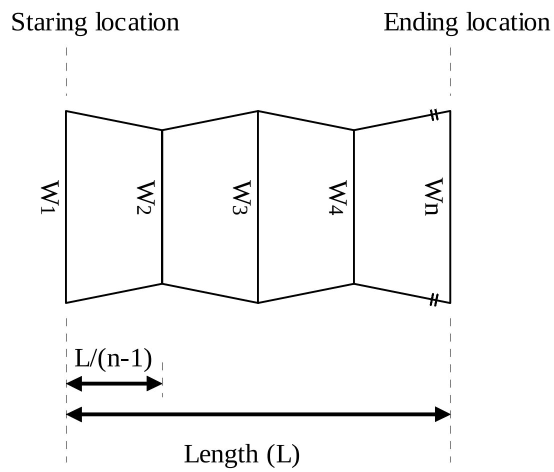


Figure 14. Swept area calculated using equally spaced trawl widths.

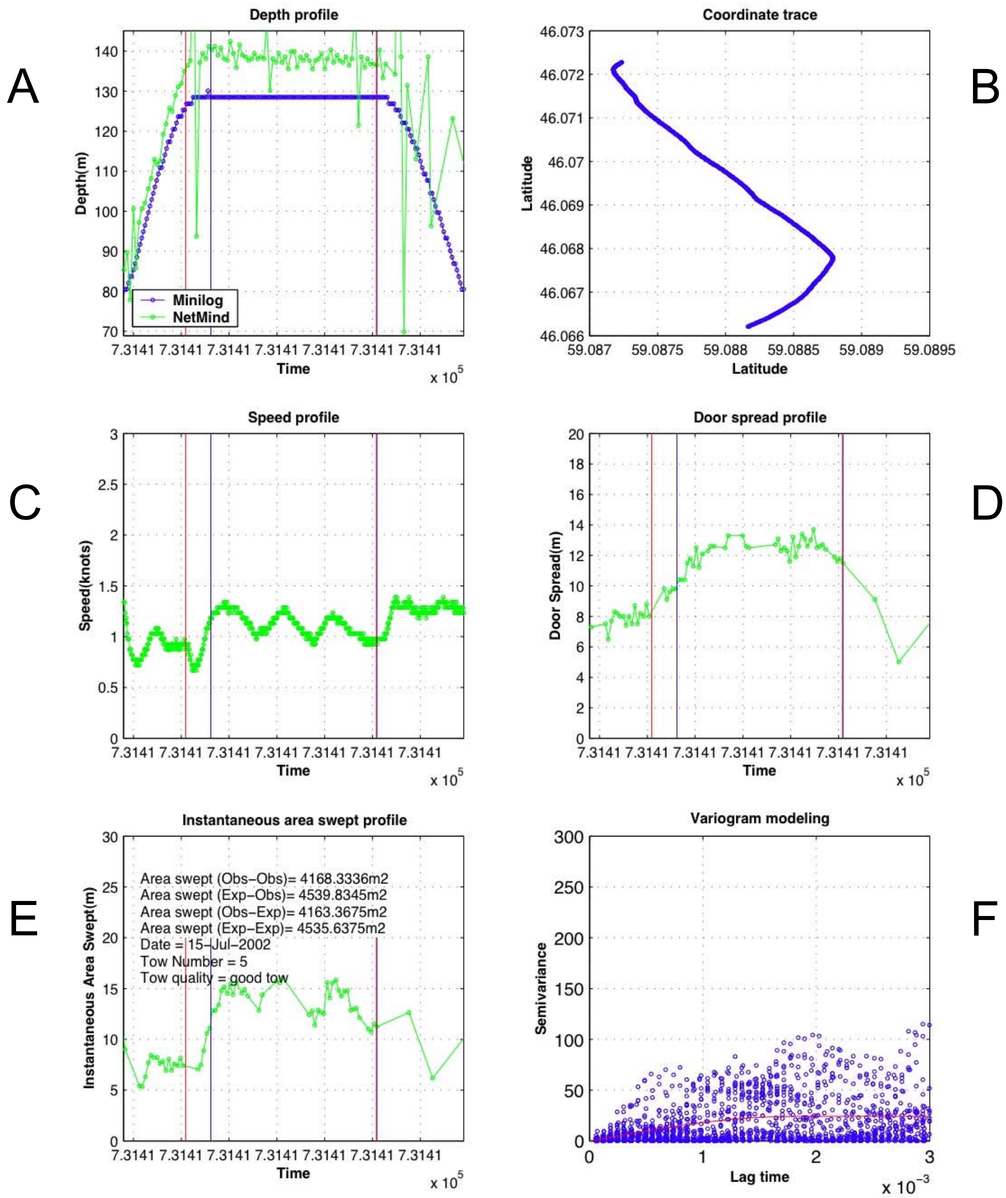


Figure 15. Netmind analysis output.

