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# Assessment of the Bay of Fundy sea urchin fishery, Lobster Fishing Area 38

# Évaluation de la pêche à l'oursin de la Baie de Fundy, zones de pêche du homard 38

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## ABSTRACT

The green sea urchin (*Strongylocentrotus droebachiensis*) commercial fishery was initiated along the coast of southwestern New Brunswick, in the Bay of Fundy, in 1989. The sea urchin fishery was separated into 2 management areas. These 2 areas were assigned the same boundaries as Lobster Fishing Areas (LFAs) 36 and 38. In LFA 38, the existing sea urchin fishery is based on a total allowable catch (TAC) system and under non transferable individual boat quota. The urchins are harvested by dragging. Presently, there are 13 licensed dragging operators. It is currently managed using a minimum legal size limit of 51 mm test diameter (TD) and by a fishing season. A TAC of 979 t was set in 1996. Since then, the TAC has been reduced 3 times and presently the fleet operates under a TAC of 176.9 t. In this assessment, fishing effort, landings trends, and catch rates were evaluated using logbook information. In addition, sea urchin size structure, densities, and biomass were re-evaluated, using diver based sea urchin survey information. The traditional fishing grounds on the east side of Grand Manan Island were re-surveyed in 2005, and the results were compared with the previous results from the 1992 survey. During 2006 and 2007, a selected subset of transects were sampled and the survey results from these specific transects compared with the corresponding transects that were surveyed in 1992 and 2005. The TAC and harvesting rates were reviewed. By-catch was evaluated by at-sea observer during the 2007-08 fishing season.

Since 1996, there has been a consistent decrease in catch per unit effort (CPUE) until it reached its lowest during the 2006-07 fishing season. During the 2007-08 fishing season, catch rates increased for the first time since 1996. The number of fishing trips has declined to a low of 179 trips during the 2007-08 fishing season. Total biomass and estimated fishable biomass have declined between 1992 and 2005. However, there is no statistically significant difference in the density of legal-sized sea urchin between the 2 survey periods due to a high degree of variability. Nevertheless, on a selected subset of transects the density of legal-size sea urchins was significantly lower in 2006 and 2007 compared to 1992. Based on the established TAC of 176.9 t, the present exploitation rate is estimated to be 1.5%, which is lower than the harvesting rate of 3.3% set in 1996. Implementation of the new logbook format will facilitate collection and analysis of effort and harvesting rate. At-sea observer sampling showed that the by-catch amount varies between sampling periods and fishing areas, but was consistent in the species type present. Most of the by-catch consisted of kelp and of blue mussels. All other species combined made up only 3% and 4% of the catch. A review of the survey design and another survey in the next 2-3 years is recommended.

## RÉSUMÉ

La pêche commerciale de l'oursin (*Strongylocentrotus droebachiensis*) a débuté le long des côtes sud-ouest du Nouveau-Brunswick, dans la baie de Fundy en 1989. Cette pêche d'oursin a été divisée en deux zones de gestion. Ces deux zones possèdent les mêmes délimitations que les Zone de Pêche du Homard (ZPH) 36 et 38. Présentement, dans la ZPH 38, la pêche d'oursin est basée sur un système de Prise Totale Alloué (PTA) et sous un quota par bateau individuel non transférable. Les oursins sont pêchés avec des dragues. Actuellement, il y a 13 opérateurs de dragage. Cette pêcherie est actuellement gérée en utilisant une limite de taille légale minimale de 51 millimètres (diamètre du test) et par une saison de pêche. Une PTA de 979 t a été établi en 1996. Depuis, la PTA a été réduite trois fois et la flotte fonctionne maintenant sous un PTA de 176.9 t. Dans cette évaluation, l'effort de pêche, les tendances des débarquements et le taux des prises ont été évalués en utilisant l'information des journaux de bord. De plus, la structure de taille, la densité et la biomasse des oursins ont été réévalués pour la ZPH 38, en utilisant l'information obtenue par des échantillonnages en plongé sous marine. Les lieux traditionnels de pêche sur la côte est de Île de Grand Manan ont été échantillonnées en 2005 et les résultats ont été comparés avec les résultats du sondage précédent en 1992. En 2006 et 2007 un sous-ensemble de transects a été échantillonné et les résultats ont été comparés aux mêmes transects des sondages effectués en 1992 et 1995. Le PTA et les taux de capture ont été passés en revue. Les prises accessoires ont été évaluées par des observateurs en mer pendant la saison de pêche 2007-08.

