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# Recent Studies of Lobster, (*Homarus americanus*), Size at Onset of Sexual Maturity in Nova Scotia 2008-2011: Canso, Tangier, Port Mouton and Lobster Bay - A Progress Report

# Études récentes portant sur la taille du homard (*Homarus americanus*) à l'aube de la maturité en Nouvelle-Écosse de 2008 à 2011 : Canso, Tangier, Port Mouton et Lobster Bay – Rapport d'étape

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## TABLE OF CONTENTS

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## ABSTRACT

This research document presents an update of ongoing studies of female lobster maturity research in four lobster fishing areas (LFA 31A, LFA 32, LFA 33 and LFA 34) in Nova Scotia. The main aim of this study is to provide updated information on the current status of size at onset of maturity for areas where older information existed, compare with previous evaluations and provide new information for areas where information did not exist. The main criteria to discriminate mature female lobsters was based on assessment of cement gland development in pleopods that have at least reached stage 2, and females that have eggs. Sampling of female lobsters took place during spring in fishing areas of Canso - LFA 31 (2008-2011) and Tangier - LFA 32 (2010-2011) and from late spring to summer in Port Mouton – LFA 33 (2009-2011) and in two areas within Lobster Bay - LFA 34 (2010-2011). A greater proportion of legal size lobsters (82.5 mm and larger) were sampled in Canso (51%-77%) and Tangier (69%-75%) than in southwest areas off Port Mouton (38%-40%) and Lobster Bay (24%-47%). Of all areas sampled, Canso had the highest proportion of mature female legal (82.5 mm and larger) and sub-legal (<82.5 mm) lobsters. In Canso, mature legal lobsters fluctuated from 41% to 100% for all years, where maturity was expressed earlier in the spring. Fewer mature legal lobsters were found in Tangier (38%-84%), Port Mouton (10%-59%), Lobster Bay Outside (6%-51%) and Lobster Bay Inside (12%-29%). Mature sub-legal lobsters were also most abundant in Canso (32%-92%) and had an increasing trend each season, while fewer were found in Tangier (5%-22%) with no clear trend. A smaller proportion of sub-legal mature lobsters were found in Port Mouton (0-5%), Lobster Bay Outside (0-14%) and Lobster Bay Inside (0-5%).

## RÉSUMÉ

Ce document de recherche représente une mise à jour des études en cours portant sur la maturité des homards femelles dans quatre zones de pêche du homard (ZPH 31A, ZPH 32, ZPH 33 et ZPH 34) de la Nouvelle-Écosse. Cette étude vise principalement à fournir de l'information sur l'état actuel de la taille à l'aube de la maturité des femelles, dans des zones pour lesquelles d'anciennes données existaient, à effectuer des comparaisons avec les évaluations précédentes et à fournir de nouveaux renseignements sur les zones pour lesquelles aucune information n'était disponible. Le principal critère utilisé pour distinguer les femelles matures reposait sur l'évaluation de la croissance de la glande cémentaire chez les pléopodes ayant franchi l'étape 2 et les femelles ayant des œufs. L'échantillonnage des homards femelles a eu lieu au printemps dans les zones de pêche de Canso, ZPH 31 (de 2008 à 2011), et de Tangier, ZPH 32 (de 2010 à 2011), et de la fin du printemps à l'été, à Port Mouton, ZPH 33 (de 2009 à 2011), et dans deux zones de Lobster Bay, ZPH 34 (de 2010 à 2011). Une plus grande proportion de homards de taille réglementaire (≥82,5 mm de longueur de céphalothorax) a été échantillonnée à Canso (entre 51 % et 77 %) et à Tangier (entre 69 % et 75 %) que dans les zones du sud-ouest au large de Port Mouton (entre 38 % et 40 %) et Lobster Bay (entre 24 % et 47 %). Parmi toutes les zones échantillonnées, Canso affichait la plus forte proportion de femelles matures ayant la taille réglementaire (82,5 mm et plus) et de femelles matures n'ayant pas encore la taille réglementaire (moins de 82,5 mm). À Canso, le nombre de femelles matures ayant la taille réglementaire variait entre 41 % et 100 % sur toutes les années étudiées, alors que la maturité intervenait plus tôt au printemps. Un plus petit nombre de femelles matures ayant la taille réglementaire ont été trouvées à Tangier (de 38 % à 84 %), à Port Mouton (de 10 % à 59 %), à l'extérieur de Lobster Bay (de 6 % à 51 %) et à l'intérieur de Lobster Bay (de 12 % à 29 %). Les femelles n'ayant pas encore la taille réglementaire étaient également plus abondantes à Canso (de 32 % à 92 %) et suivaient une tendance à la hausse chaque saison, mais étaient en nombre plus restreint à Tangier (de 5 % à 22 %) et ne révélaient aucune tendance évidente. On a retrouvé une plus petite proportion de femelles matures n'ayant pas encore la taille réglementaire à Port Mouton (de 0 % à 5 %), à l'extérieur de Lobster Bay (de 0 % à 14 %) et à l'intérieur de Lobster Bay (de 0 % à 5 %).

## INTRODUCTION

Knowing the size at which lobsters become sexually mature in their natural environment is important for the management of the fishery. Estimating size at maturity of lobsters requires the adoption of a standard approach for evaluating reproductive condition of non-ovigerous females prior to spawning during spring (Waddy and Aiken, 2005). Once a lobster reaches sexual maturity, it generally follows a two year cycle of maturity of the ovary changing between immature and mature states (Aiken and Waddy, 1982). When a female lobster matures for the first time, it will be expressed with extrusion of eggs, though this generally occurs during summer months when the fishery has ended. It had been 20-30 years since lobster size at maturity was evaluated in coastal Nova Scotia, until a recent evaluation by Reeves et al. (2011) that documents a recent decrease in size at maturity at a northern site off eastern Cape Breton from 2006-2008. It is not known if the size at onset of maturity has changed in recent years in other areas of Nova Scotia. Size at onset of maturity of lobster may be affected by changes in bottom temperature throughout their geographic range, but it is not known if this would affect lobsters in their natural environment in Nova Scotia. Size at onset of sexual maturity may also respond to other factors such as lobster density and fishing pressure.

This research document provides preliminary results from studies outside of Cape Breton from 2008-2011. Recent studies of sexual maturity for Canso and for some areas for which there are no published estimates are documented.

Size at onset of sexual maturity in lobsters could be assessed by monitoring sizes of ovigerous females that have already reached functional maturity; however, this method will likely result in higher estimates of size at sexual maturity because extrusion of new eggs usually occurs in summer, after the fishing season. Mature females that have not yet extruded eggs (non-ovigerous) are not detectable and are removed by the fishery before maturity is expressed. In Nova Scotia, fishing takes place during spring in areas east of Halifax, which coincides with development of maturity of ovaries in lobsters and facilitates a study of sexual maturity during the fishing season.

Extensive literature discussing best methods to determine sexual maturity in lobsters has considered morphometric relationships, development of ovary, presence of sperm plug, presence of eggs and staging of cement gland in pleopods (Aiken and Waddy, 1982; MacDiarmid, 1989; Comeau and Savoie, 2002; Comeau, 2003; Gendron et al., 2004; Little and Watson, 2005; Waddy and Aiken, 2005; Laurans et al., 2009; Emond et al., 2010). Though a careful assessment of cement gland is considered adequate to conduct a maturity assessment, it has been recommended by Waddy and Aiken (2005) that more than one criteria, and, in particular, an assessment of ovarian condition of non-ovigerous females should be used to clarify status of questionable animals. Aiken and Waddy (1982) adapted and developed a method that uses the evaluation of cement gland development that was found to correlate highly with the development of ovaries. The cement gland method has been used in many subsequent studies (Campbell and Robinson, 1983; Miller and Watson, 1991; Ugarte, 1994; Comeau, 2003; Gendron, 2003; Gendron et al., 2004; Waddy and Aiken, 2005; and, more recently, by Reeves et al., 2011). Observation of development of cement glands (tegumental glands) using a standard protocol are recognized broadly as a good indicator of ovarian maturation. The results presented in this research document are preliminary and no statistical analyses have been conducted.

# METHODS

## STUDY AREAS

Female lobsters were sampled at various times from 2008 to 2011 in four lobster fishing grounds in the province of Nova Scotia, Canada. Selected areas were Canso in LFA 31A; Tangier in LFA 32; Port Mouton in LFA 33, and two sites in Lobster Bay (Inside – near shore, and Outside - further off the coast) in LFA 34 (Figure 1). All field sampling in Canso (LFA 31A) and Tangier took place aboard volunteer fishing vessels between May and June from 2008 to 2011 in Canso, and from 2010 to 2011 in Tangier. Field sampling in Port Mouton (LFA 33) and Lobster Bay (LFA 34) took place aboard a volunteer vessel during the month of May, and on a chartered vessel at other times, from 2009 to 2011 in Port Mouton, and from 2010 to 2011 in Lobster Bay. Each area was sampled every two weeks when feasible during the spring fishing season (May to June) in areas east of Halifax (Canso and Tangier). Areas located West of Halifax (Port Mouton and Lobster Bay) were sampled only once during May during the last month of their winter-spring fishing season. All other sampling took place bi-weekly outside the fishing season from June to August.

## FIELD SAMPLING AND DATA COLLECTION

A sampling protocol to collect a single pleopod (abdominal appendage, endopodite) and eggs from female lobsters sampled during fishing activities was organized and tested in the area of Canso in 2008 aboard a volunteer lobster fishing vessel. The area of Port Mouton was added to sampling protocols in 2009. Tangier and Lobster Bay were added in 2010 after obtaining resources for training technicians and students to conduct field sampling. Sampling of female lobsters of a broad size range and condition (ovigerous and non-ovigerous) included collection of data from the first 150 to 250 females collected in traps depending on availability. Besides a clipped pleopod, data collected included location (geographical position with GPS), carapace length (CL) measured to 0.1 mm, and whether or not the female had eggs. Trap by trap information and other biological information (shell hardness, egg condition, cull) was collected whenever feasible. The clipped pleopod (right side abdominal appendage, endopodite) from each sampled female lobster was kept in individual glass vials filled with cold sea water at 4ºC and kept in coolers for 24-48 hours, until analysis in the laboratory. If females were carrying eggs, a small sample of eggs (20-40), were also collected and kept to later determine stage of egg development. All lobsters were unharmed and promptly returned to the water after sampling if sub-legal (of size smaller that minimum legal size) and/or if ovigerous (berried). If lobsters were of commercial size and not ovigerous, these were placed in lobster crates with running sea water, as these would be part of the harvest during the fishing season. All lobsters sampled outside the fishing season in Port Mouton and Lobster Bay were returned to the water immediately after sampling. All collected pleopod samples were transported to the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, and evaluation of maturity took place within 48 hours in the laboratory. Field samples from Canso were obtained by Fisheries and Oceans (DFO) personnel and summer interns from the Guysborough County Inshore Fishermen Association (GCIFA). Field samples in Port Mouton were collected by DFO personnel. Field samples from Tangier and Lobster Bay were obtained by interns from Fishermen and Scientists Research Society (FSRS) under the direction of a DFO researcher.

## LABORATORY ANALYSIS

Evaluation of cement gland stages for each pleopod was conducted by A. Silva using an Olympus Stereoscope, and followed an earlier description of cement gland staging developed by Aiken and Waddy (1982) for non-ovigerous females. If development of cement glands was

taking place, there were 4 cement gland stages that could be identified, from stage 1 with minimum development to stage 4, in which the entire area within the pleopod is covered with a white cement gland of granular appearance indicative of imminent extrusion of eggs. In addition, a stage zero (0) was assigned when no evidence of cement gland development was observed, and in the case of ovigerous females, a stage 5 was assigned when remnants of cement glands were observed that appeared mostly degenerating. Some organization of cement glands was observed in some larger specimens, but these were rare and are not included in this document. Criteria used to discriminate between mature and immature lobsters was that when cement gland development was at stage 2 (CGS 2) or greater, it was mature, and this can be used as an indicator that egg extrusion will take place during the current season if there is no evidence of molting to occur in the same season. Immature lobsters did not have observable activity of cement glands or they were at stage 1. Assessment of cement gland development in the laboratory was feasible when samples were kept in good condition at low temperature at about 4ºC for up to 48 hours after sampling. A photographic record of most pleopods was kept to ensure consistency with staging of cement glands. An evaluation of presence/absence of moulting activity was evaluated from 2009 to 2011 along with the maturity staging. An assessment of ovarian development stage and cement gland activity for lobsters form Canso (LFA 31A) was conducted on a small sample of lobsters during June 2009 and June 2011 to confirm maturity evaluated by cement gland development.

## RESULTS

A total of 11,755 female lobsters were sampled from the areas of Canso (LFA 31A), Tangier (LFA 32), Port Mouton (LFA 33), and Lobster Bay (LFA 34) (Figure 1, Table 1).

Overall, a total of 59 field samples were collected between May 28, 2008, and August 24, 2011, for all locations. The areas of Canso and Tangier, located east of Halifax (Nova Scotia), were sampled within the regular spring lobster fishing season for a total of 24 sampling events. Canso was sampled 17 times between May and June of each year from 2008 to 2011, while Tangier (LFA 32) was sampled 7 times between May and June of each year from 2010 to 2011 (Table 1). The areas of Port Mouton and Lobster Bay were sampled 35 times, but only once during the month of May of each year, which corresponded to the last month of the fishing season for these areas, all other samples were collected outside the fishing season using chartered vessels. The area of Port Mouton was sampled 15 times between May and July of each year from 2009 to 2011. The area of Lobster Bay was sampled between May and July of 2010 and from May to August in 2011. There were two sampling areas, an “Inside” or near-shore area, and an “Outside” or more-offshore area. The Outside area was sampled 11 times in two years and included the only samples collected in the month of May at the end of the fishing season. The Inside area was sampled 9 times between June and August (Table 1).