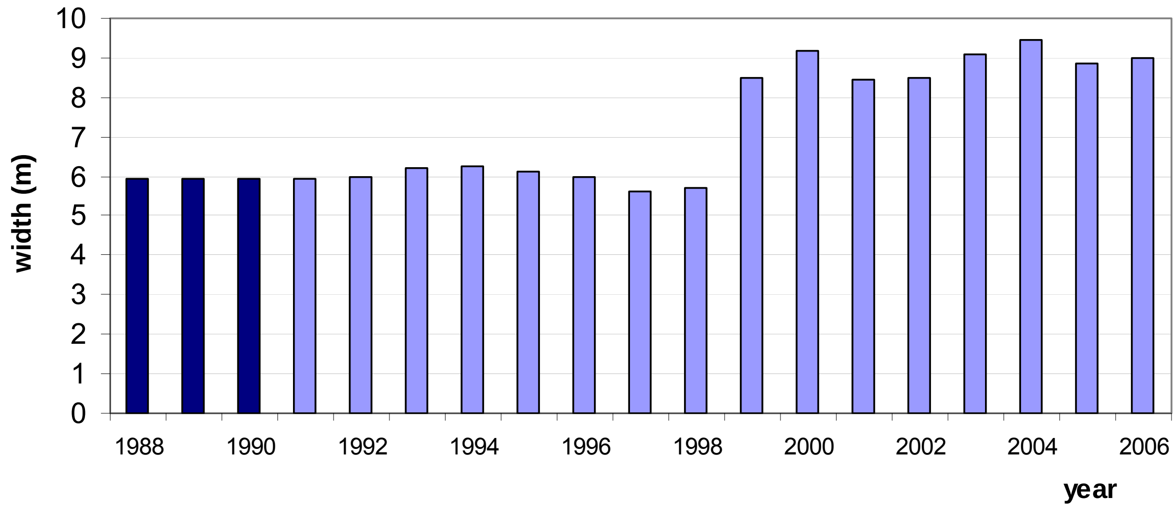


Figure 16. Average tow width determined by the SCANMAR system (1991 to 1998) and the NETMIND system (1999 to 2006). Darker bars indicate a constant mean width used in area swept calculation.

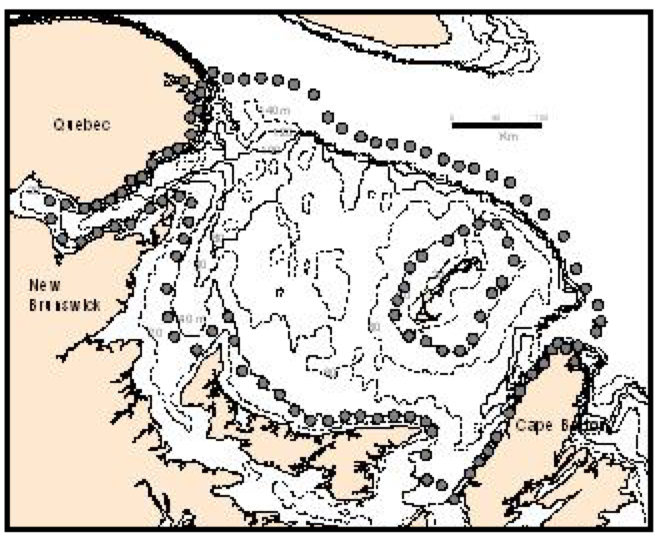


Figure 17. Location of pseudo-zeros used during the kriging analysis.