Depuis 1996, il y a eu une constante diminution dans les prises par unité d'effort jusqu'à ce qu'elles atteignent le plus bas niveau pendant la saison de pêche 2006-07. Pendant la saison de pêche 2007-08, les taux des prises ont augmenté pour la première fois depuis 1996. Le nombre de voyage de pêche a baissé à un minimum de 179 voyages pendant la saison de pêche 2007-08. La biomasse totale et la biomasse d'oursins de taille commerciale a baissé entre 1992 et 2005. Cependant, aucune différence significative statistique n'a été observée dans la densité d'oursin de taille légale entre les deux périodes de sondage en raison d'un haut degré de variabilité. Néanmoins, sur un sous-ensemble de transects, la densité d'oursins de taille légale était significativement inférieure en 2006 et 2007 comparé à 1992. Basé sur une PTA de 176.9 t, le taux d'exploitation présent a été évalué à 1.5 %, ce qui est inférieur au taux d'exploitation de 3.3 % établi en 1996. L'utilisation du nouveau format de journal de bord facilitera la collection et l'analyse des données d'effort et du taux des prises. L'échantillonnage d'observateur en mer a démontré que la quantité des prises accessoires variait dans le temps et selon les secteurs de pêches mais que la composition d'espèces des prises accessoires était similaires dans l'ensemble. La plupart des prises accessoires consistait de varech et de moules bleues. Toutes les autres espèces combinées constituaient seulement 3 % et 4 % de la prise. On recommande une revue des méthodes de sondage et un autre sondage dans les prochain 2 à 3 ans.

# 1. INTRODUCTION

The green sea urchin (*Strongylocentrotus droebachiensis*) fishery along the coast of southwestern New Brunswick, in the Bay of Fundy, operated at a small scale in the 1950s, 1960s, and the early 1980s. The commercial industry did not actually develop until 1989. The sea urchin fishery in southwestern New Brunswick was separated into 2 management areas. These 2 areas were assigned the same boundaries as Lobster Fishing Areas (LFAs) 36 and 38 (Figure 1). In LFA 38, the existing sea urchin fishery is based on a total allowable catch (TAC) system and under non-transferable individual boat quota. The sea urchins are harvested by dragging. It is currently managed using a minimum legal size limit of 51 mm test diameter (TD) and by a fishing season. Fisheries based in both LFAs are also eligible to fish in a small adjoining area, LFA 37. The majority of the catch is taken from shallow water coastal areas less than 10 m.

Department of Fisheries and Oceans (DFO) Fisheries and Aquaculture Management (FAM) Branch and sea urchin fishers were concerned about the decline in landings over the last 8 years and the lack of up to date information on the status of the sea urchin stock. In order to address this lack of information, diver based sea urchin surveys were initiated during the summer of 2005, 2006, and 2007. The objective was to resurvey the traditional urchin fishing grounds off Grand Manan Island and update the information on the status of the urchin resource.

This report has the following objectives:

- Evaluate the status of the sea urchin stock in LFA 38 and the impact of the fishery.
- Compare the more recent information with the previous survey results from the 1992 survey.
- Revise the overall legal biomass estimates and review the total allowable catch.