All field samples were collected within the same generalized fishing area as shown for Canso (Figure 2), Tangier (Figure 3), Port Mouton (Figure 4), and Lobster Bay (Figure 5). The overall range of carapace length (CL) of female lobsters sampled fluctuated between the smallest at 46.5 mm found in Port Mouton (2010) to the largest of 175 mm sampled in Lobster Bay Outside (2011) (Table 2). The overall smallest ovigerous females were found in 2011 in Canso (66.1 mm) and Tangier (69.3 mm). The smallest ovigerous females for other areas were much larger at 77.6 mm (Port Mouton, 2010) and 73.3 mm (Lobster Bay, 2011). The smallest lobsters observed to have reached sexual maturity as identified by stage 2 of cement gland development, were also detected in 2011 in Canso (67.3 mm) and Tangier (73.1 mm). Sexual maturity by reaching stage 2 of cement gland development was also observed in Port Mouton and Lobster Bay lobsters, but these were slightly larger (6-7 mm) lobsters than those observed

east of Halifax, with the smallest mature female (CGS 2) for the areas of Port Mouton (2009) and Lobster Bay (Inside - 2011) detected at 74.1 mm and at 73.3 mm, respectively.

**CANSO**

A total of 3,007 individual female lobsters were sampled from 2008 to 2011 aboard volunteer fishing vessels and, on average, 63% were of legal size and 37% sub-legal lobsters (Table 1). The generalized area of sampling varied slightly from year to year, but it remained within the allocated fishing grounds (Figure 2). Of all sampled areas, ovigerous females were most common in Canso, where on average they made up between 20% (2008) to 35% (2009) of all lobsters sampled. The overall range of lobster CL varied from the smallest of 49.2 mm (2011) to 56.8 mm (2009) to the largest size sampled that fluctuated between 127.8 (2009) to 148.5 mm (2008) (Table 2).

The average lobster CL fluctuated between 83.8 mm (June 26, 2008) and 91.4 mm (May 18, 2011) (Table 3). The size frequency of all female lobsters sampled in Canso from 2008 to 2011, along with assessed cement gland staging, are shown in Figures 6a, b, c, and d. As the season progressed each year, Canso sampled lobsters decreased in size and the proportion of ovigerous females increased.

A comparison of the proportion of lobsters that were sexually mature for each sampling date was made by combining all ovigerous females and all those deemed mature (CGS 2 and greater) within the categories of sub-legal and legal lobsters (Table 3). Canso sub-legal lobsters had the highest estimated level of maturity of any other location sampled in this study, fluctuating between 32% (May 20, 2009) and 92% (June 1, 2011) (Table 3). Overall, sexual maturity of sub-legal lobsters in Canso had an increasing trend from 2008 to 2011, as fewer sub-legal were estimated mature in 2008 (37% to 69%) than in 2011 (75% to 82%). Most legal size lobsters sampled in Canso were at least 80% mature at any given time, though there was one instance in which only 41% were mature at the beginning of 2010 (Table 3). In the most recent year sampled, 97% to 100% were mature.

**TANGIER**

A total of 1,390 female lobsters were sampled in Tangier during the fishing season, and while fishing was taking place during May and June of each year from 2010 to 2011 (Table 1) aboard a volunteer fishing vessel. The generalized area of sampling varied slightly from year to year, but it remained within the allocated fishing grounds (Figure 3). Completion of a total of 7 field sampling events allowed collection of information from 1,390 female lobsters; most of these, 69% (2010) and 64% (2011), were lobster legal (market size or larger), and 31% and 37% were sub-legal for the same years (Table 1). Of all sampled areas, the area of Tangier had the second highest representation of ovigerous female lobsters after Canso, and it did fluctuate from 25% (2010) to 17% (2011) of all lobsters sampled at this location. The range of lobster CL varied from the smallest of 49.9 mm (2011) to the largest measured from all areas sampled of 151 mm (2011) (Table 2).

The smallest size of mature female lobsters for the period 2010 to 2011 in Tangier corresponded to lobsters found at 76.4 mm (2010) and 73.1 mm (2011) that have reached a CGS stage 2. The smallest ovigerous females and therefore sexually mature lobsters were detected within a similar size range to cement gland development and corresponded to 72.6 mm (2010) and 69.3 mm (2011) (Table 2).

The average lobster CL fluctuated between 84.5 mm (June 4, 2011) and 90.6 mm (June 16, 2010, and May 17, 2011) (Table 4). Distribution of lobster size (CL) frequency of all female lobsters sampled in Tangier areas is shown in Figures 7a and b (2010, 2011). Immature females within each size interval are shown as white or no colour, and all mature individuals are depicted as blue if mature according to CGS development, and red if they were ovigerous. The area of Tangier has been sampled for only two years, and it appears that only a few lobsters that are smaller than minimum legal size (sub-legal) reach sexual maturity during this period (up to 20% in June 16, 2010, and May 3, 2011), while a great number of those at legal size and larger are found mature above 68%, a lower level of maturity of 38% of all legal was found once in May 19, 2010.

A comparison of the proportion of lobsters that were found sexually mature within the categories of sub-legal and legal lobsters for each sampling date was made after combining all ovigerous females and all those deemed mature at stage 2-4 (cement development) within each category. Overall, sexual maturity of sub-legal lobsters in Tangier was low in comparison to Canso (it does not show a clear trend of maturity over the period of 2010 to 2011), and fluctuated from 5% (May 19, 2010) to 22% (May 3, 2011). Legal female lobsters in Tangier were consistently found to have reached sexual maturity in greater proportion with a similar trend to Canso. When combined sexual maturity (CGS 2-4 and ovigerous) was estimated, it was found to fluctuate between 38% (May 19) to 84% (June 16) in 2010 and between 68% (May 3) to 82% (June 17) in 2011, suggesting an increasing trend.

**PORT MOUTON**

Female lobsters were sampled in Port Mouton during fishing activities in the month of May and outside the fishing season during June and July of each year from 2009 to 2011 (Table 1). The generalized area of sampling varied only slightly from year to year, but it remained within the allocated fishing grounds (Figure 4). Completion of a total of 15 field sampling events allowed collection of information from 2,714 female lobsters. On average, 61% of all sampled lobsters corresponded to legal size lobsters (Table 1) and 39% were sub-legal. The range of lobster CL length varied from 46.5 mm (2010), the smallest sampled at any location, to the largest of 171 mm (2010) (Table 2). The average lobster CL fluctuated between 79.7 mm (May 25, 2011) and 85.8 mm (May 26, 2010) (Table 5) and the size frequency distribution of lobster size (CL) for all individual sampling events for Port Mouton are shown in Figures 8a, b, and c, which clearly depicts that the level of maturity among sub-legal was insignificant (< 5%). Maturity of legal size lobsters varied greatly from 10% to 59%, though mostly below 36%. In general, fewer mature lobsters were found in this area and those were mostly larger than 85 mm.

The presence of ovigerous females was among the lowest in Port Mouton and fluctuated between 2% to 3% of all lobsters sampled at this location. The smallest mature female lobster for the period 2009 to 2011, on the basis of cement gland development was found at 74.1 mm (2009), and the smallest ovigerous female was detected at 77.6 mm (2010) (Table 2).

**LOBSTER BAY**

Female lobsters were sampled in two areas of Lobster Bay during fishing activities in the month of May aboard a volunteer lobster fishing vessel and from June to July (2010, 2011) or August (2011) aboard a chartered vessel (Table 1). The generalized area of sampling varied slightly from year to year, but it remained within the allocated fishing grounds (Figure 5). Completion of a total of 20 field sampling events allowed collection of information from 4,644 female lobsters, where 56% were obtained from 11 sampling events in the Lobster Bay-Outside area and 44% were obtained from 9 sampling events in the Lobster Bay-Inside area. On average, sub-legal

lobsters composed 75% of all sampled lobsters in 2010 and 54% in 2011, with only 25% and 46% of lobsters of legal size for each respective year (Table 1). Presence of ovigerous females was generally very low representing between 2% to 8% of all sampled in the area. The range of lobster CL varied from the smallest of 52.3 mm (2011 - Lobster Bay - Outside) to the largest of 175 mm (2011 - Lobster Bay - Outside) (Table 2).

The smallest mature female lobsters for the period 2010 to 2011 on the basis of cement gland development were found in Lobster Bay at 73.3 mm (2011 - Lobster Bay - Inside) and at 77.3 mm (2011 - Lobster Bay - Outside), because they had reached a stage 2 CGS. The smallest ovigerous females and therefore sexually mature lobsters corresponded to 83.7 mm (2011 – Lobster Bay - Inside) and 80 mm (2011 - Lobster Bay - Outside) (Table 2). The average lobster CL fluctuated between 77 mm (May 26, 2011 – Lobster Bay - Outside) and 96.6 mm (July 26, 2011) (Table 6). Distribution of lobster size (CL) frequency of all female lobsters sampled in Lobster Bay areas are shown in Figures 9a and b for Lobster Bay - Outside area and Figures 10a and b for Lobster Bay - Inside area, which clearly depicts that mature lobsters were mostly larger than 80 mm.

A comparison of the proportion of lobsters that were found sexually mature within the categories of sub-legal and legal for each sampling date was made after combining all ovigerous females and all those deemed mature at stage 2-4 (cement development) within each category. Lobster Bay pre-recruit lobsters had the lowest estimated level of maturity of any other location sampled in this study, and it did fluctuated between 0% to 14% (July 20, 2011) of all sub-legal lobsters (Table 6) with no clear trend. A smaller proportion of legal size female lobsters were found sexually mature in Lobster Bay, appearing to fluctuate between as low as 6% (June 10, 2010) to a maximum recorded of 51% (July 20, 2011) in Lobster Bay Outside area, and between 12% (July 6, 2010) to 29% (June 22, 2011) in Lobster Bay Inside area.

## DISCUSSION AND FUTURE DIRECTION

This study has established a baseline for the study of lobster maturity by using a standard protocol for the areas of Canso (LFA 31A), Tangier (LFA 32), Port Mouton (LFA 33), and Lobster Bay (LFA 34) in Nova Scotia.

Though the intention was to sample all locations every two weeks, there was some variability due to weather and logistics. The locations where samples were collected were not fixed, but they were generally obtained within the vicinity of areas previously sampled. Variability of lobster size frequencies and the increasing numbers of ovigerous females over the season may be due in part to differences between dates and sample location. This should be further investigated.

Among the four areas, Canso had the largest number of: (i) mature females of all sizes as per cement gland development in May and June of each year; (ii) ovigerous females at all times, (iii) sub-legal ovigerous females, and iv) mature sub-legal females as per cement gland development. The smallest mature females were found in 2011 (CGS 2 = 67.3 mm; Min ovigerous = 66.1 mm) in Canso. From 2008 to 2011, there was a clear trend of higher percentages of maturity, though the reasons for this apparent increase are unknown.

Tangier was sampled in 2010 and 2011, and maturity estimates indicate that fewer sub-legal (5%-22%) reach maturity in this area than in Canso. As no sampling took place outside the fishing season, it is not possible to determine whether some sub-legal expressed maturity later in the summer, or if they simply do not mature at all until they reach larger sizes. This could be

discerned through assessment of ovarian development, along staging of cement gland. Though a great number of legal lobsters (38%-82%) were found mature as the season progressed each year suggesting an increasing trend over time, verifying ovarian development for legal size lobsters could also be considered in the future and will be important to determine size at onset of maturity. With only two years of sampling in Tangier, it is not possible to draw firm conclusions about sexual maturity for sub-legal and legal lobsters; however, the information collected is most useful to set up a baseline to determine size at onset of maturity. It seems that lobsters in Tangier are reaching maturity at a slightly larger size (CL) than in Canso, but at smaller sizes than other southwest areas.

Lowest maturity of sub-legal lobsters was observed in Port Mouton and Lobster Bay, where sub-legal lobsters were most abundant in samples (range of 36% to 92% for all). A maximum of 5% of sub-legal lobsters were found mature in Port Mouton and 14% in Lobster Bay (Outside, 2011). Fewer legal lobsters in Port Mouton and Lobster Bay were ovigerous or had cement stages at CGS 2 or greater. Most samples in Port Mouton and Lobster Bay were collected after the fishing season ended and may be the reason of finding mostly sub-legal lobsters. Verification of ovarian maturity could be necessary for these areas for both sub-legal and legal lobsters to clarify maturity status as it has been recommended for situations of uncertainty (Waddy and Aiken, 2005).

Ugarte (1994) sampled lobsters in Canso in 1992 and determined that size at onset of maturity of lobsters was different for shallower inner areas (76 mm) than those from deeper areas (99 mm), and that 50% would have reached maturity at these sizes. The same study provided an overall size at onset of maturity of 83 mm and also found that ovigerous lobsters were moving from deeper to shallow areas in 1992. By assessing maturity on the basis of cement gland development and presence of ovigerous females more legal and sub-legal lobsters that were mature were detected as the season progressed (Figure 11). It would be useful to monitor lobster maturity in the long term off Canso to compare with findings from southwest areas, and to better understand how lobster reproductive processes may be affected by environmental changes.

Intensive sampling over the last four years indicates that the cement gland development method is feasible for inferring status of sexual mature lobsters. Verification of maturity of ovaries from Canso was conducted during June in 2009 and 2011 and confirmed that cement glands are a good indicator of ovarian maturation for this area. Additional verification that lobsters deemed mature were not moulting was also carried out. Maturity is occurring at smaller sizes in Canso than areas further to the west. The reasons are not clear but may be related to differences in the seasonal temperature regime.

Examination of variability in size-maturity relationships across years and areas in Cape Breton areas (Reeves et al., 2011) suggest that studies should be conducted for at least three years at any given location. Statistical analysis of lobster maturity data for all areas of Canso, Tangier, Port Mouton and Lobster Bay will help elucidate the spatial and temporal scale of variability and relationships between lobster maturity and lobster size, sampling date and year. The potential effect of fine-scale distribution of animals on size at maturity should be investigated. Lobsters from northeast areas have been detected mature earlier in the season and at smaller sizes, it is therefore important to incorporate temperature data in future analyses to assess the effect of changes in the physical environment on lobster maturity for these areas.