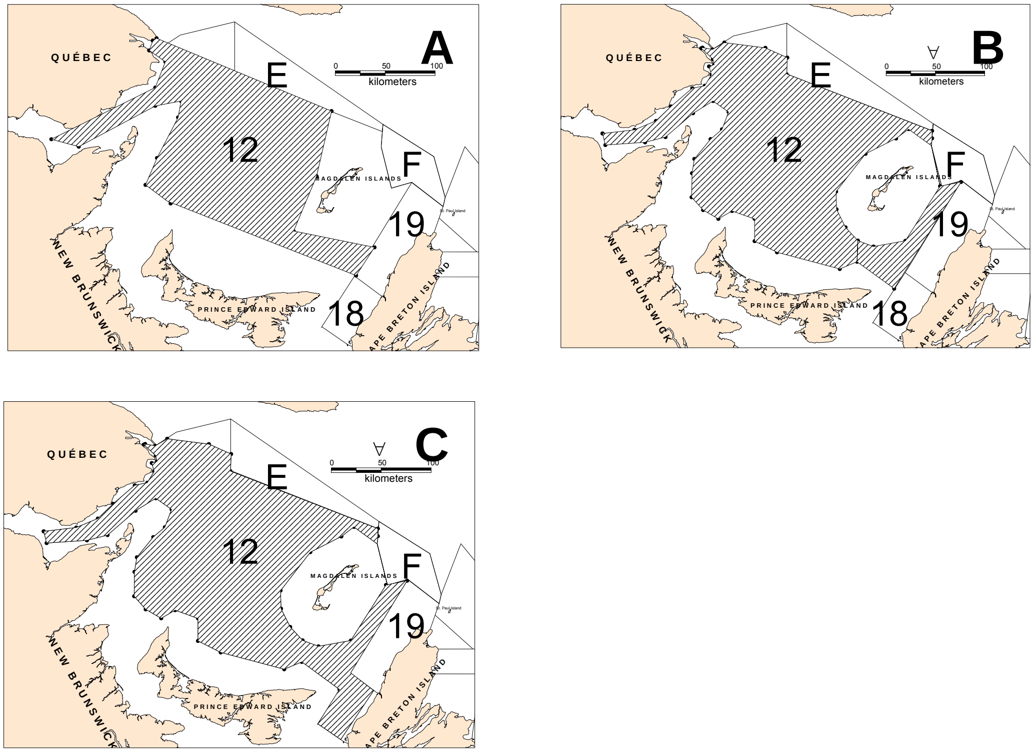


Figure 18. Kriging polygon used during the years 1988 to1997- a surface of 29,254 km^2 (A), 1998 to 2003 - a surface of 35,748 km^2 (B), and 2003 to 2006 - a surface of 37,518 km^2 (C)

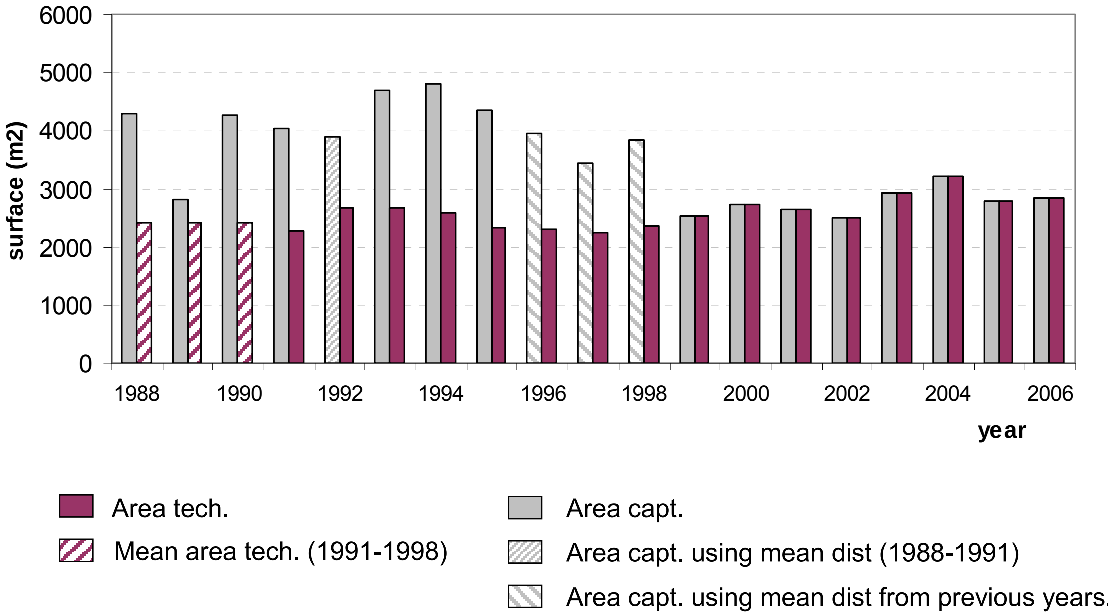


Figure 19. Average swept area (m^2) using two references – captain's logbook data (area capt) and onboard scientist's data (area tech).

APPENDIX 1

Details of changes in survey tow numbers and kriging polygone surface together with history of creation and amalgamation of crab fishing areas.

1988 and 1989:

The number of tows was 155 (122 in Area 12 and 33 in Areas25/26) covering the Areas 12 and 25/26 fisheries and the polygons used to estimate the commercial biomass in Area 12 were 29,336 and 29,345 km^2, respectively.

1990:

The survey expanded to cover Area 19, the number of tows increased to 212 (124 in Area 12, 33 in Areas 25/26 and 55 in Area 19) while the surface of polygon to estimate the abundance in Area 12 was 29,250 km^2.

1991:

The number of tows slightly increased to 215 (127 in Area 12, 33 in Areas 25/26 and 55 in Area 19). The survey polygon in Area 12 was 29,254 km^2 and remained unchanged until 1998.

1992:

The survey expanded again to cover the Area 18 fishery. The number of tows increased to reach 233 (127 in Area 12, 33 in Areas 25/26, 55 in Area 19 and 18 in Area 18).

1993:

Only 208 tows of the 233 pre-determined stations were completed (102 in Area 12, 33 in Areas 25/26, 55 in Area 19 and 18 in Area 18) due to bad weather condition, mechanical problems on the chartered vessel (Emy-Serge D.) and the installation of the new Scanmar hydrophone on this vessel.

1994 and 1995:

The number of tows increased to 262 (156 in Area 12, 33 in Areas 25/26, 55 in Area 19 and 18 in Area 18). The increase of stations in Area 12 was based on discussions at the 1995 RAP meeting concerning an edge effect of the commercial biomass observed in 1993 in peripheral areas such as Shediac Valley, Chaleur Bay and the Magdalen Channel.

1996:

The survey was not conducted in Area 12 due to a lack of funding. The survey was only conducted in Areas 18 and 19 and the number of stations was 72 (54 in Area 19 and 18 in Area 18).