## 1.1. BIOLOGY

The green sea urchin, *Strongylocentrotus droebachiensis*, is an echinoderm that is distributed in the Atlantic Ocean from New Jersey to the Arctic, extending south to Britain. It is also distributed in the Pacific Ocean from Washington to Alaska. The animals are omnivorous in nature, although they feed primarily on seaweeds. Sea urchins are most plentiful in shallow waters less than 10 m deep, although they may be found down to 1,200 m. Urchins can be found on virtually any type of substrate, but they generally prefer harder surfaces. The animals have separate sexes, mature at approximately 25 mm TD, and spawn in late winter/early spring. The resulting planktonic larvae settle in 8 to 12 weeks. Growth can be quite variable, and is dependent on food supply and environmental conditions. The time estimated to reach commercial size (51 mm TD) may take from 3 to 15 years. Currently there are no estimates of natural mortality available. There is no evidence of mortality due to the infectious disease caused by *Paramoeba invadens* in the Bay of Fundy, as has been experienced in the past along the Atlantic coast of Nova Scotia.

## 1.2. RECENT MANAGEMENT ISSUES

The sea urchin fishery exploitation rate is currently based on a percentage of fishable biomass (3.3%, implemented in 1996) that was estimated using survey data from 1992 (DFO 1996). The last peer-reviewed advice on that biomass for LFA 38 was done in 2000 (DFO 2000). In 2007, a DFO Science Response Report to Fisheries and Aquaculture Management Branch recommended the lowered 2006-07 TAC be maintained in the LFA 38 urchin fishery until a more rigorous assessment was done (DFO 2008). Updated peer-reviewed advice on the fishable biomass is required, including results of resource surveys from 2005, 2006, and 2007.

## 2. THE FISHERY

The LFA 38 sea urchin fishery is currently managed by DFO. A Conservation and Harvesting Plan (CHP) was developed in consultation with all the license holders in the fishery. At the present time, 8 of the 13 licenses are issued to 3 different First Nations as commercial communal licenses. The remaining 5 licenses are issued to independent core fish harvesters and are subject to the owner-operator policies. The CHP includes; a minimum size limit (TD) of 51 mm (2.0 in.); sea urchins to be sorted and culled at sea, harvesting between sunrise and sunset; mandatory submission of logbooks; and 100% dockside monitoring of landings. During 2007-08, the fishing season extended from the second Monday of December to March 14, or until the licence holder's initial individual quota (IQ) of 13.6 t (30,000 lbs) round weight has been caught, whichever comes first. At the inception of the commercial LFA 38 sea urchin fishery in the early 1990s, this fishery was limited entry. Presently, there are 13 licensed dragging operators with the option of converting (not permanently) to dive licenses if requested by the fishers.

Dragging operations are required to use urchin drags with a maximum opening width of 1.8 m (6 ft). The diver based fishing consists of a maximum of 4 divers in the water and 2 skiffs with a maximum length of 7.3 m (24 ft) each. The skiffs may be used within 457 m (1,500 ft) of the mother boat to tend the divers.

The fleet operates under a TAC of 176.9 t. The fleet TAC is divided amongst the 13 licenses to provide an equal IQ to each license. IQs are non-transferable. As the commercial communal licenses must designate an individual to fish the IQ on behalf of the First Nation, there is, however, some potential for transfer of benefits associated with an IQ.

These management measures are reviewed on an annual basis with Grand Manan Urchins Inc., the licence holder association, and other Industry stakeholders.

A TAC of 979 t was set in 1996. Since then, the TAC has been voluntarily reduced 3 times by the Industry. The original TAC was reduced to 778 t during the 2000-01 fishing season, to 590 t during the 2004-05 fishing season, and to 176.9 t (or 13.6 t individual non transferable quotas) in 2006-07 (Figure 2). During the 2006-07 fishing season, an additional TAC of 176.9 t was allocated to an urchin fishing area situated on the back side of Grand Manan called Zone 2. Zone 2 was originally part of Zone 1 where the traditional fishing occurs. Very little fishing occurs in Zone 2 because of difficult access, long distances from home port, and lower catch rate. Fishing in Zone 2, is only allowed after IQ on the traditional fishing ground had been caught. During the last 2 seasons, the limited urchin landings from fishing Zone 2 all came from diving activity.