## ACKNOWLEDGEMENTS

We thank the many lobster fishermen from Nova Scotia that helped us to collect information in the field during the fishing season in Canso, Tangier, Port Mouton and Lobster Bay, as well as outside the fishing season in Port Mouton and Lobster Bay. In particular, we thank Mr. P. Richardson, Mr. K. Snow, Mr. B. Dobson, Mr. G. Boutilier, Mr. P. Burgess, and Mr. A. Spinney. Special thanks to field technicians from GCIFA that provided valuable support in the field: Catherine Newell, Miles Jackson, Danielle Parker and Sara Delorey. Ginny Boudreau greatly contributed essential logistics. FSRS field technicians provided valuable support in Tangier and Lobster Bay, as well as organizing samples in the laboratory: Jeanna Fletcher; Trish Pearo, Shaun Allan. Shannon Scott-Tibbetts and Patricia King provided essential logistic support. Many thanks to all DFO technical expertise provided by Alan Reeves, the late Stephen Nolan, Cheryl Denton, Shelley Armsworthy and Manon Cassista-Da Ros. Thanks to Keegan McGrath for help with data entering, and patience with checking and clarifying entries and producing data summaries and tables. We also thank Meade Humble, Rachel Chudnow and Charles Krishnamoorthy that were either students or interns and provided help during the preparation of materials for field sampling and in the laboratory. This research has been carried out with funding from DFO Science Branch, Maritimes Region, and the most recent expansion to include Tangier and Port Mouton was possible with two sources of funding, DFO to scientific personnel participation and the provincial Nova Scotia Department of Fisheries and Aquaculture support for FSRS participation.

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*Table 1. Summary of field sampling information 2008-2011 by lobster fishing area (LFA). Total number of female lobsters sampled (N total) (ovigerous/berried and non-ovigerous), total number of sub-legal (N<MLS – smaller than Minimum Legal Size of 82.5 mm) and total number of ovigerous/berried (N ovig).*

| LFA | AREA | YEAR | May | June | July | Aug | N total | N <MLS | N ovig |
|---|---|---|---|---|---|---|---|---|---|
| **31A** | **Canso** | 2008 | 28 | 5, 18, 26 | - | - | 721 | 315 | 147 |
| | **Canso** | 2009 | 20 | 2,16, 23 | - | - | 665 | 329 | 235 |
| | **Canso** | 2010 | 19,30 | 22, 28 | - | - | 677 | 267 | 170 |
| | **Canso** | 2011 | 3, 18 | 1, 21,27 | - | - | 944 | 214 | 253 |
| **32** | **Tangier** | 2010 | 19 | 1,16 | - | - | 526 | 161 | 130 |
| | **Tangier** | 2011 | 3, 17 | 4,17 | - | - | 864 | 314 | 148 |
| **33** | **Port Mouton** | 2009 | 27 | 9, 24 | 6 | - | 859 | 512 | 21 |
| | **Port Mouton** | 2010 | 26 | 9, 22, 29 | 14,21 | - | 886 | 550 | 26 |
| | **Port Mouton** | 2011 | 25 | 7,21 | 4, 25 | - | 969 | 585 | 24 |
| **34** | **Lob Bay Outside** | 2010 | 25 | 10, 22 | 5,20 | - | 1258 | 933 | 52 |
| | **Lob Bay Outside** | 2011 | 26 | 8, 21 | 4,20 | 23 | 1335 | 726 | 112 |
| **34** | **Lob Bay Inside** | 2010 | - | 11, 23 | 6,21 | - | 998 | 758 | 17 |
| | **Lob Bay Inside** | 2011 | | 9,22 | 5,21 | 24 | 1053 | 564 | 51 |

*Table 2. Comparison of lobster size (CL) range (Minimum CL and Maximum CL) and size of smallest mature lobsters when ovigerous (Minimum CL ovigerous) and at stage 2 of cement gland development (Min CL CGS2) from areas of Canso, Tangier, Port Mouton and Lobster Bay.*

| Year | AREA | Minimum CL (mm) | Maximum CL (mm) | Min CL(mm) Ovigerous | Min CL(mm) CGS 2 |
|---|---|---|---|---|---|
| **2008** | **Canso** | 55.1 | 148.5 | 71.1 | 67.8 |
| 2009 | **Canso** | 56.8 | 127.8 | 67.4 | 71.1 |
| 2010 | **Canso** | 53.2 | 132.0 | 70.2 | 70.3 |
| 2011 | **Canso** | 49.2 | 146.8 | 66.1 | 67.3 |
| **2010** | **Tangier** | 54.1 | 125.7 | 72.6 | 76.4 |
| 2011 | **Tangier** | 49.9 | 151.0 | 69.3 | 73.1 |
| **2009** | **Port Mouton** | 51.0 | 128.5 | 91.0 | 74.1 |
| 2010 | **Port Mouton** | 46.5 | 171.0 | 77.6 | 82.0 |
| 2011 | **Port Mouton** | 49.7 | 126.7 | 89.8 | 79.0 |
| **2010** | **Lob Bay Outside** | 57.8 | 168.3 | 88.0 | 79.4 |
| 2011 | **Lob Bay Outside** | 52.3 | 175.0 | 80.0 | 77.3 |
| **2010** | **Lob Bay Inside** | 65.3 | 136.4 | 88.0 | 75.3 |
| 2011 | **Lob Bay Inside** | 62.0 | 163.2 | 83.7 | 73.3 |

*Table 3. Canso 2008-2011. Summary of lobster maturity data for Canso for each sampled date, and includes number of female lobsters (N all), average carapace length (CL ± sd) and percentage (%) of mature legal and sub-legal lobsters mature lobsters are those with cement gland stages 2-4 and those that have eggs (ovigerous).*

| CANSO | Sample date | N all | Average All CL (mm)± sd | % Mature legal | % Mature sub-legal |
|---|---|---|---|---|---|
| **2008** | May 28 | 172 | 86.1± 8.3 | 85 | 69 |
| | June 5 | 186 | 84.6± 8.6 | 88 | 60 |
| | June 18 | 216 | 83.2±11.4 | 96 | 57 |
| | June 26 | 147 | 83.8±10.1 | 89 | 37 |
| **2009** | May 20 | 265 | 84.5± 9.5 | 79 | 32 |
| | June 2 | 191 | 84.5± 8.5 | 82 | 48 |
| | June 16 | 62 | 85.9± 8.0 | 100 | 75 |
| | June 23 | 147 | 86.5± 9.6 | 100 | 85 |
| **2010** | May 19 | 212 | 85.6± 9.6 | 41 | 33 |
| | May 30 | 165 | 86.4 ±10.3 | 96 | 65 |
| | June 22 | 144 | 84.8 ±11.7 | 99 | 63 |
| | June 28 | 156 | 88.5± 10.0 | 98 | 79 |
| **2011** | May 3 | 170 | 88.9± 7.7 | 98 | 80 |
| | May 18 | 173 | 91.4 ±10.8 | 99 | 81 |
| | June 01 | 264 | 91.5 ±11.1 | 97 | 92 |
| | June 21 | 169 | 89.4± 10.3 | 98 | 86 |
| | June 27 | 168 | 89.3± 13.3 | 100 | 75 |

*Table 4. Tangier 2010-2011. Summary of lobster maturity data for Tangier for each sampled date, and includes number of female lobsters (N all), average carapace length (CL ± sd) and percentage (%) of mature legal and sub-legal lobsters mature lobsters are those with cement gland stages 2-4 and those that have eggs (ovigerous).*

| Tangier | Sample date | N all | Average All CL (mm)± sd | % Mature legal | % Mature sub-legal |
|---|---|---|---|---|---|
| **2010** | May 19 | 189 | 89.6± 11.8 | 38 | 5 |
| | June 1 | 175 | 88.3 ±12.5 | 73 | 18 |
| | June 16 | 162 | 90.6± 10.3 | 84 | 20 |
| **2011** | May 3 | 194 | 88.5 ±14.4 | 68 | 22 |
| | May 17 | 259 | 90.6± 11.9 | 74 | 10 |
| | June 4 | 210 | 84.5 ±13.3 | 75 | 10 |
| | June 17 | 201 | 87.7 ±14.9 | 82 | 6 |

*Table 5. Port Mouton 2009-2011. Summary of lobster maturity data for Port Mouton for each sampled date, and includes number of female lobsters (N all), average carapace length (CL ± sd) and percentage (%) of mature legal and sub-legal lobsters mature lobsters are those with cement gland stages 2-4 and those that have eggs (ovigerous).*

| Port Mouton | Sample date | N all | Average All CL (mm)± sd | % Mature legal | % Mature sub-legal |
|---|---|---|---|---|---|
| **2009** | May 27 | 198 | 83.1 ±11.8 | 59 | 1 |
| | June 9 | 193 | 81.9± 11.2 | 35 | 3 |
| | June 24 | 191 | 81.7± 9.5 | 23 | 5 |
| | July6 | 277 | 83.8± 9.2 | 24 | 5 |
| **2010** | May 26 | 171 | 85.8 ±11.2 | 26 | 0 |
| | June 9 | 129 | 78.6± 9.8 | 29 | 0 |
| | June 22 | 233 | 81.3 ±10.9 | 33 | 1 |
| | June 29 | 134 | 79.9 ±10.5 | 30 | 2 |
| | July 14 | 94 | 80± 8.6 | 10 | 0 |
| | July 21 | 125 | 81.9 ±11 | 29 | 1 |
| **2011** | May 25 | 200 | 79.7 ±8.7 | 32 | 5 |
| | June 7 | 111 | 80.5±11.7 | 36 | 0 |
| | June 21 | 232 | 80.9 ±10.2 | 23 | 0 |
| | July 4 | 239 | 80.6 ±10.7 | 36 | 1 |
| | July 25 | 187 | 82.4±10.2 | 18 | 0 |

*Table 6. Lobster Bay 2010-2011. Summary of lobster maturity data for Lobster Bay two locations (Outside and Inside) for each sampled date, and includes number of female lobsters (N all), average carapace length (CL ± sd) and percentage (%) of mature legal and sub-legal lobsters mature lobsters are those with cement gland stages 2-4 and those that have eggs (ovigerous).*

| Lobster Bay | Sample date | N all | Average CL (mm) ± sd | % Mature legal | % Mature sub-legal |
|---|---|---|---|---|---|
| **2010–Outside** | May 25 | 260 | 83.8 ± 10 | 29 | 0 |
| | June 10 | 249 | 79.5 ± 5.2 | 6 | 2 |
| | June 22 | 251 | 78.9 ± 5.1 | 26 | 0 |
| | July 5 | 248 | 83.9 ± 9.9 | 35 | 2 |
| | July 20 | 250 | 86.1 ± 12.1 | 32 | 1 |
| **2011-Outside** | May 26 | 261 | 77 ±12.1 | 39 | 1 |
| | June 8 | 226 | 80.2 ± 7.4 | 24 | 2 |
| | June 21 | 211 | 82.8 ± 10.7 | 36 | 1 |
| | July 4 | 208 | 85.9 ± 11.5 | 39 | 2 |
| | July 20 | 225 | 96.6±18.0 | 51 | 14 |
| | August 23 | 204 | 92.0±14.9 | 16 | 0 |
| **2010-Inside** | June 11 | 249 | 79.7 ± 7.3 | 22 | 0 |
| | June 23 | 253 | 79.3 ± 5.2 | 18 | 0 |
| | July 6 | 246 | 80.8 ± 6 | 12 | 1 |
| | July 21 | 250 | 83.2 ± 9 | 14 | 1 |
| **2011-Inside** | June 9 | 207 | 77.8 ± 8 | 13 | 2 |
| | June 22 | 206 | 80.3 ± 8.6 | 29 | 2 |
| | July 5 | 225 | 86.3 ± 8.9 | 19 | 4 |
| | July 21 | 204 | 91.4±14.1 | 18 | 5 |
| | August 24 | 211 | 88.4±11.4 | 28 | 3 |

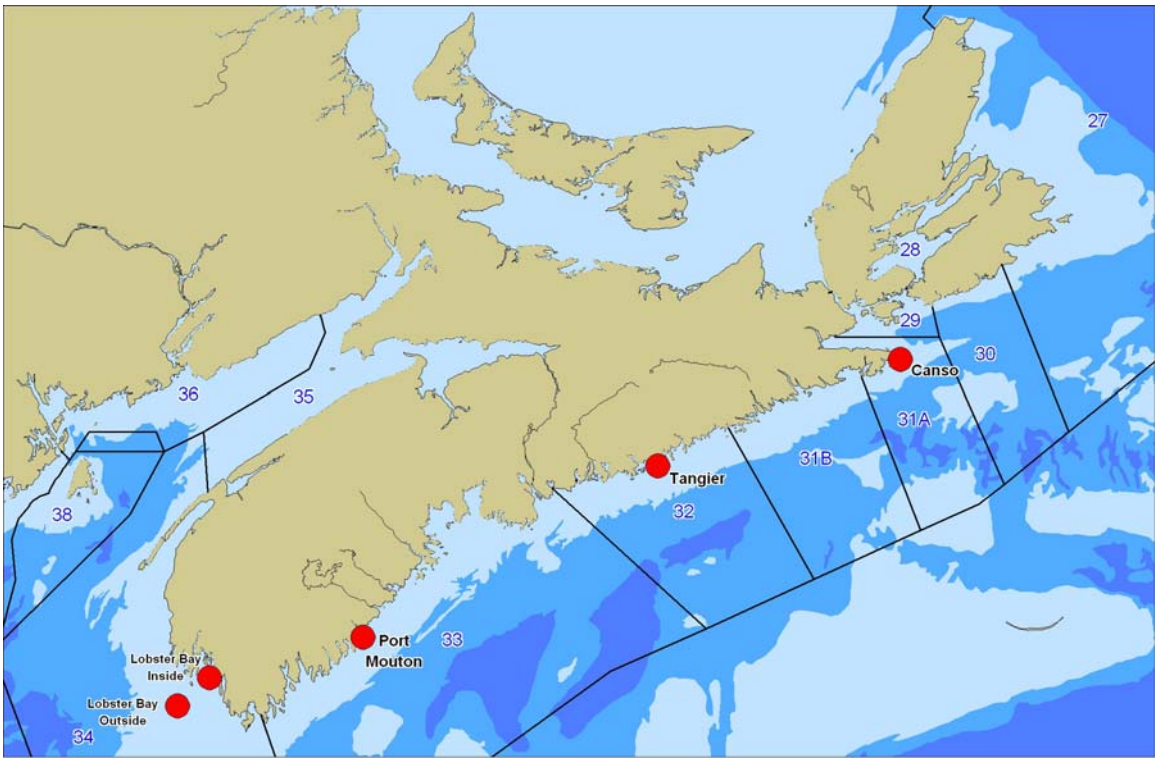


*Figure 1. Geographic location of lobster maturity study sites in Nova Scotia 2008-2011, as well as location of Lobster Fishing Areas (LFAs) 27-38..*