1997:

The Areas 25/26 were amalgamated into Area 12. Therefore, 16 stations from a total of 33 stations in the former Areas 25/26 were re-distributed throughout Area 12 to homogeneously distribute the stations within Area 12. In addition, the survey expanded again to cover Areas E and F. The survey in Area 18 was not conducted due to a lack of funding. The number of tows was 259 and was distributed as follows: 182 in the new Area 12-25/26, 53 in Area 19, 10 in Area E and 14 in Area F.

1998:

The survey was conducted in Areas 12-25/26, 19, E and F and the number of stations increased to 278 (182 in Areas 12-25/26, 54 in Area 19, 20 in Area E and 22 in Area F). The survey in Area 18 was not conducted due to a lack of funding. The survey polygon surface for Area 12 increased to 31,696 km^2.

1999 and 2000:

The number of tows remained at 278 but the survey included all fisheries (164 stations in Areas 12-25/26, 18 stations in Area 18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F). Eighteen stations were re-distributed from Area 12 to cover Area 18. The survey polygon in Area 12 increased to 35,748 km^2 based on a re-distribution of stations (without increasing the total number of stations) within Area 12 to cover areas with contour depths at 20 fathoms. The survey polygon remained the same until 2003.

From 2001 to 2006:

The Chaleur Bay and Shediac Valley areas were the subject of much debate over the health of the reproductive stock and local over-fishing, and the addition of more stations to better monitor the abundances in these small areas was suggested at the RAP meeting. Consequently, the number of tows increased from 292 (178 stations in Area 12-25/26, 18 stations in Area 18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F) in 2001 to 321 (207 stations in Areas 12-25/26, 18 stations in Area 18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F) in 2002 to address these concerns.

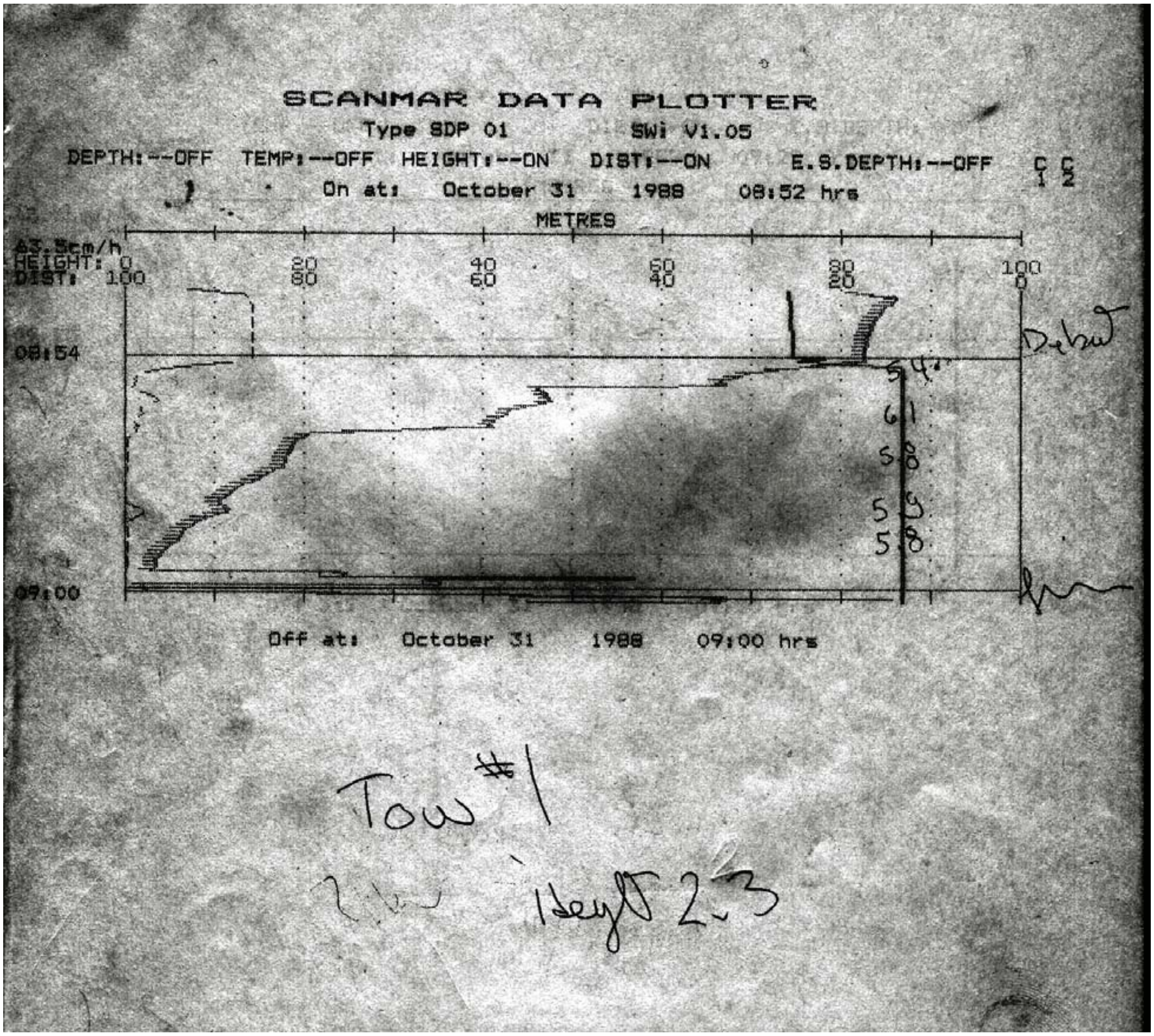
In 2003, Area 18 was amalgamated with Areas 12-25/26 and stations from Area 18 to Area 12 were re-distributed to homogeneously spread the stations within the new management area. A total of 317 stations were completed in 2003 (202 stations in Areas 12-25/26-18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F) and with the integration of Area 18 into Area 12-25/26, the survey polygon surface increased to 37,518 km^2 and has remained until 2006.