### 2.1. LOGBOOKS, LANDINGS, AND CATCH RATES

Landing trends in LFA 38 are analyzed using logbook information. Logbook data are used to calculate effort trends and CPUE indices for individuals, groups, and locations. Catch rate and effort trends based on the analysis of logbook information is presented as the average kilogram of sea urchin landed per fishing trip (kg/trip) and the total number of fishing trips during each fishing season.

Accurate log information on number of tows, average duration of each tow, or average dive time per diver is only available since 2003. All fishing trips with landings less than 200 kg were not included in the analysis. These trips were considered incomplete due to boat breakdown or bad weather condition. The CPUE information used for the fishing seasons between 1991-92 and 1996-97 comes from the DFO 2000 Stock Status Report (DFO 2000). For that data series, separate urchin landings from drag and dive licences are not available.

During fall 2008, a new type of logbook was introduced, that reported the location of fishing in detail using previously defined fishing areas (Appendix 1). The fishing areas were determined based on biological and fishing characteristics that were previously determined during diver based surveys and fisheries information from the urchin fishers. However, data from the new logbook were not yet available in time to be analysed for this report.

### 2.2. AT-SEA OBSERVER SAMPLING (2007-08 FISHING SEASON)

During the 2007-08 sea urchin fishing season, at-sea observers sampled 5 fishing trips during the week of December 17 to 21, 2007, and 5 fishing trips during the week of January 7 to 11, 2008. The protocol was to record trip information; vessel information; gear specifications; set by set data, such as time, location (degrees, minutes, and fractions of minutes), and depth for start and end of each tow. The observer estimated the weigh of all sea urchin legal catch, discards, and by-catch species for each tow. A random sample of 100-150 unsorted urchins was taken at every 4 to 5 tows or when the fishers changed location. The data collected was reviewed by the observer and a JAVITECH staff person. The data was then sent out to be double keypunched to electronic form. The electronic files were returned to the Bedford Institute of Oceanography (BIO), checked again, and then uploaded to the Observer Program Oracle Database and backed up.

## 3. DIVER BASED SEA URCHIN SURVEYS

### 3.1. INTRODUCTION

In LFA 38, a TAC of 979 t was established in 1996 based on biomass estimates from a diver based survey that was conducted in 1992 around the whole Island of Grand Manan. The TAC was set on an estimated total biomass of legal size urchins of 29,879 t (3.3%), (DFO 1996; Robinson and MacIntyre 1993).

More recently, urchin surveys were initiated during the summer of 2005 and were continued during the summer of 2006 and 2007. These initiatives were made possible through Joint Project Agreements (JPAs) between the Grand Manan Urchins Inc. and DFO.

The primary objectives of the 2005 survey were to resurvey all the sea urchin fishing locations that were surveyed in 1992 (locations 72 to 89), and to compare the results with the original survey (Figure 3). However, because of funding problems and time restrictions, only the traditional fishing grounds on the east side of Grand Manan (locations 76 to 82) were resurveyed in 2005.

During the summer of 2006 and 2007, 2 follow up surveys were initiated. The primary objectives of these surveys were to resurvey a subset of specifically selected transects, on fishing grounds where high fishing effort had occurred during the 2005-06 and 2006-07 winter fishing seasons and where these transects had been previously surveyed in 2005 and 1992 (Figure 4). For comparison, 2 transects were resurveyed on urchin grounds where there was no fishing activity, with the goal of documenting possible changes in the density of urchins that may occur independently of fishing impact. In addition, 2 transects were surveyed in Cheney Passage and Cow Passage, areas that have been closed to urchin dragging since 2006 in order to prevent conflict with dulse harvesting (Figure 4).

## 3.2. MATERIALS AND METHODS

### 3.2.1. Survey Methods (1992 versus 2005)

Prior to the start of the 2005 sea urchin diver based survey, preliminary information on the distribution of commercially important beds of sea urchin was gathered from urchin logbooks and from confidential interviews with individual fishers. This information was used to define fishing locations of relative importance that would be included in the survey. The 2 subsequent surveys during the summers of 2006 and 2007 were based on this same information and on the results of the 2005 survey.