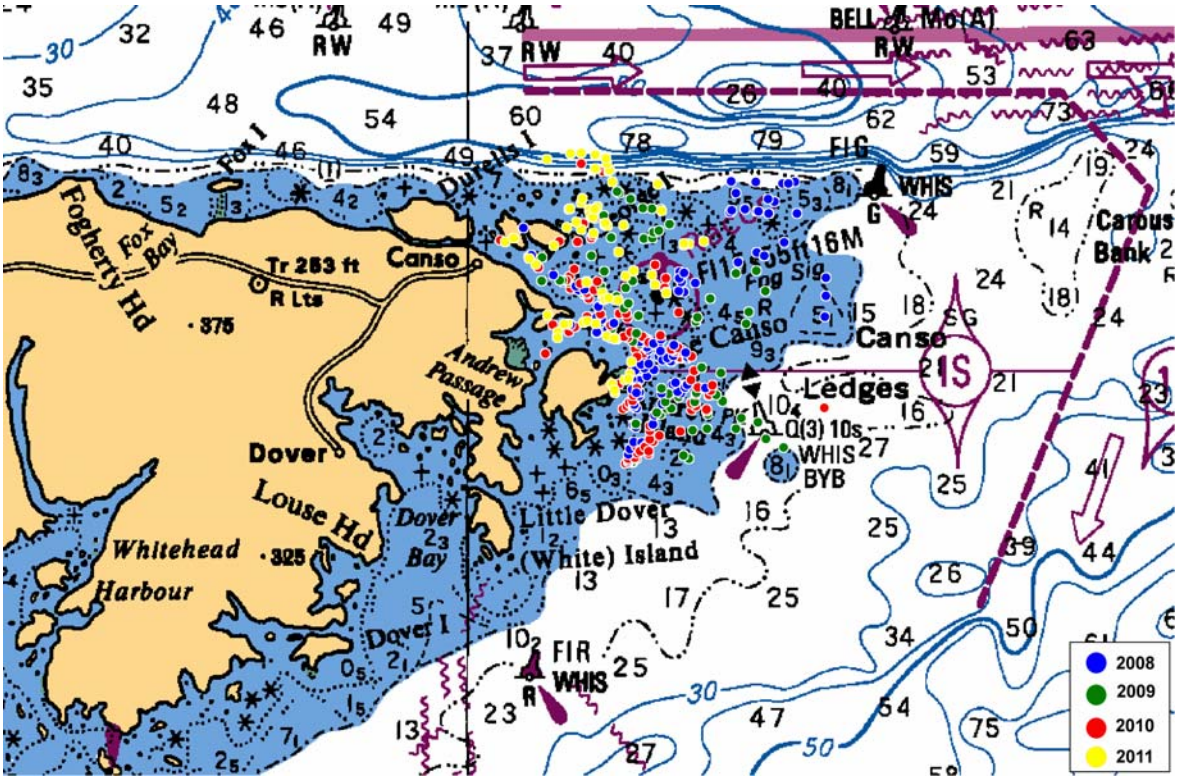


*Figure 2. Canso sampled sites in 2008 (blue), 2009 (green), 2010 (red) and 2011 (yellow).*

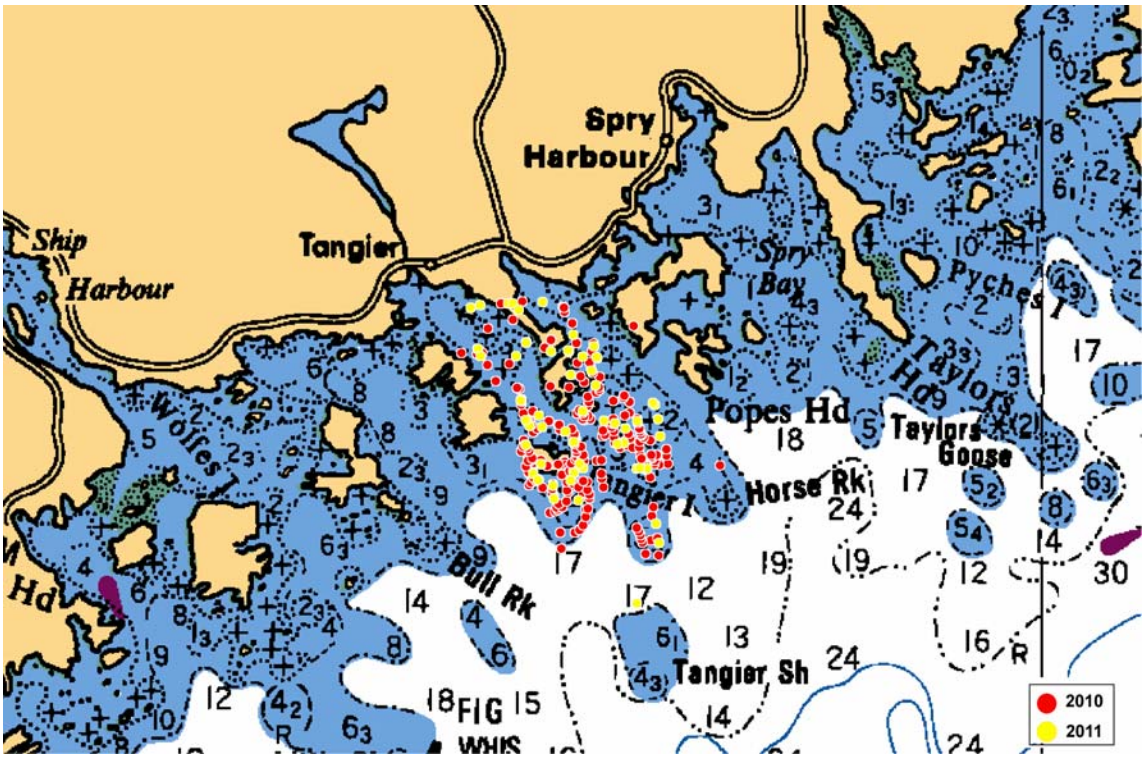


*Figure 3. Tangier sampled sites in 2010 (red) and 2011 (yellow).*

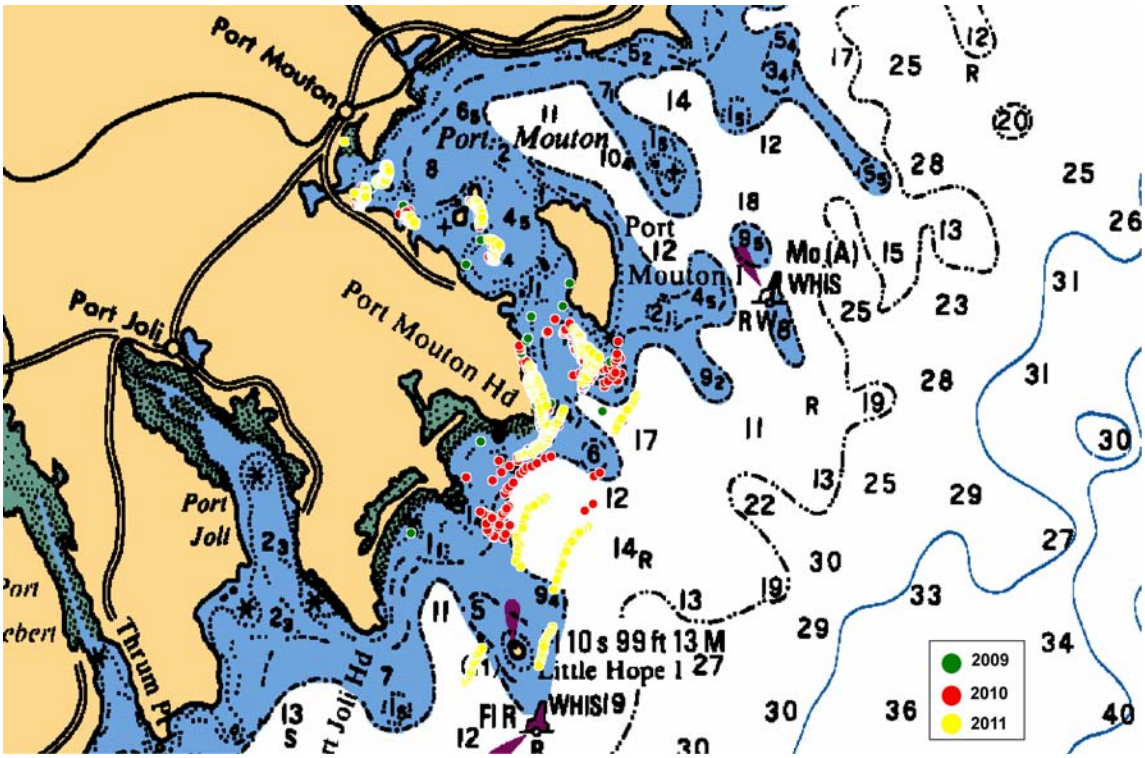


*Figure 4. Port Mouton sampled sites in 2009 (green – mostly covered by red and yellow), 2010 (red) and 2011 (yellow).*