The number of stations increased from 334 (238 stations in Areas 12-25/26-18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F) in 2004 to 341 (245 stations in Areas 12-25/26-18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F) in 2005.

Following the recommendation from the Snow Crab Kriging Methodology Workshop in 2005 (DFO 2006), a more homogeneous distribution of the samples was designed in 2006 to cover all depths greater than 20 fathoms in the sGSL by redistributing of the existing 355 stations (259 stations in Areas 12-25/26-18, 54 stations in Area 19, 20 stations in Area E and 22 stations in Area F).

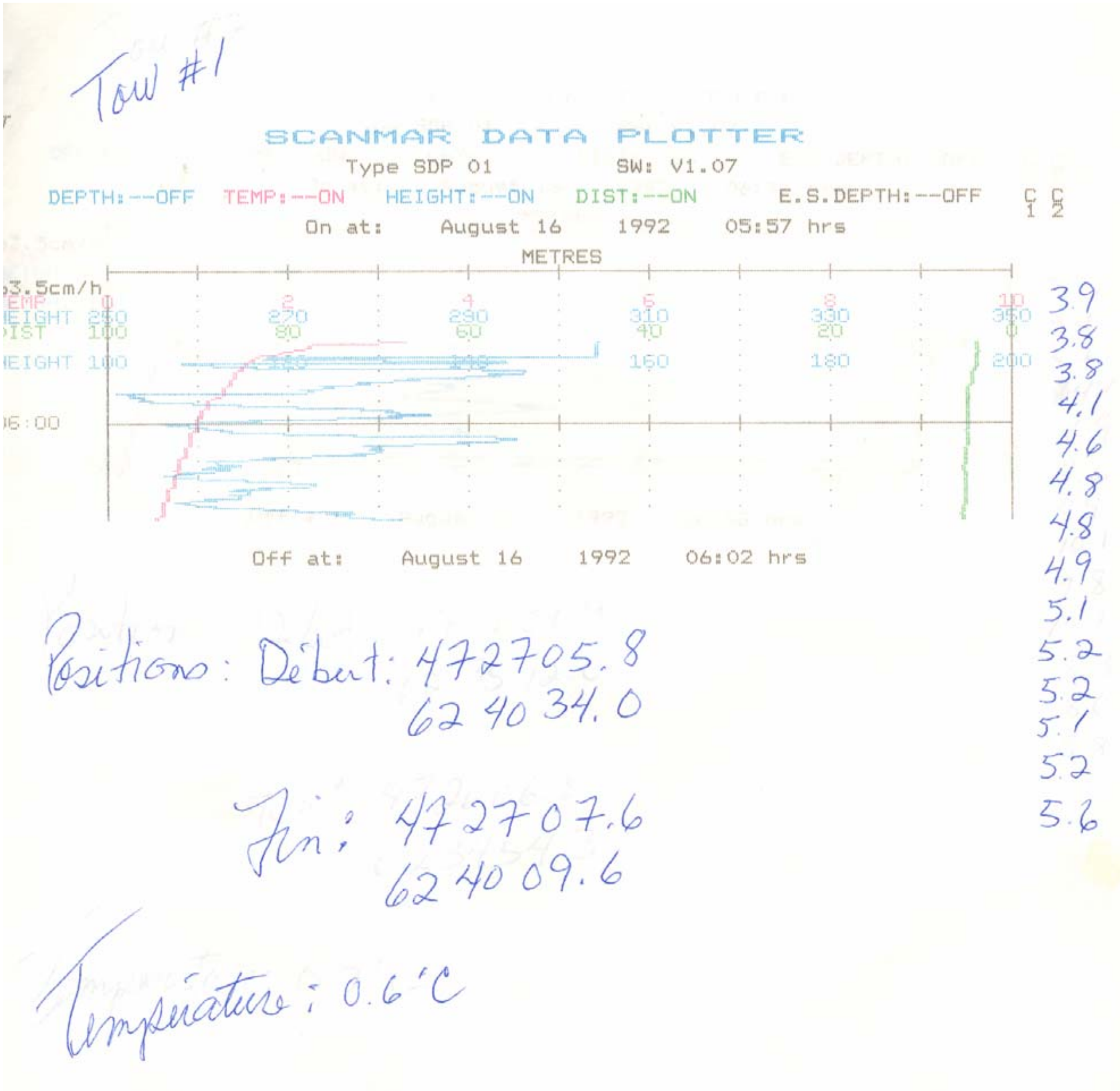
APPENDIX 2.