The coastline around Grand Manan was divided into the same fishing locations and was based on the same survey methods used during the 1992 survey (Robinson and MacIntyre 1993, 1995), (Figure 3). During 1992, each location was prioritized as high, medium or low importance based on fisher information. The coastline within each location was then divided into 250 m intervals and each potential transect was assigned a number. The position of each transect was selected so that they began at mean low water (MLW) and extended perpendicular to shore. In areas where water depth of less than 10 m extended longer distances from MLW, additional transects were placed further out at 250 m distance from MLW. Transects were then randomly selected within each location. The number of dive transects within each location was determined based on the size of each fishing location and weighted by an importance factor of high: medium: low, (3:2:1). For example, a high importance location was assigned 3 times as many dive transects as a low importance location of the same size.

During 2005, instead of randomly selecting new positions for the survey transects, each transect was located in the exact same coordinates as during the previous survey in 1992. The initial objective was to resurvey all transects that were previously surveyed in 1992. However, due to administrative delays, funding problems, survey vessel availability, and time constraint only transects located on the most important fishing grounds were revisited.

Transects were laid out with a collapsible 2-meter bar holding 150 m of 3/16” nylon rope wound on a rotating spool. The line was marked with twine markers every meter and with numbered tags every 10 m. At the end of each transect, one of the divers would collapse the bar and rewind the transect line on the rotating spool with the help of an attached handle.

Using this survey protocol, most transects began at MLW and continued perpendicular to shore up to a maximum distance of 150 m. GPS coordinates were recorded at the beginning of each transect along with a compass heading. Two divers swam side-by-side, jointly holding a 2 m long, foldable bar and counted the urchins as they passed under the bar 1 m on each side of the transect line. At every 10 m interval along the transect line, the divers recorded the numbers of urchins, noted their relative size, depth and bottom type. Macrophyte composition and other commercially important benthic species were recorded.

After the completion of each dive transect, a maximum of 4 size frequency samples of 100 urchins each were collected along each transect based on previously observed size characteristics and depth. The 4 samples were then brought up to the vessel, and the TD were measured to the nearest millimetre. Approximately thirty urchins of commercial size (≥ 51 mm

TD) were broken open and the roe was graded into 6 categories according to the following description:

**1. Grade A light:** The roe is a bright yellow color and has a very smooth, firm texture. The roe is 2.5 to 3 cm long and is divided into 2 clear distinct halves by a small vein running down the middle.

**2. Grade A dark:** The roe is a tangerine orange color and has a smooth, firm texture. The roe is 2.5 to 3 cm long and divided into 2 clear distinct halves by a small vein running down the middle.

**3. Grade B light:** The roe is a paler yellow color and has a smooth firm texture but softer than Grade A. The roe is 2.5 to 3 cm long and the 2 halves are less distinguishable.

**4. Grade B dark:** The roe is a paler orange color and has a smooth firm texture but softer than Grade A. The roe is 2.5 to 3 cm long and the 2 halves are less distinguishable.

**5. Grade C:** The roe is a dark yellow or orange color and has soft rough texture. The roe is 2 cm long and the 2 halves can still be differentiated.

**6. Poor quality roe:** The roe is red, brown, greyish brown or very dark in color and can be variable sizes. The roe has a very soft texture and has a rough or granular appearance with occasional whitish patches.

Roes rated into the first 4 categories are considered acceptable for market.