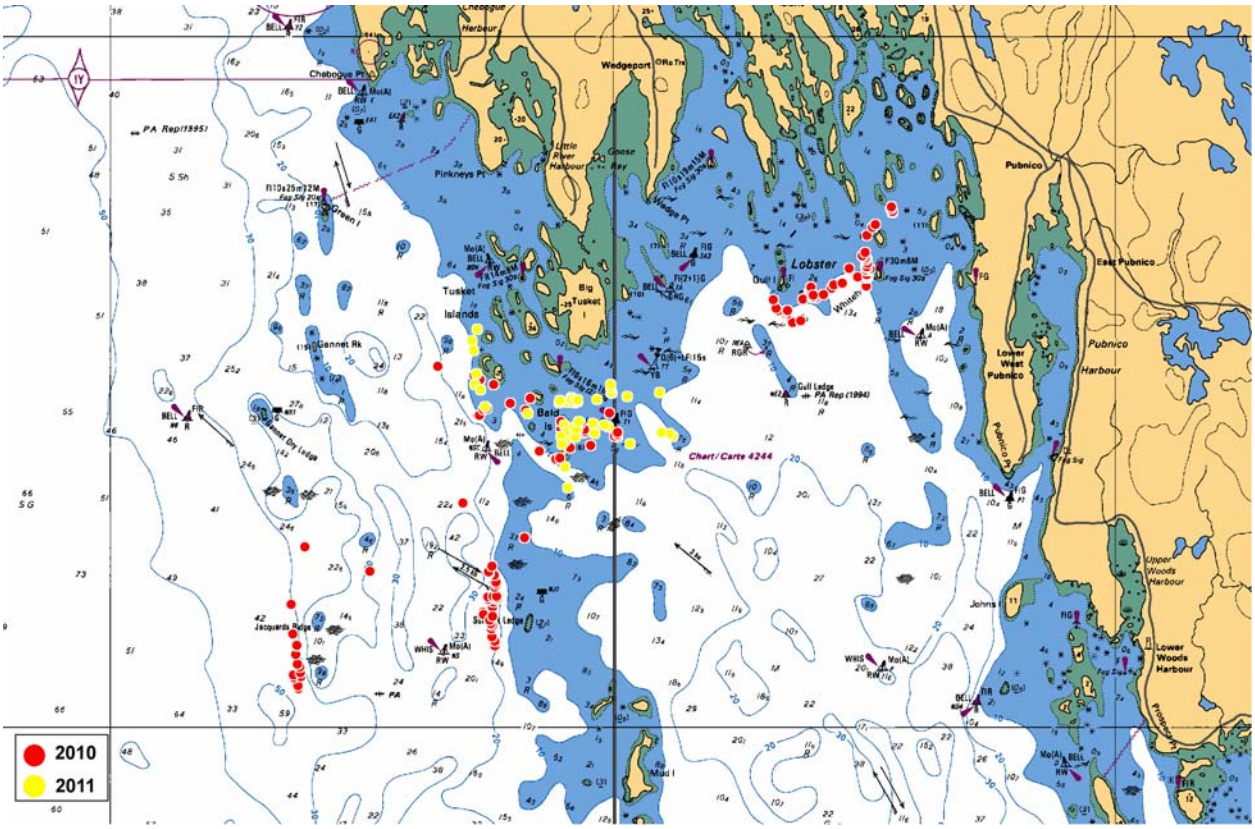


*Figure 5. Lobster Bay sampled sites in 2010 (red) and 2011 (yellow).*

***Canso 2008***

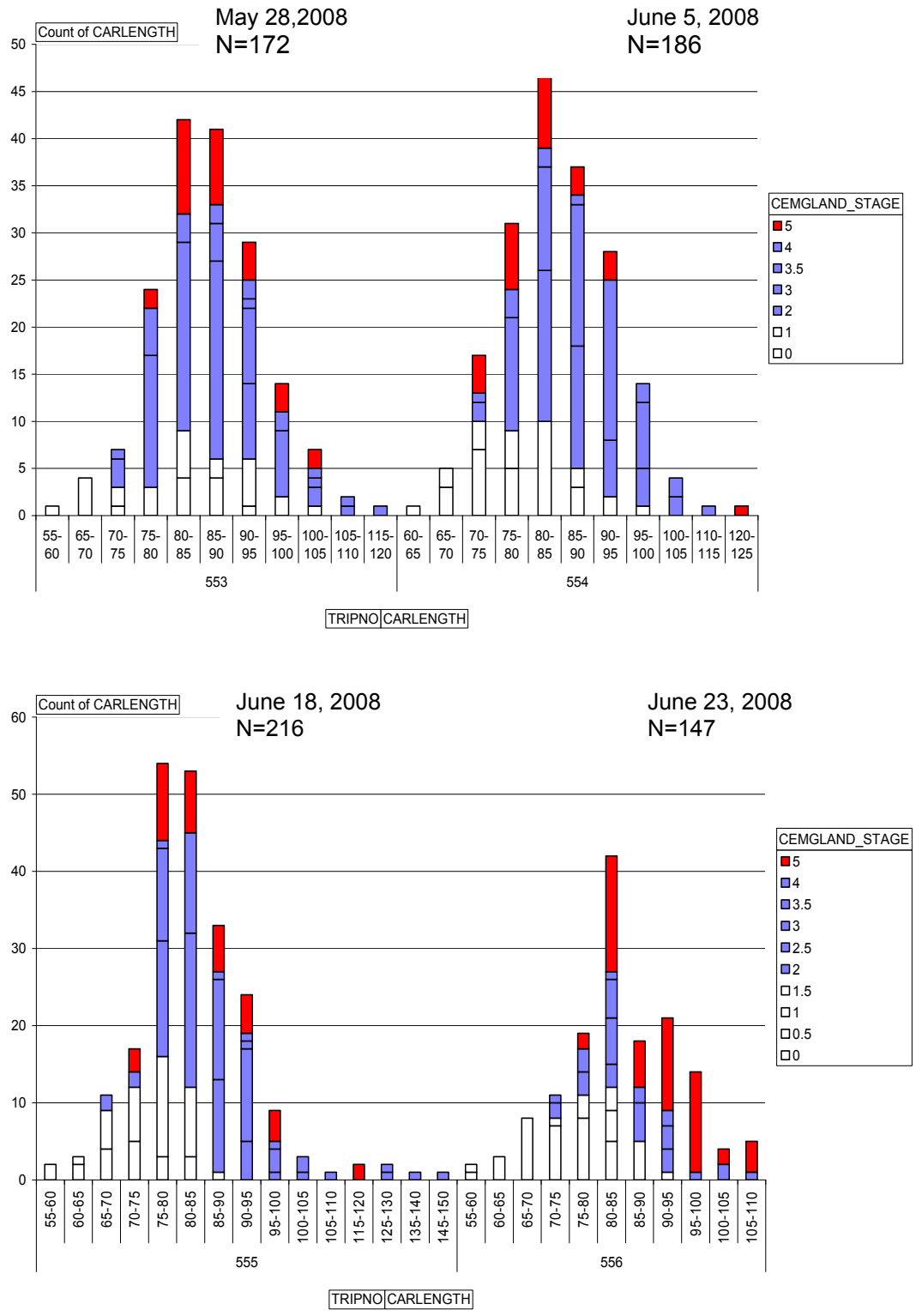


*Figure 6a. Canso, 2008. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Canso 2009***

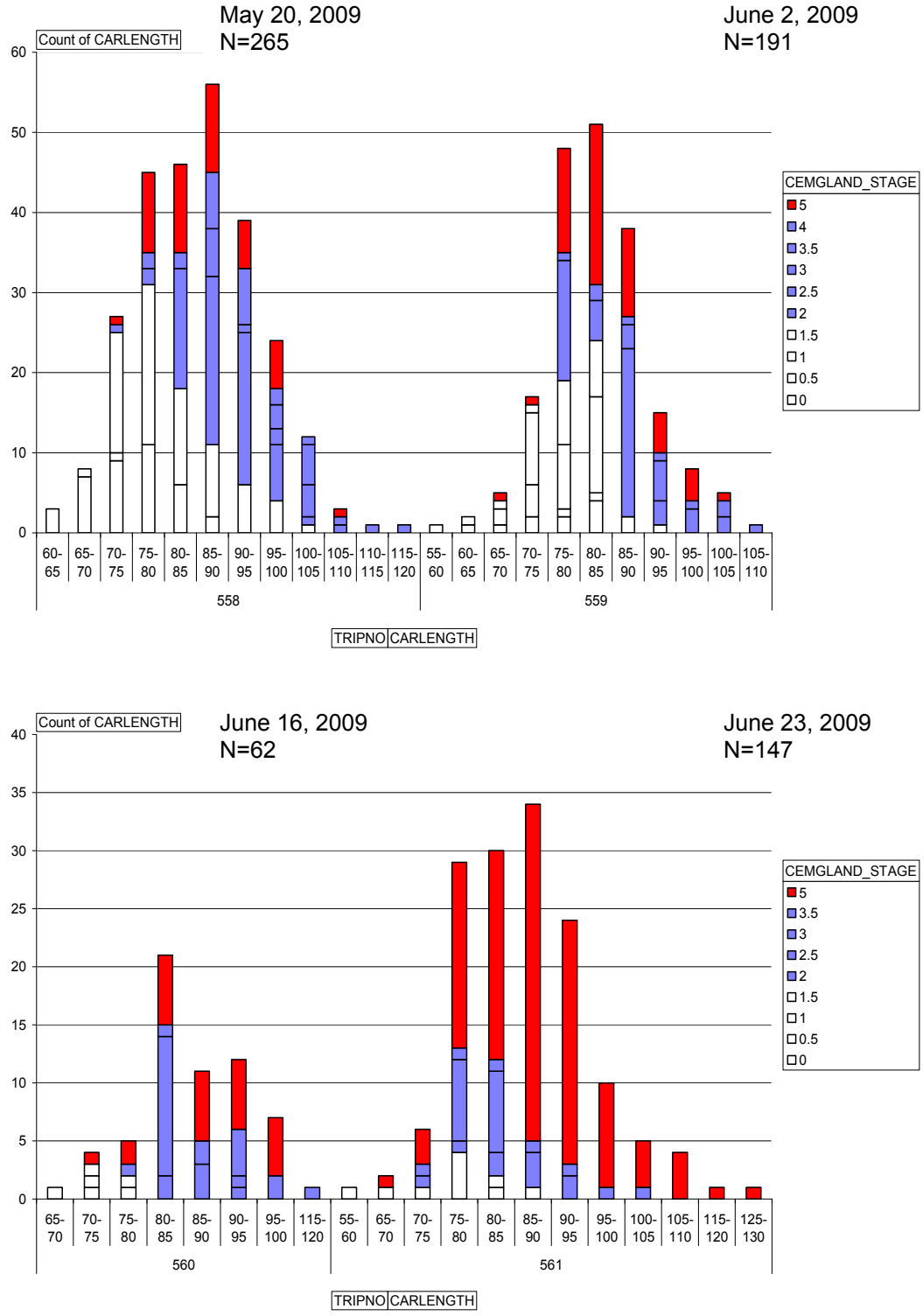


*Figure 6b. Canso, 2009. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Canso 2010***

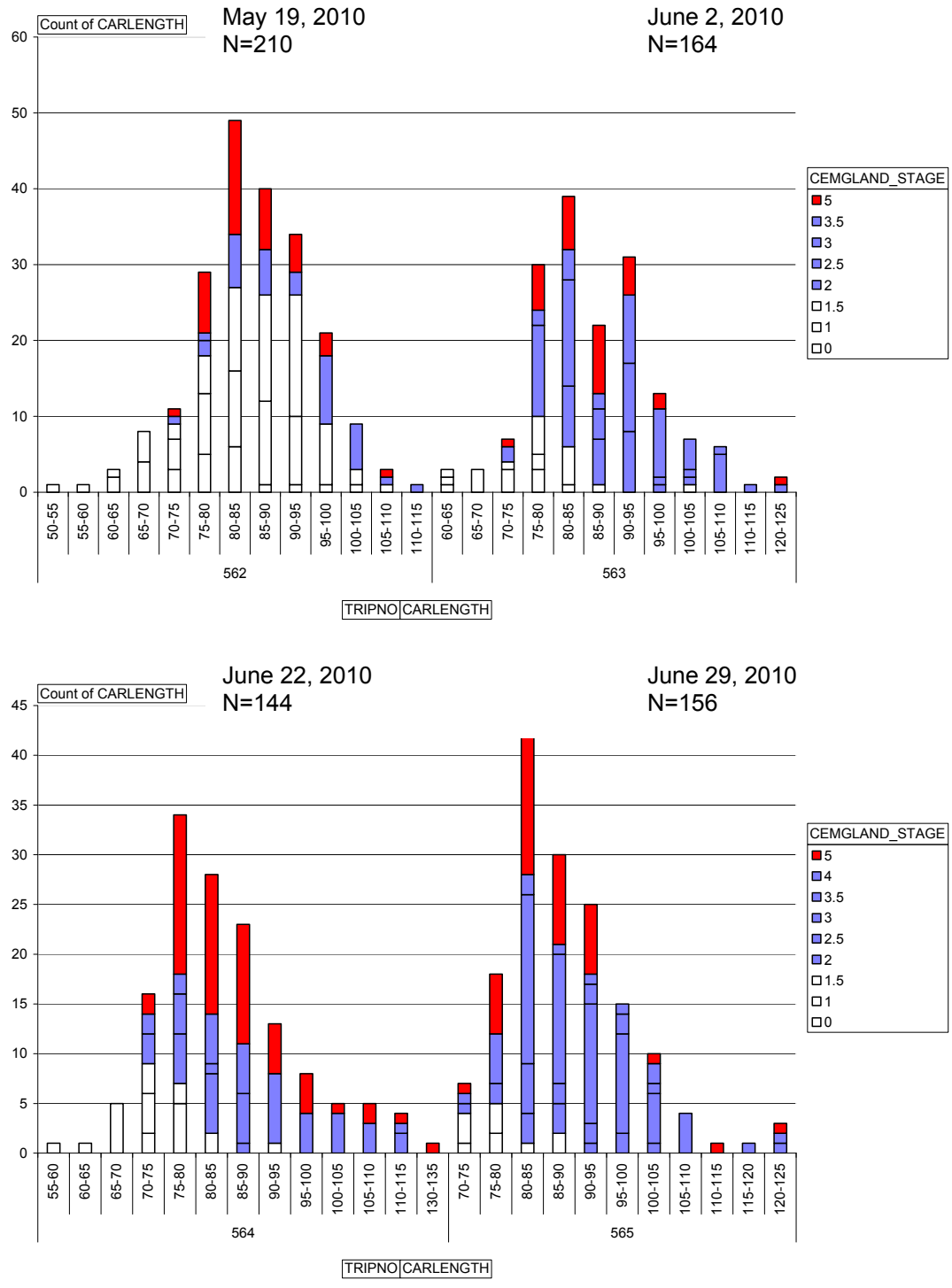


*Figure 6c. Canso, 2010. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

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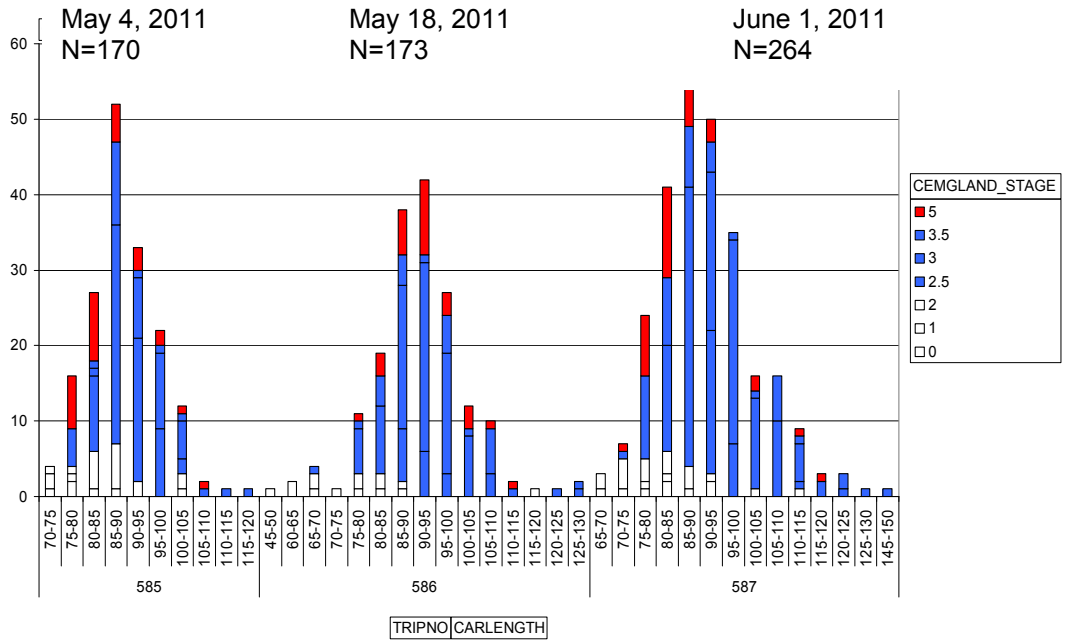
***Canso 2011***