Scanmar® data plotter sheet (1988)



APPENDIX 3.

Scanmar data plotter sheet (1992)



APPENDIX 4.

Electronic file from Scanmar system (1995-1998).

```
"Filename: pos063.SCD"
"Date    : 1995-07-28 19:38:01"
"Format  : Normal"
"Comments: Zone 12 - Repri le trait POS062"
"YYYY MM DD""HH MM SS""  Latitude "" Longitude " "Mets""Knots"   "DI1"   "ë""?"   "CL1"   "ë""q""?"   "TO1"   "ë""?"   "CS1""?"   "TM1"   "ë""?"
"------------------------------------------------------------------------------------------------------------------------------------------------------"
"1995-07-28""19:38:01""N047:12.110""W063:05.700"   0.0   0.00    4.2   0.3"."    0.3  -9.0  4"."    2.6  0.0"."     0"?"    2.3  0.0"."" 0"
"1995-07-28""19:38:08""N047:12.290""W063:05.660" 337.3  93.62    3.9  -1.4"."    0.3  -4.0  4"."    2.6  0.0"."     0"?"    1.9  0.0"."" 0"
"1995-07-28""19:38:10""N047:12.290""W063:05.660"   0.0   0.00    3.9  -1.0"."    0.2  -3.0  4"."    2.6  0.0"."     0"?"    1.9  0.0"."" 1"
"1995-07-28""19:38:15""N047:12.290""W063:05.660"   0.0   0.00    3.8  -1.6"."    0.2  -2.0  4"."    2.6  0.0"."     0"?"    1.8  0.0"."" 0"
"1995-07-28""19:38:22""N047:12.290""W063:05.660"   0.0   0.00    3.5  -2.0"."    0.0  -2.0  4"."    2.5  0.0"."     0"?"    1.4  0.0"."" 0"
"1995-07-28""19:38:29""N047:12.290""W063:05.650"  12.6   3.49    3.4  -0.9"."    0.0  -1.0  4"."    2.5  0.0"."     0"?"    1.3  0.0"."" 0"
"1995-07-28""19:38:36""N047:12.290""W063:05.650"   0.0   0.00    3.4  -0.8"."    1.3   7.0  4"."    2.4  0.0"."     0"?"    1.0  0.0"."" 0"
"1995-07-28""19:38:43""N047:12.290""W063:05.650"   0.0   0.00    3.4  -0.7"."    3.5  10.0  4"."    2.4  0.0"."     0"?"    0.9  0.0"."" 0"
"1995-07-28""19:38:50""N047:12.300""W063:05.650"  18.5   5.14    3.4  -0.5"."    2.8  -1.0  4"."    2.4  0.0"."     0"?"    0.7  0.0"."" 0"
"1995-07-28""19:38:57""N047:12.300""W063:05.650"   0.0   0.00    3.6  -0.3"."    2.1  -4.0  2"."    2.4  0.0"."     0"?"    0.6  0.0"."" 0"
"1995-07-28""19:39:04""N047:12.300""W063:05.650"   0.0   0.00    3.9   1.1"."    1.4  -4.0  2"."    2.4  0.0"."     0"?"    0.5  0.0"."" 0"
"1995-07-28""19:39:11""N047:12.300""W063:05.650"   0.0   0.00    4.2   2.2"."    1.1  -3.0  4"."    2.4  0.0"."     0"?"    0.5  0.0"."" 0"
"1995-07-28""19:39:18""N047:12.300""W063:05.650"   0.0   0.00    4.7   2.5"."    0.6  -3.0  4"."    2.4  0.0"."     0"?"    0.4  0.0"."" 0"
"1995-07-28""19:39:25""N047:12.310""W063:05.640"  22.4   6.22    5.1   2.8"."    0.2  -3.0  4"."    2.4  0.0"."     0"?"    0.4  0.0"."" 0"
"1995-07-28""19:39:32""N047:12.310""W063:05.640"   0.0   0.00    5.6   2.9"."   -0.1  -2.0  4"."    2.3  0.0"."     0"?"    0.3  0.0"."" 0"
"1995-07-28""19:39:39""N047:12.310""W063:05.640"   0.0   0.00    5.8   2.3"."   -0.2  -2.0  4"."    2.3  0.0"."     0"?"    0.3  0.0"."" 0"
"1995-07-28""19:39:46""N047:12.320""W063:05.640"  18.5   5.14    6.1   2.3"."   -0.4  -2.0  4"."    2.1  0.0"."     0"?"    0.3  0.0"."" 0"
"1995-07-28""19:39:53""N047:12.320""W063:05.640"   0.0   0.00    6.4   2.6"."   -0.4  -2.0  3"."    2.1  0.0"."     0"?"    0.2  0.0"."" 0"
"1995-07-28""19:40:00""N047:12.320""W063:05.630"  12.6   3.49    6.7   2.1"."   -0.4  -1.0  3"."    2.0  0.0"."     0"?"    0.2  0.0"."" 0"
"1995-07-28""19:40:49""N047:12.350""W063:05.620"  22.4   6.22  998.0   0.0"."   -0.4  -1.0  1"."    1.6  0.0"."     0"?"   -0.1  0.0"."" 0"