#### 3.2.2. Survey Methods (2006 and 2007)

Data from a subset of specifically selected transects during the 2006 and 2007 surveys were compared with sea urchin density data from corresponding transects that were sampled during the 1992 and 2005 survey periods (Figure 4). Because of the low number of transects sampled and the smaller bottom area covered, no biomass estimates were possible and no weight conversion was done. To calculate the total bottom area surveyed within each transect, the total length of each transect was multiplied by the 2 m width sampled along each transect. Along each transect, the density of urchins, in number of urchin per meter square (# urchin/m$^2$), was determined for each 10 m sections and the average density of urchin for each transect was determined by calculating the average density of urchins per square meter from the total number of 10 m section sampled. Subsequently, the overall average density of sea urchins from all sections and from all transects located in areas were fishing occurs, were combined and the overall density of urchins was calculated and compared with the density of urchin observed during previous survey periods. The same calculations were used for transects located in areas that were not fished and for those transects located in areas that were closed to fishing in 2006 (Figure 4).

The 2006 and 2007 surveys were designed so that a selected subset of transects were sampled where high fishing effort occurred during the 2005-06 and 2006-07 winter fishing seasons (Figure 4). In addition, 2 transects were resurveyed on urchin grounds where no fishing had ever occurred and 2 transects were surveyed in Cheney Passage and Cow Passage, areas that have been closed to urchin dragging during the fall of 2005 in order to prevent conflict with dulse harvesting.

### 3.2.3. Biomass Calculation

The sea urchin biomass was calculated for each location based on the urchins' size, density, and the relationship between the test diameter and wet weight. Within each location, the total bottom area was estimated for the section between the MLW and the 10 m stratum and the section between the 10 and 20 m stratum. Within each location, the density of sea urchins in number per meter square, was calculated separately for the 2 depth strata and then the total number and biomass of urchin were summed up for each location. Within each location, the dive transects data were pooled. The size-weight equation (Robinson and MacIntyre 1993, 1995) used in the conversion of the size frequency data is:

Weight (g) = 0.0009947 x Test Diameter (mm) $^{2.77}$.

As in the 1992 survey, the total number of urchin and the biomass were estimated for each location. Urchin densities, in number of urchins per square meters (Number of urchins/m$^2$), based on size groupings, locations, and depth strata were compared between survey periods using ANOVA analysis. In the analysis of variance, only the averages of all the mean densities from each location within each fishing area were compared between survey periods and depth strata.

# 4. RESULTS AND DISCUSSION

## 4.1. THE FISHERY

### 4.1.1. Landings

For the first 6 years, since the inception of this commercial fishery in 1989-90, landings increased dramatically until the 1995-96 fishing season (Table 1; Figure 2). A TAC of 979 t was established in 1996. The TAC was never reached. During the subsequent 4 years, landings remained above 830 t with the exception of the 1998-99 season when landings decreased to 581 t. After the 1999-2000 fishing season. landings began to decline. During the 2000-01 season, the TAC was reduced to 778 t. Only 734 t were landed that year and landings continued to decline. During the 2004-05 fishing season, the TAC was reduced to 590 t. Again the TAC was never reached and landings continued to decline. During the 2006-07 fishing season, the TAC was reduced to 176.9 t for Zone 1. That year, the reduced TAC was easily reached and 174 t was landed and another 165 t was landed the following year.

During the 2006-07 and 2007-08 seasons, an additional 8 t and 5 t, respectively, were landed by diving operators in Zone 2. During the 2001-02 season, 42 t of urchin were landed using divers. Prior to the 1996-97 fishing season, there were urchin landings from diving operations. However, these were not recorded separately in the landing statistics.

### 4.1.2. Catch Rates

Catch rate based on the analysis of logbook information can be presented in several ways using different units of effort. For comparison, the following 3 different units of catch rate were plotted by weekly periods for the last 4 fishing seasons: 1) average kilogram of urchin landed per fishing trip (kg/trip); 2) average kilogram of urchin landed per tow (kg/tow); and 3) average kilogram of urchin landed per hour of towing (kg/hour), (Figure 5). All 3 methods of analysis provided similar information as to the weekly fluctuation of catch rate throughout each season. For this reason, and based on the fact that reliable logbook information on the amount of urchin landed per trip is available since 1996, all catch rate information used in the analysis for this report is presented as the average kilogram of urchin landed per fishing trip (kg/trip), and the total number of fishing trips during each week or fishing season (Figures 6 and 7).