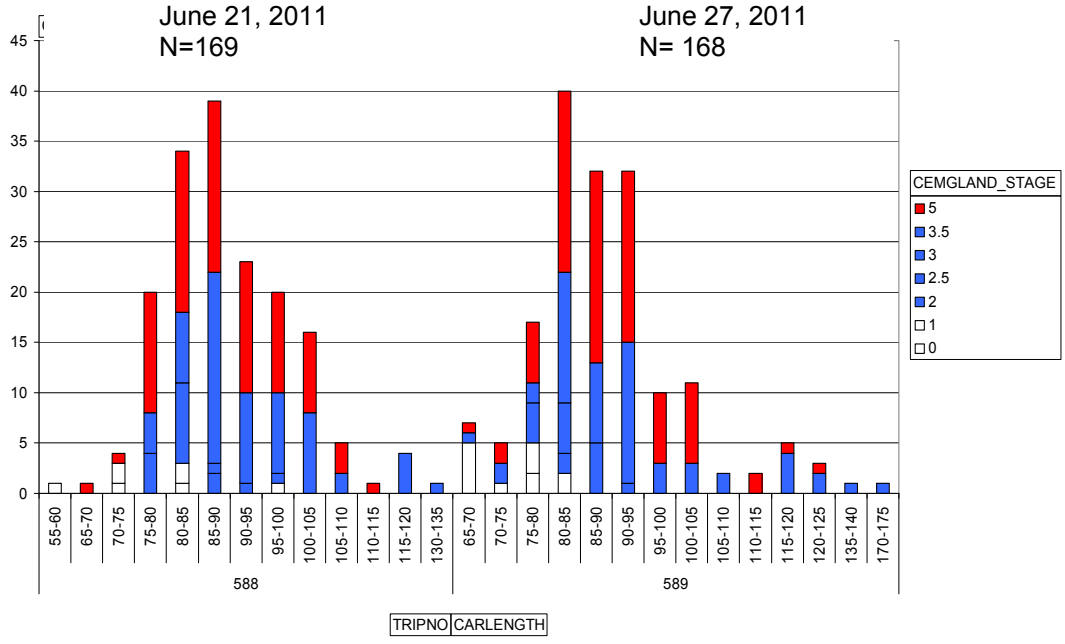
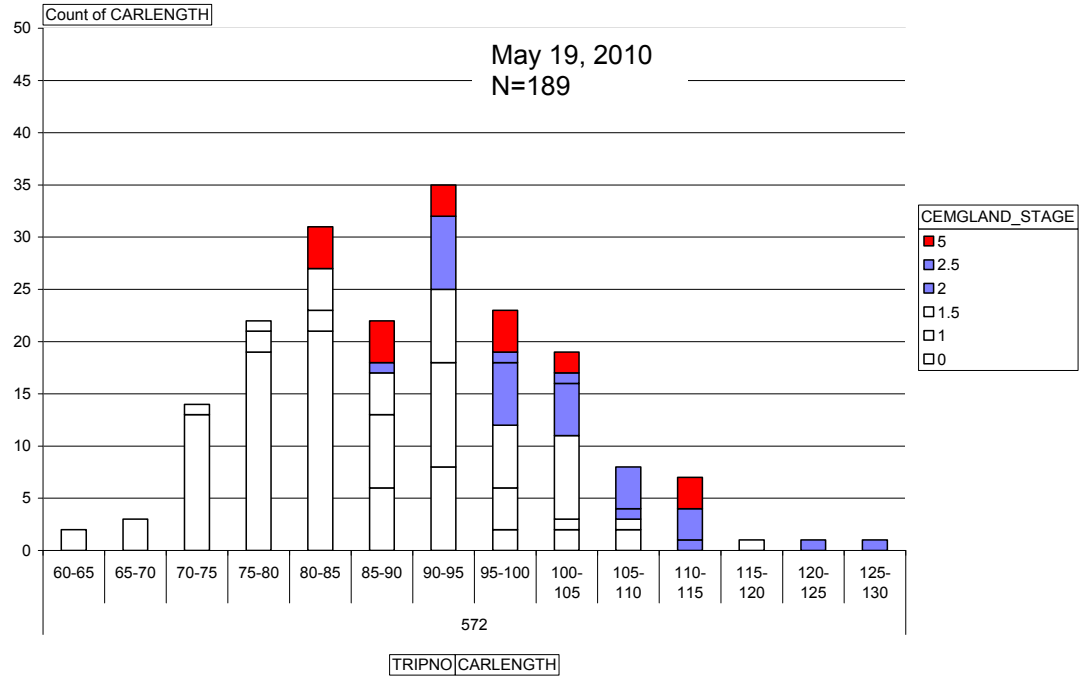




*Figure 6d. Canso, 2011. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Tangier 2010***



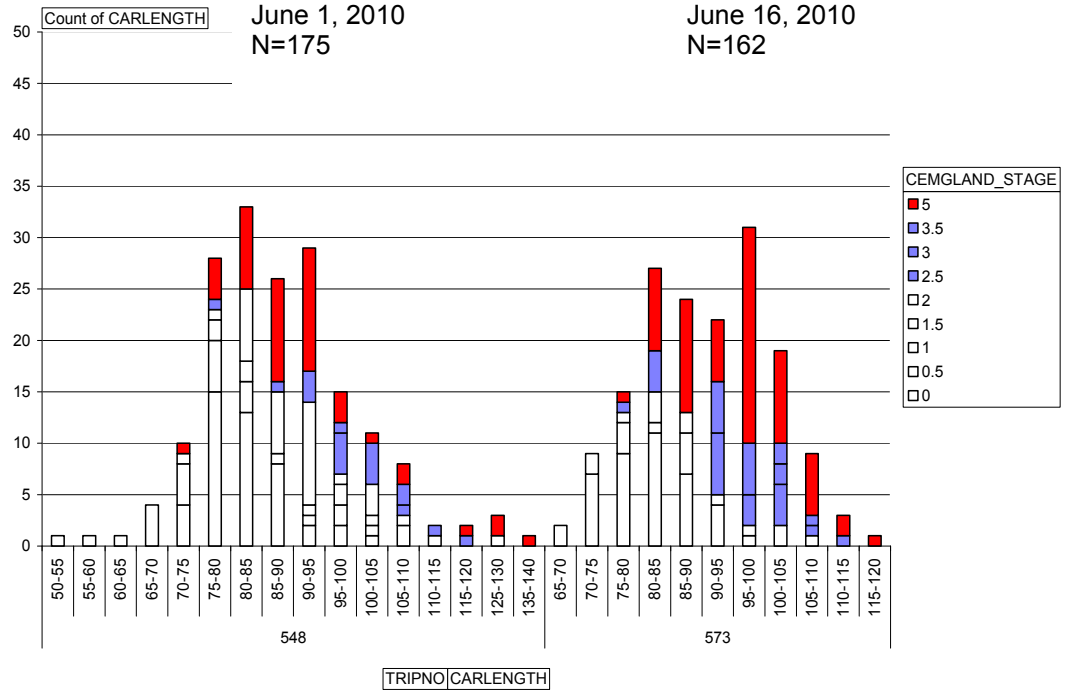
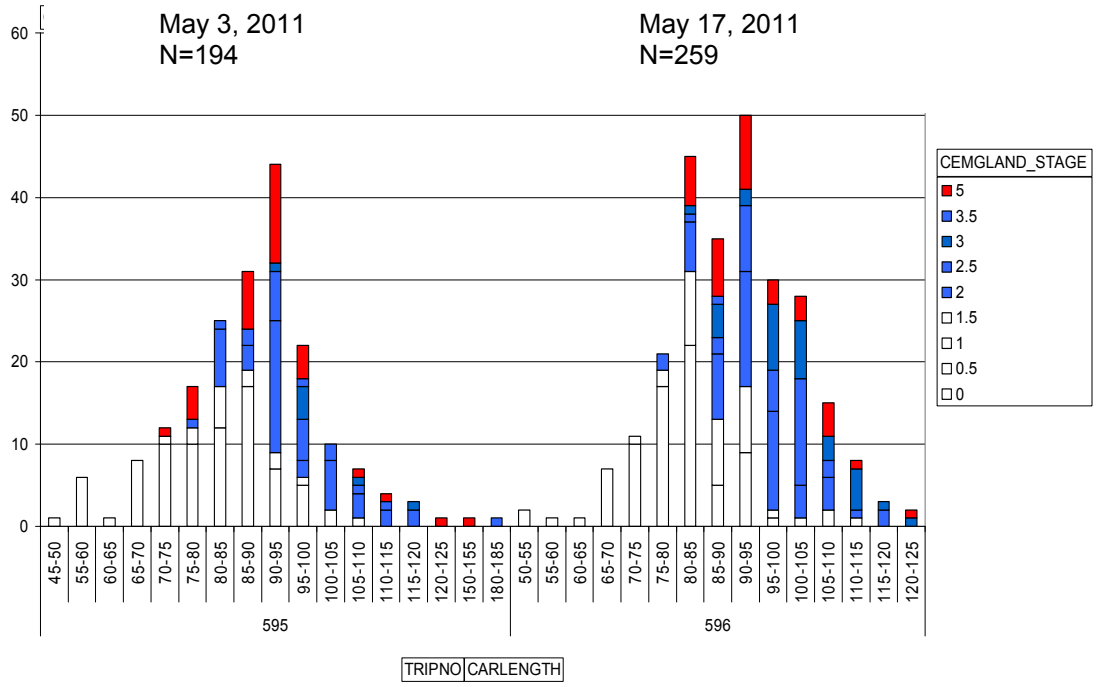




*Figure 7a. Tangier, 2010. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Tangier 2011***



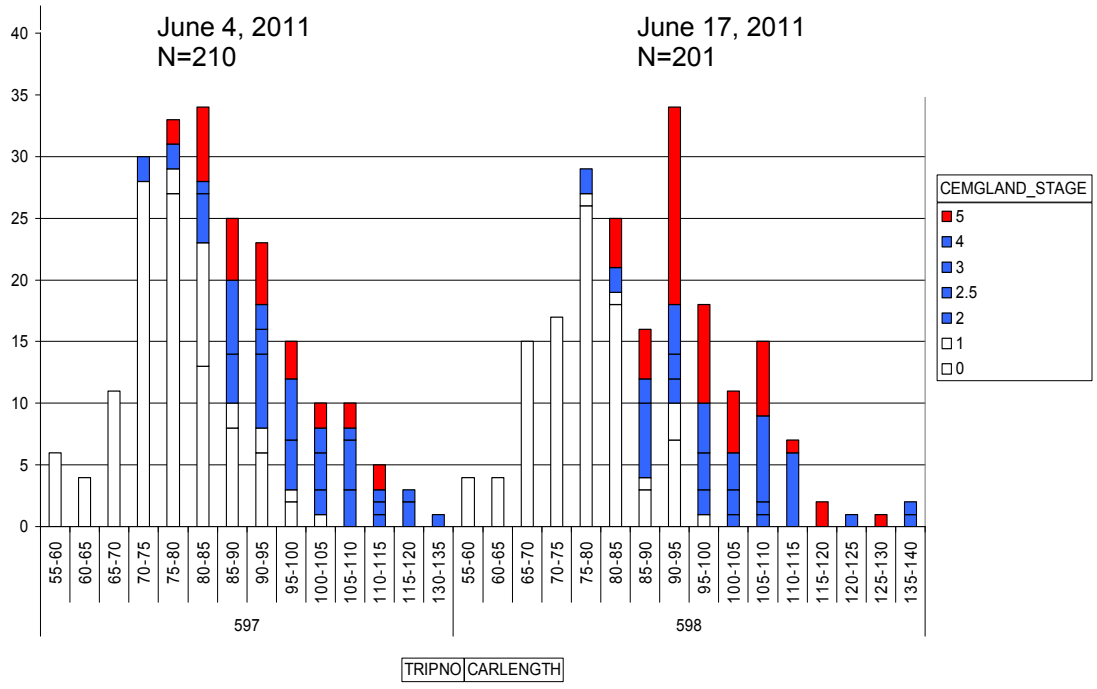




*Figure 7b. Tangier, 2011. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Port Mouton 2009***

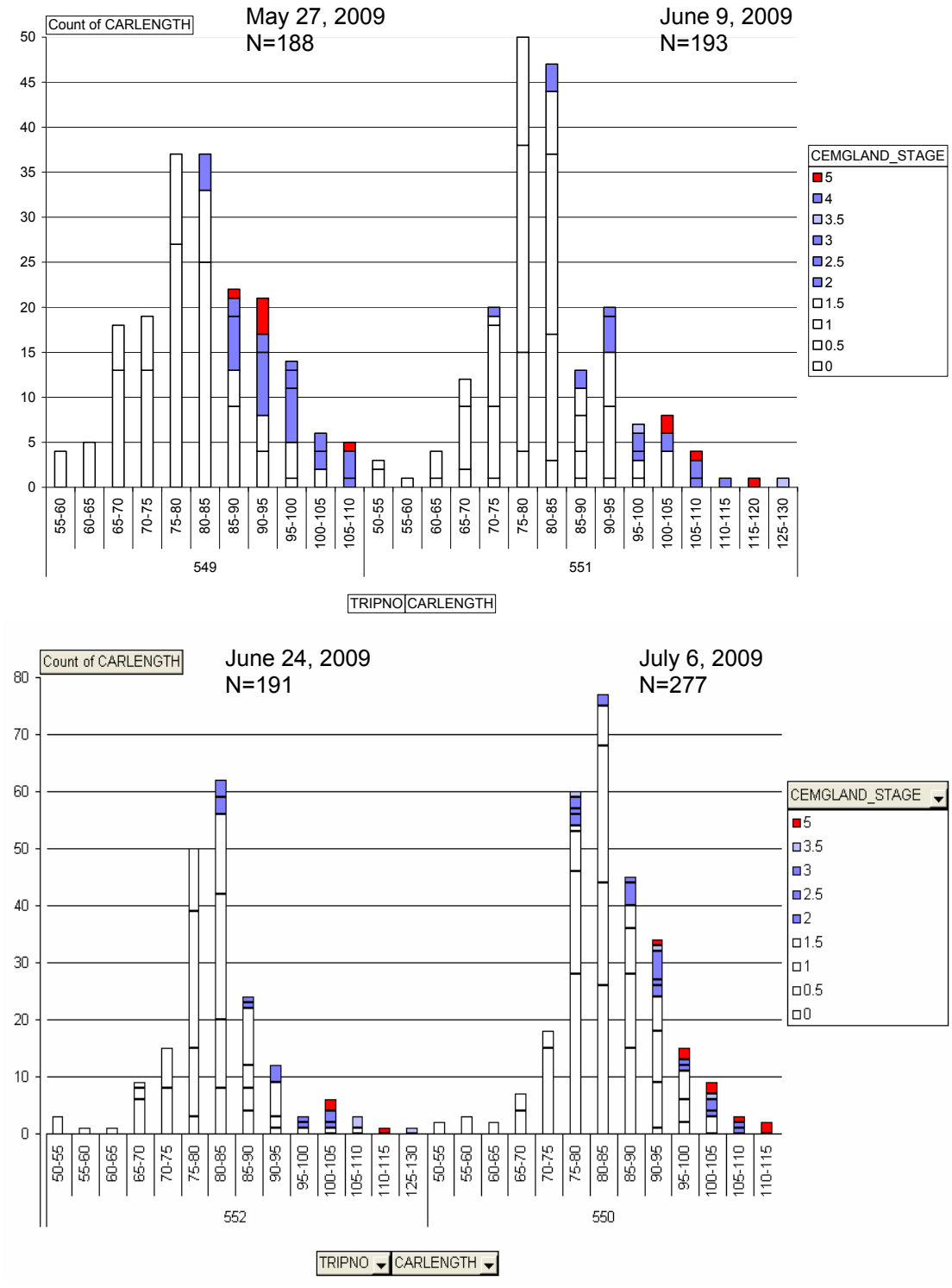



*Figure 8a. Port Mouton, 2009. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Port Mouton 2010***