"1995-07-28""19:40:56""N047:12.350""W063:05.620"   0.0   0.00  998.0   0.0"."   -0.4  -1.0  1"."    1.5  0.0"."     0"?"   -0.1  0.0"."" 0"
"1995-07-28""19:41:03""N047:12.350""W063:05.620"   0.0   0.00  998.0   0.0"."   -0.3  -1.0  1"."    1.4  0.0"."     0"?"   -0.1  0.0"."" 0"
"1995-07-28""19:41:10""N047:12.350""W063:05.620"   0.0   0.00  998.0   0.0"."   -0.3  -1.0  0"."    1.4  0.0"."     0"?"   -0.2  0.0"."" 0"
"1995-07-28""19:41:17""N047:12.360""W063:05.620"  18.5   5.14  998.0   0.0"."  114.4  -1.0  0"."    1.4  0.0"."     0"?"   -0.2  0.0"."" 0"
"1995-07-28""19:41:24""N047:12.360""W063:05.620"   0.0   0.00  998.0   0.0"."  118.6  16.0  0"."    1.3  0.0"."     0"?"   -0.3  0.0"."" 0"
"1995-07-28""19:41:31""N047:12.360""W063:05.620"   0.0   0.00  998.0   0.0"."  119.6  14.0  0"."    1.3  0.0"."     0"?"   -0.3  0.0"."" 0"
"1995-07-28""19:41:38""N047:12.360""W063:05.620"   0.0   0.00  998.0   0.0"."   -0.3   7.0  0"."    1.3  0.0"."     0"?"   -0.3  0.0"."" 0"
"1995-07-28""19:41:45""N047:12.370""W063:05.610"  22.4   6.22  998.0   0.0"."   -0.2   2.0  0"."    1.3  0.0"."     0"?"   -0.3  0.0"."" 0"
"1995-07-28""19:41:52""N047:12.370""W063:05.610"   0.0   0.00    9.8  -0.1"."   -0.2   0.0  0"."    1.3  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:41:59""N047:12.370""W063:05.610"   0.0   0.00    9.9   0.0"."   -0.1   0.0  0"."    1.2  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:06""N047:12.380""W063:05.610"  18.5   5.14   10.1   0.3"."   -0.1   0.0  0"."    1.2  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:13""N047:12.380""W063:05.610"   0.0   0.00    9.6  -8.6"."   -0.1   0.0  0"."    1.2  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:20""N047:12.380""W063:05.600"  12.6   3.49    5.7 -12.7"."    0.2   0.0  0"."    1.1  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:27""N047:12.380""W063:05.600"   0.0   0.00    3.5 -14.1"."    0.3   0.0  0"."    1.1  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:34""N047:12.380""W063:05.600"   0.0   0.00    2.8  -4.5"."    0.3   0.0  0"."    1.2  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:41""N047:12.380""W063:05.590"  12.6   3.49    2.6  -1.7"."    0.3   0.0  0"."    1.3  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:48""N047:12.390""W063:05.590"  18.5   5.14    2.6  -0.9"."    0.2  -1.0  0"."    1.3  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:42:55""N047:12.390""W063:05.590"   0.0   0.00    2.6  -0.7"."    0.1  -1.0  0"."    1.3  0.0"."     0"?"   -0.4  0.0"."" 0"
"1995-07-28""19:43:02""N047:12.390""W063:05.580"  12.6   3.49    2.6  -0.7"."    0.1  -1.0  0"."    1.3  0.0"."     0"?"   -0.5  0.0"."" 0"
"1995-07-28""19:43:03""N047:12.390""W063:05.580"   0.0   0.00    2.6  -0.7"."    0.1  -1.0  0"."    1.3  0.0"."     0"?"   -0.5  0.0"."" 2"
"1995-07-28""19:43:09""N047:12.390""W063:05.580"   0.0   0.00    2.5  -0.6"."    0.1  -1.0  0"."    1.3  0.0"."     0"?"   -0.5  0.0"."" 0"
"1995-07-28""19:43:14""N047:12.390""W063:05.580"   0.0   0.00    2.4  -0.7"."    0.8   2.0  0"."    1.3  0.0"."     0"?"   -0.5  0.0"."" 0"
"Straight Line Distance(DL) = ""   0.540"" Km"
"Sum of all Distances  (DS) = ""   0.597"" Km"
```

APPENDIX 5

Electronic file from Netmind system.