There has been a consistent decrease in CPUE (kg/trip) since 1996-97 (Figure 6). During the 2007-08 fishing season, catch rates increased for the first time in a decade to 922 kg/trip. This could be due to changes in abundance or the availability of urchins with marketable roe condition. The number of fishing trips has also declined since the 1999-00 fishing year to a low of 179 trips during the 2007-08 fishing season.

CPUE has elements of population abundance, but is influenced by discarding due to product quality and market prices. For these reasons, the weekly average catch rates based on logbook information do not seem to accurately reflect the actual changes in abundance that may occur throughout a fishing season (Figure 7). A good example of this occurred during the 2005-06 urchin fishing season, when fishers voluntarily stopped fishing approximately 5 weeks prior to the end of the regular fishing season because of concerns of the obvious decline of their marketable catches (Figure 7). However, during that season the weekly average catch rate in kg/trip stayed the same throughout the last 2 months of the season. Therefore, the CPUE series must be interpreted with caution, and cannot be used exclusively as an indicator of population abundance or even local abundance.

## 4.2. DIVER BASED SURVEYS (1992 VERSUS 2005)

During July and August of 2005, 46 dive transects were completed in the traditional fishing areas that were surveyed in 1992 (Figure 3; Table 2). Due to budget constraint and time limitation, only 63% of the 73 dive transects previously surveyed in 1992 were resurveyed in 2005. All the dive transects were located at the same place as those completed in 1992. For comparison with the 1992 survey, only data from locations resurveyed in 2005 (locations 76, 77, 78, 79, 80, 81, and 82) were used in the analysis (Figure 3; Table 2).

### 4.2.1. Size Structure (1992 versus 2005)

The proportion of legal size urchins (≥ 51 mm TD) was lower, within each location and in both depth strata during 2005 in comparison to 1992 (Figures 8 and 9; Table 3). The proportions of fishable urchins showed in Table 3 are weighted by the bottom area ($m^2$) represented in each location and those in Figures 7 and 8 are not. Therefore, the estimated percentages of fishable urchins in Table 3 are lower and more representative of the overall proportion of legal size urchins than those showed in Figures 8 and 9.

The overall proportions of legal size sea urchins declined from 60% (0 to 10 m depth strata) and 8% (> 10 m) in 1992, to 29% and 3%, respectively, in 2005 (Table 3). However, in 2005, the proportion of sub-legal size sea urchins (25 to 50 mm TD) in the 0 to 10 m depth stratum was higher (average across survey locations was 62% compared to 38%), (Table 3). In contrast, the proportion of sub-legal size urchin in deeper water > 10 m was lower in 2005 (59%) than in 1992 (83%). The overall proportion of immature urchins (<25 mm TD) was higher for both depth strata during 2005 (9% and 38%) in comparison to 1992 (2% and 9%), (Table 3).

### 4.2.2. Density (1992 versus 2005)

During 2005, the overall density of sea urchins (all sizes combined), was 12.9 urchins/$m^2$ in the shallow depth stratum (0 to 10 m) and 11.7 urchins/$m^2$ in the deeper depth stratum (11 to 20 m), (Table 4A). In 1992, the overall density of urchins was 8.4 urchins/$m^2$ in the shallow stratum and

16.6 urchins/m$^2$ in the deeper stratum. However, due to the high variability in urchin densities between locations there was no significant difference in the overall urchin densities between the 2 survey periods and between depth strata (Tables 4B).

During the 1992 and 2005 survey periods, the overall density of legal size urchins (≥ 51 mm TD) was 5.0 and 3.8 urchins/m$^2$, respectively, in shallow water in comparison to 1.6 and 0.4 urchin/m$^2$, respectively, in deeper water (Table 4A). However, due to the high variability in the density of urchins between locations there was no significant difference in the overall legal size urchin densities between the 2 survey periods (Table 4B). However, the density of legal size urchins (≥ 51 mm TD) was significantly higher in the shallow depth (0 – 10 m) strata in comparison to the deeper strata (> 10 m) during both survey periods (Table 4B).