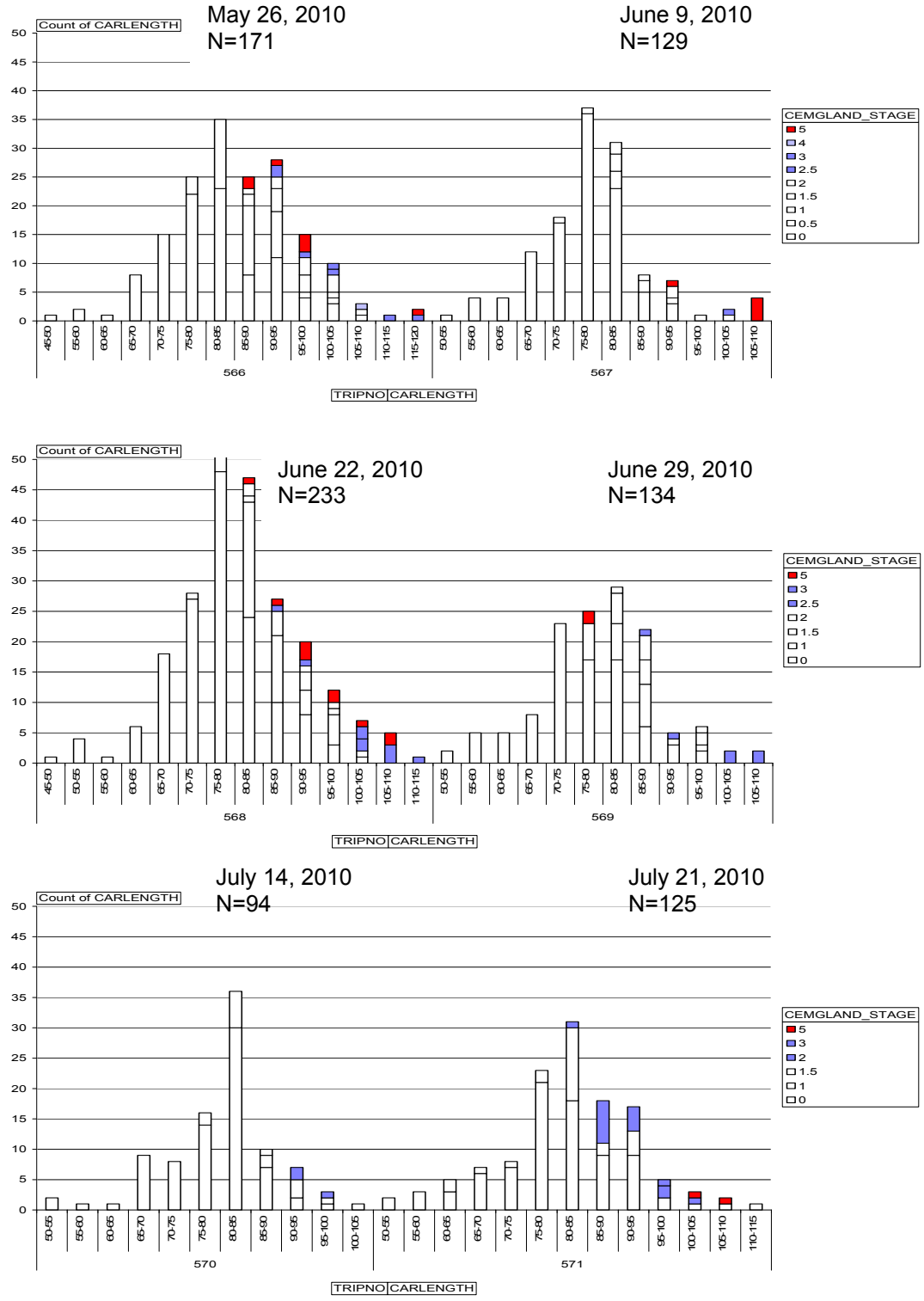
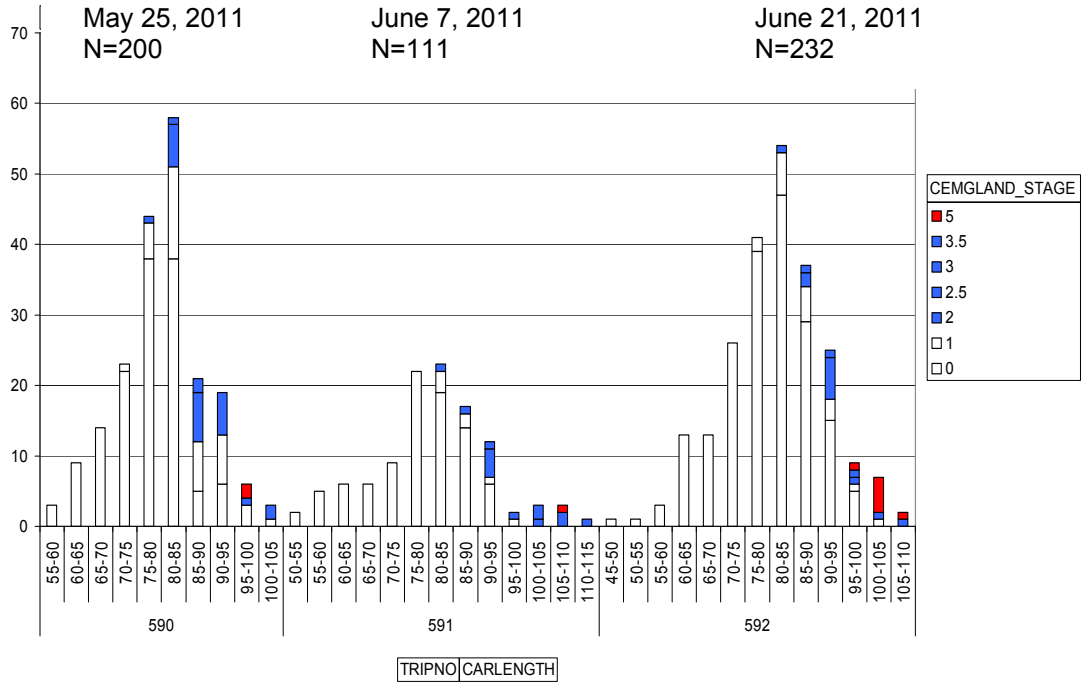



*Figure 8b. Port Mouton, 2010. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Port Mouton 2011***



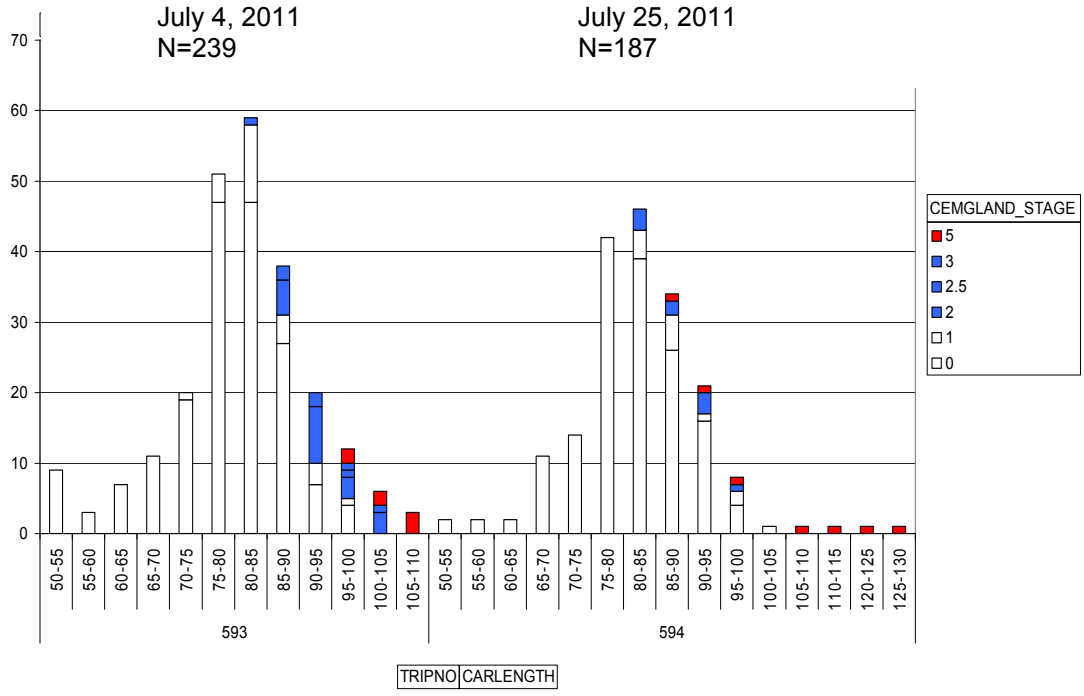




*Figure 8c. Port Mouton, 2011. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Lobster Bay - Outside 2010***

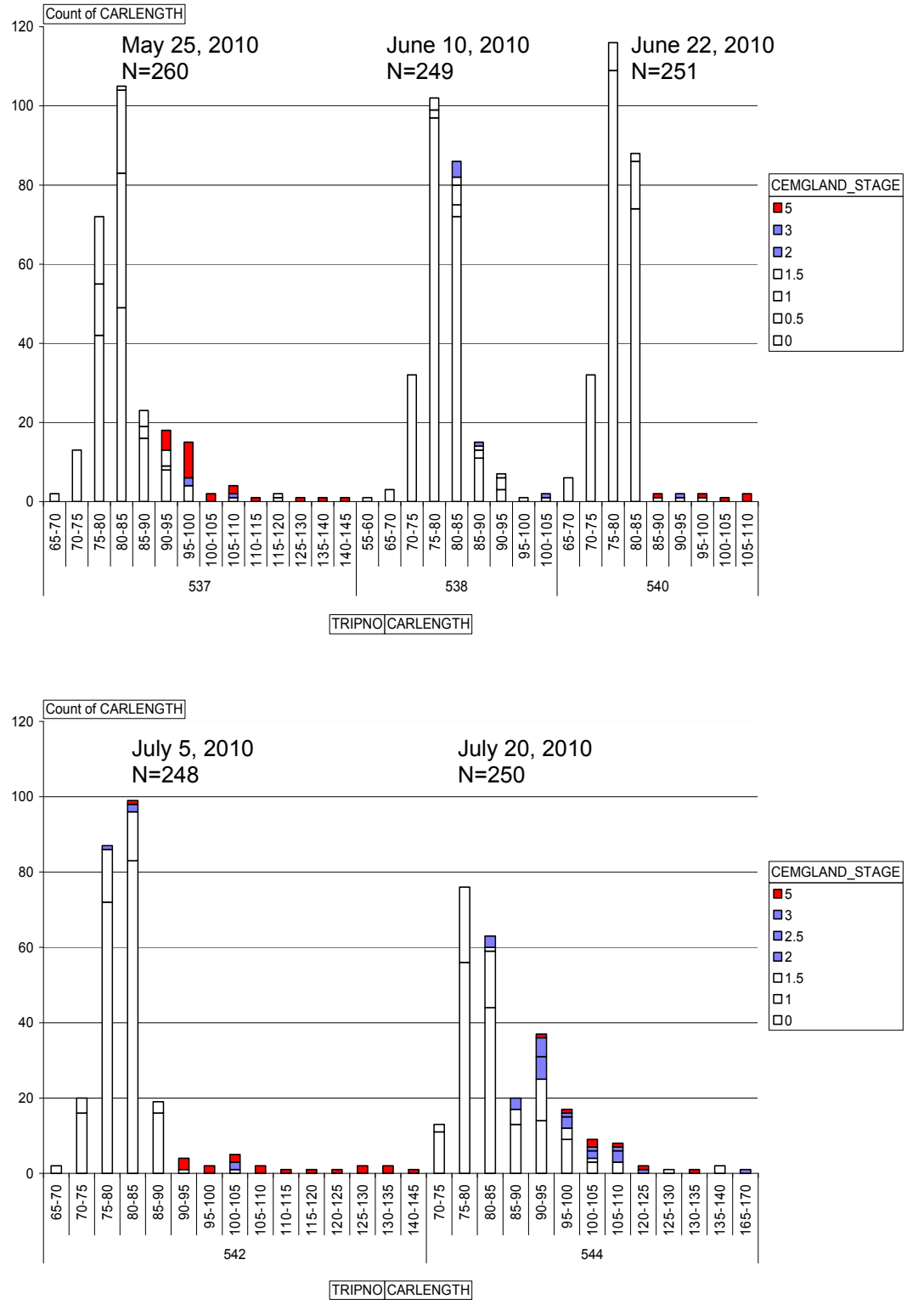



*Figure 9a. Lobster Bay - Outside, 2010. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Lobster Bay - Outside 2011***