FileName: C:\2005NE~1\GP023.TXT
Local Time: Sun Jul 24 06:16:57 2005

Ship: Marco Michel Trip: 05 Tow: gp023
Comments: zone 12

Date	Time	Latitude			Longitude			Speed	Primary	Secondary	DoorSpread	WingSpread	Depth
050724	092308	48	21.2960	N	64	18.5340	W	2.0	3.7	2.4	6.0*	0.0	119.6*
050724	092310	48	21.2970	N	64	18.5330	W	2.3	3.7	2.4	6.0	0.0	119.6
050724	092312	48	21.2980	N	64	18.5320	W	2.2	3.7	2.4	6.9*	0.0	122.7*
050724	092314	48	21.2990	N	64	18.5310	W	2.2	3.7	2.4	6.9	0.0	122.7
050724	092316	48	21.3000	N	64	18.5300	W	1.8	3.7	2.4	6.9	0.0	122.7
050724	093058	48	21.3850	N	64	18.4140	W	0.8	2.9	10.2	4.1*	0.0	109.1
050724	093100	48	21.3840	N	64	18.4140	W	0.8	2.9	10.2	4.1	0.0	109.1
050724	093102	48	21.3840	N	64	18.4150	W	0.7	2.9	10.2	4.1	0.0	188.3*
050724	093104	48	21.3840	N	64	18.4150	W	0.7	2.9	10.2	3.2*	0.0	188.3
050724	093106	48	21.3830	N	64	18.4160	W	0.8	2.9	10.2	3.2	0.0	188.3
050724	093108	48	21.3830	N	64	18.4160	W	0.6	2.9	10.2	3.5*	0.0	38.7*
050724	093110	48	21.3830	N	64	18.4170	W	0.7	2.9	10.2	3.5	0.0	38.7
050724	093112	48	21.3820	N	64	18.4170	W	0.6	2.9	10.2	3.5	0.0	38.7
050724	093114	48	21.3820	N	64	18.4170	W	0.8	2.9	10.2	5.5*	0.0	107.3*
050724	093116	48	21.3810	N	64	18.4170	W	0.5	2.9	10.2	5.5	0.0	107.3
050724	093118	48	21.3810	N	64	18.4180	W	0.9	2.9	10.2	5.5	0.0	99.9*
050724	093120	48	21.3800	N	64	18.4180	W	0.7	2.9	10.2	0.9*	0.0	99.9
050724	093122	48	21.3800	N	64	18.4180	W	0.6	2.9	10.2	0.9	0.0	99.9
050724	093124	48	21.3800	N	64	18.4190	W	0.6	2.9	10.2	1.7*	0.0	101.2*
050724	093126	48	21.3800	N	64	18.4190	W	0.6	2.9	10.2	1.7	0.0	101.2
050724	093129	48	21.3790	N	64	18.4190	W	0.3	2.9	10.2	1.7	0.0	96.3*
050724	093131	48	21.3790	N	64	18.4190	W	0.2	2.9	10.2	10.1*	0.0	96.3
050724	093132	48	21.3790	N	64	18.4190	W	0.2	2.9	10.2	10.1	0.0	96.3
050724	093134	48	21.3790	N	64	18.4190	W	0.2	2.9	10.2	10.1	0.0	146.5*
050724	093136	48	21.3780	N	64	18.4190	W	0.1	2.9	10.2	10.1	0.0	146.5
050724	093138	48	21.3780	N	64	18.4190	W	0.2	2.9	10.2	10.1	0.0	146.5
050724	093140	48	21.3780	N	64	18.4180	W	0.3	2.9	11.9*	13.7*	0.0	119.6*
050724	093142	48	21.3790	N	64	18.4180	W	0.8	2.9	11.9	13.7	0.0	119.6
050724	093144	48	21.3790	N	64	18.4180	W	0.7	2.9	11.9	13.7	0.0	119.6
050724	093146	48	21.3790	N	64	18.4170	W	0.8	2.9	11.9	13.7	0.0	88.9*
050724	093148	48	21.3800	N	64	18.4170	W	1.0	2.9	11.9	13.7	0.0	88.9
050724	093151	48	21.3810	N	64	18.4160	W	1.2	2.9	11.9	13.7	0.0	28.2*
050724	093152	48	21.3810	N	64	18.4160	W	1.2	2.9	11.9	13.7	0.0	28.2
050724	093154	48	21.3820	N	64	18.4150	W	1.3	2.9	11.9	13.7	0.0	28.2
050724	093156	48	21.3820	N	64	18.4140	W	1.3	2.9	11.9	13.7	0.0	96.8*
050724	093158	48	21.3830	N	64	18.4130	W	1.3	2.9	11.9	13.7	0.0	96.8
050724	093201	48	21.3840	N	64	18.4130	W	1.5	2.9	11.9	11.4*	0.0	96.8
050724	093202	48	21.3840	N	64	18.4120	W	1.7	2.9	11.9	11.4	0.0	96.8
050724	093204	48	21.3850	N	64	18.4120	W	2.0	2.9	13.0*	11.4	0.0	96.8
050724	093206	48	21.3860	N	64	18.4110	W	2.1	2.9	13.0	11.4	0.0	96.8
050724	093208	48	21.3870	N	64	18.4100	W	2.4	2.9	13.0	11.4	0.0	96.8