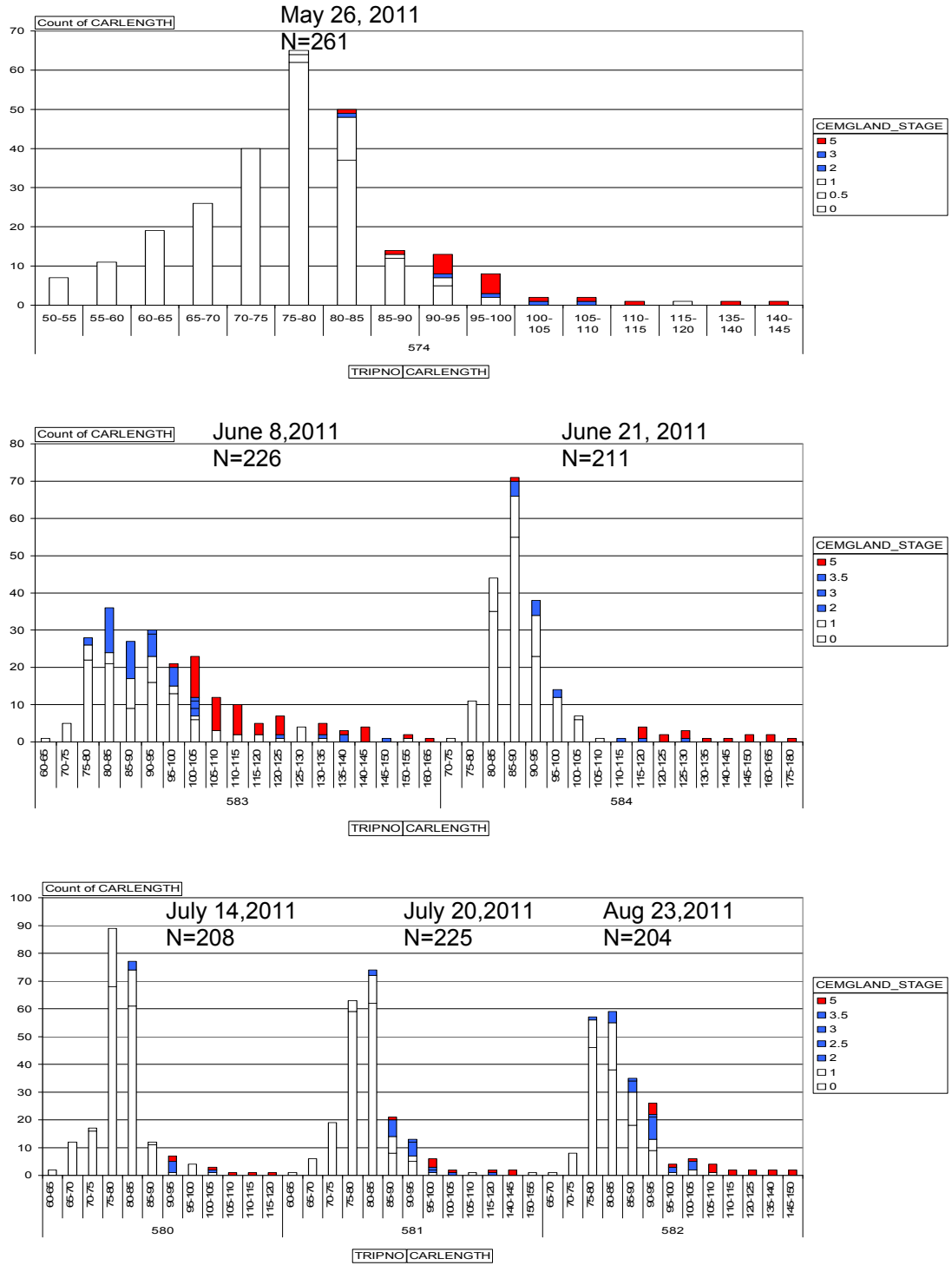



*Figure 9b. Lobster Bay - Outside, 2011. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Lobster Bay - Inside 2010***

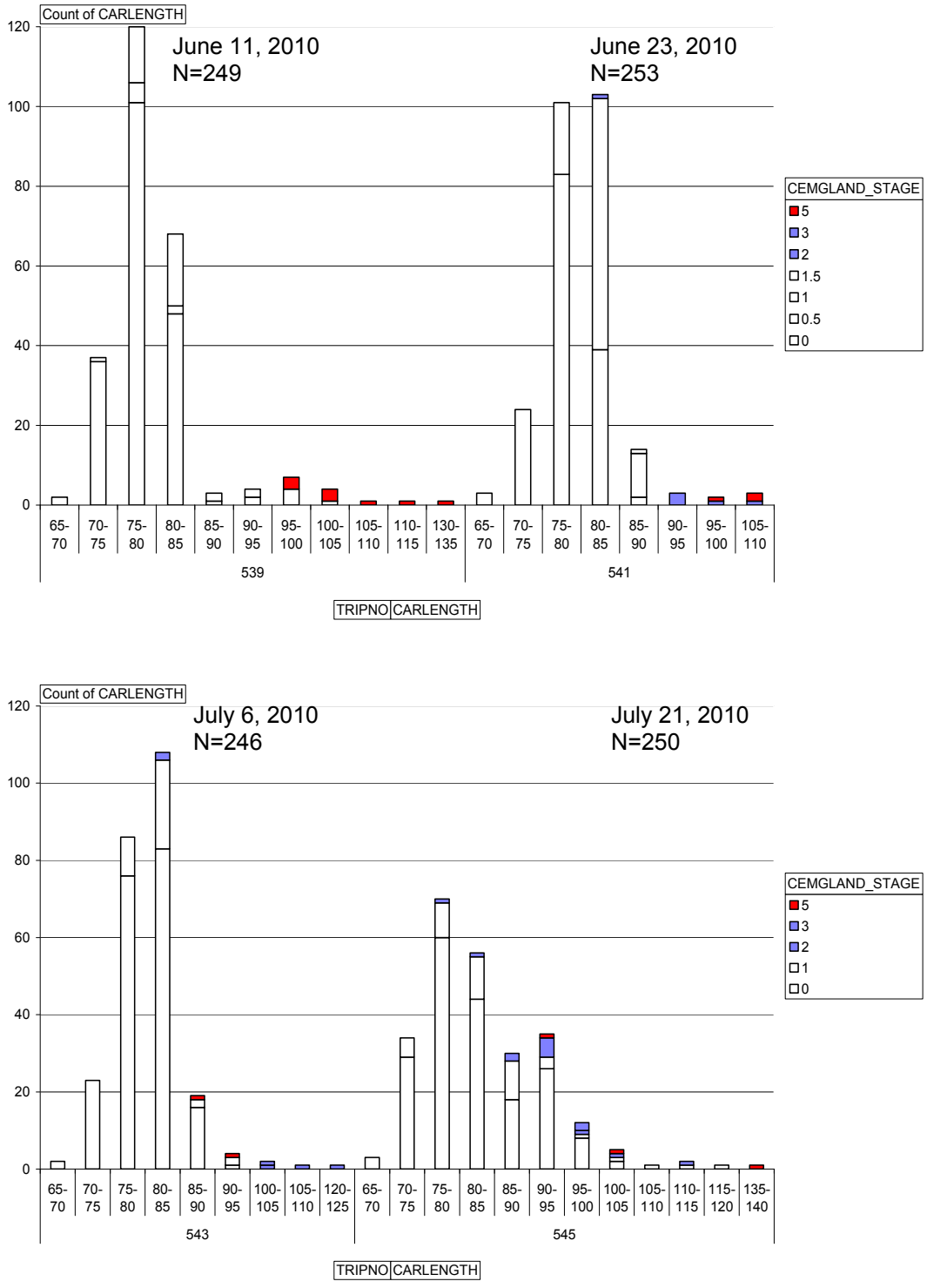



*Figure 10a. Lobster Bay – Inside, 2010. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

***Lobster Bay - Inside 2011***

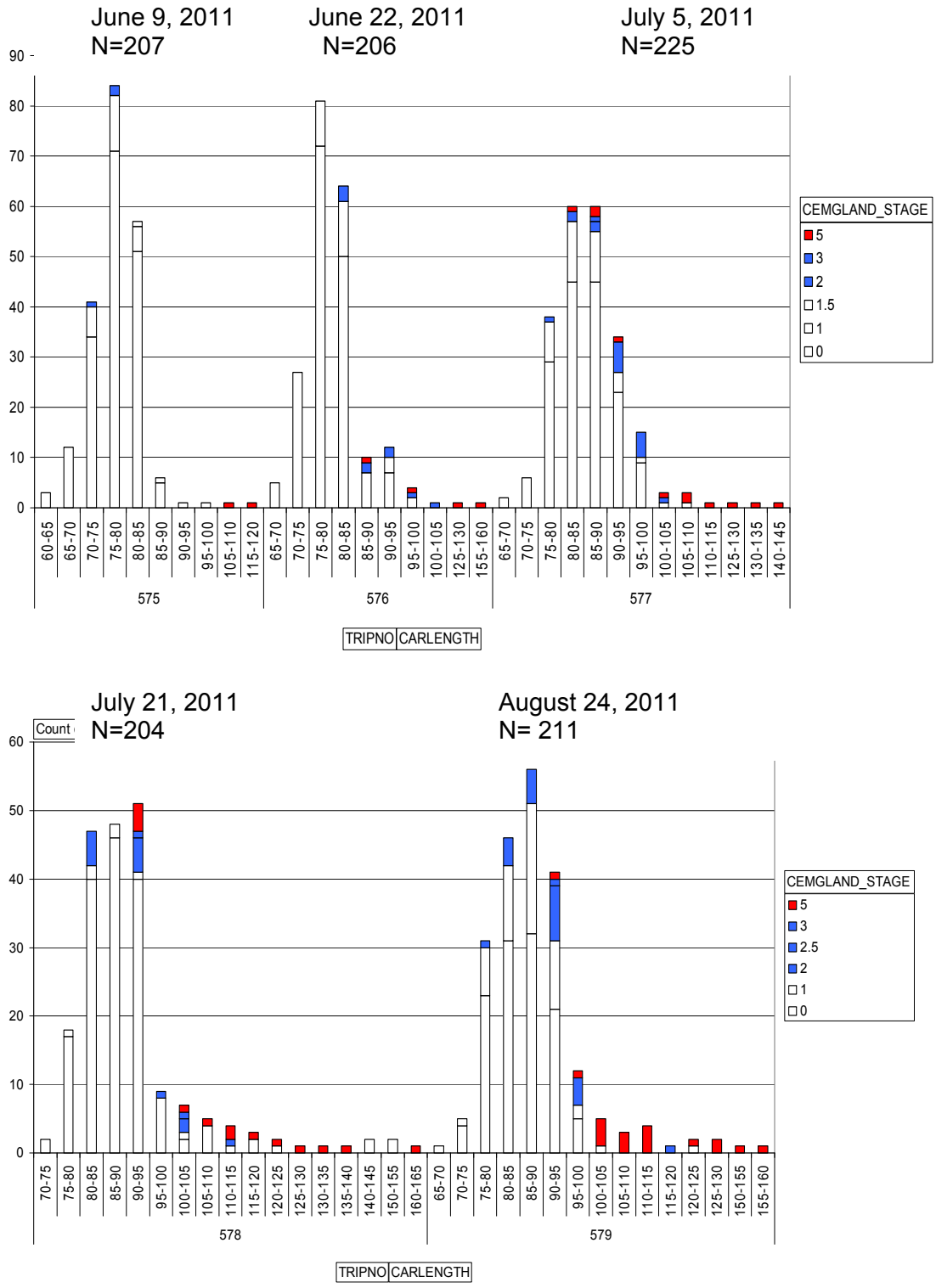



*Figure 10b. Lobster Bay - Inside 2011. Size frequency distribution and maturity status of female lobsters within each 5 mm size class. Stage 5 are ovigerous females (see text for stage description).*

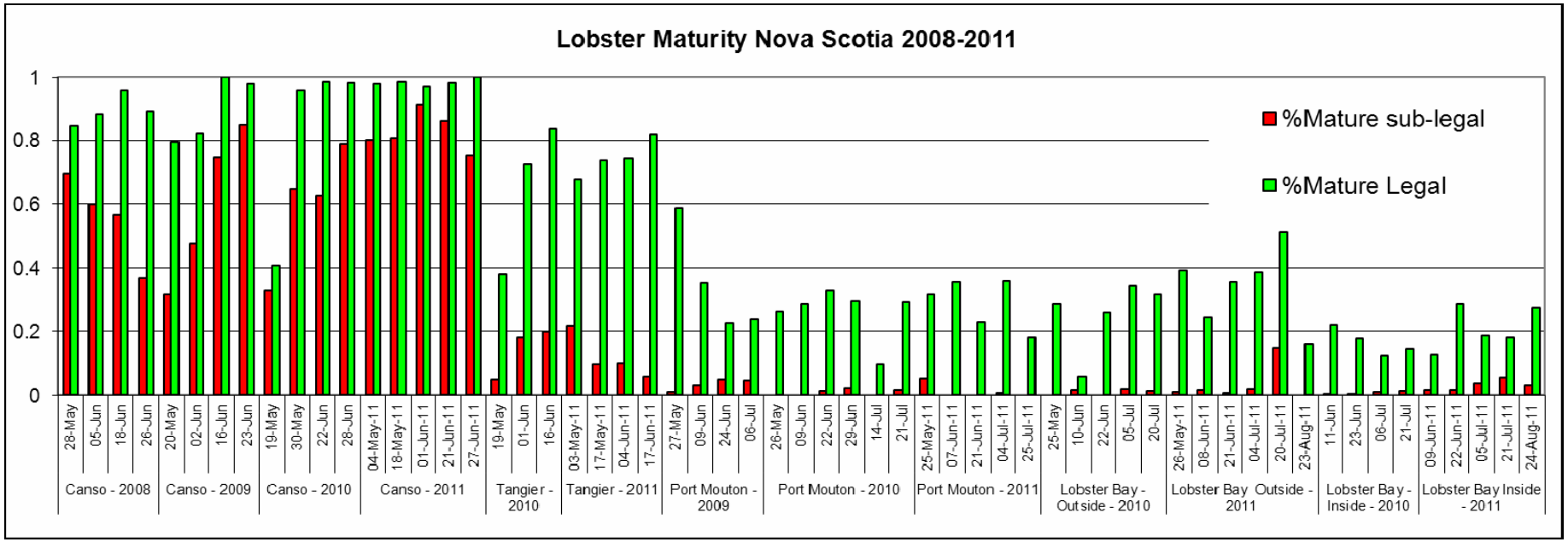



*Figure 11. Summary of lobster maturity in Nova Scotia. Proportion of mature sub-legal lobsters (red) and legal lobsters (green) found in samples from fishing areas of Canso (LFA 31A), Tangier (LFA 32), Port Mouton (LFA 33) and Lobster Bay – Outside and - Inside (LFA 34). (N for each date as per Tables 3-6, this document).*