During both survey periods and within each location the density of legal size sea urchins was always higher in the shallow depth stratum. In the 1992 survey, the highest densities of legal size urchins were found in the shallow depth stratum in locations 76, 77, 78, 79, and 80 (varied between 5.9 and 9.6 urchins/m$^2$), (Table 4). During 2005, the highest densities of legal size urchins were found in the shallow depth stratum in locations 76, 77, and 80 (varied between 3.9 and 9.3 urchins/m$^2$). The biggest decline in the density of legal size urchins occurred in locations 78 and 79 (6.2 and 5.9 urchins/m$^2$ during 1992 compared to 1.2 and 1.4 urchins/m$^2$ during 2005, respectively), (Table 4A).

There were no significant differences in the overall densities of sub-legal size sea urchins (25 to 50 mm TD) between the 2 survey periods and between depth strata (Table 4B). In the 0 to 10 m depth stratum, the density of sub-legal urchins was 8.1 urchins/m$^2$ in 2005 compared to 3.2 urchins/m$^2$ in 1992 (Table 4A). In deeper water > 10 m, the density of sub-legal urchins was 6.9 urchins/m$^2$ in 2005 compared to 13.6 urchins/m$^2$ in 1992.

The density of immature urchins (< 25 mm TD) was higher during 2005, in all depth strata and within each location (Table 4A), than in 1992. However, due to the high variability in urchin densities between locations, there were no significant differences in the overall densities of immature urchins (< 25 mm TD) between the 2 survey periods and between depth strata (Table 4B). The density of immature urchins in the 0 to 10 m depth stratum was 1.2 urchins/m$^2$ in 2005 compared to 0.2 urchins/m$^2$ in 1992 and, in deeper water > 10 m, was 4.4 urchins/m$^2$ in 2005 compared to 1.5 urchins/m$^2$ in 1992 (Table 4A).

#### 4.2.3. Biomass Estimate (1992 versus 2005)

During the 1992 survey, locations 72 to 75 and 83 to 89 were included in the overall biomass estimates (Robinson and MacIntyre 1993, 1995), (Figure 3; Table 2). According to urchin fishers, the roe quality of commercial size urchins in these locations never became of marketable quality all year round and the densities of legal size urchins remained low. These locations were not surveyed in 2005 and the biomass estimated from the 1992 survey for these locations was excluded from the biomass calculation in this report (Figure 3; Tables 2, 5 and 6).

During 2005, based on logbook information on fishing effort and landings, and due to time constraints, only locations 76 to 82 were resurveyed (Figure 3; Tables 2, 5 and 6). The 1992 biomass estimates were revised so as to reflect the equivalent locations surveyed during 2005. Based on the revised calculation, the total biomass estimated during 1992 was 23,785 t in comparison to a total biomass estimated of 22,016 t during 2005 (Table 7). This was equivalent to a total biomass reduction of only 7%. The total biomass estimated for the shallow depth stratum (0 to 10 m) was 20,164 t during 1992 in comparison to 20,369 t in 2005 (Table 7).

The updated biomass of legal size sea urchins (≥ 51 mm TD) during 1992 was estimated at 17,131 t in comparison to 11,462 t during 2005 a decrease of 5,669 t or 33% from 1992 (Table 7). The fishable biomass in the shallow depth strata was 16,267 t during 1992 compared to 11,211 t during 2005 a decrease of 5,056 t or 31%.

In 1996, a TAC of 979 t was established based on an estimated total biomass of legal size urchins of 29,879 t (3.3%), for all the locations surveyed during 1992 (Robinson and MacIntyre 1993, 1995; DFO 1996, 2000). Since 1992, the sea urchin fishery has mainly concentrated its fishing effort on the east side of Grand Manan in the shallow waters within locations 76 to 82 situated between Long Island, White Head Island, and Wood Island (Figure 3). During the 2005 summer survey, the legal size biomass was recalculated for only these fishing areas. While total biomass has changed little between the 2 survey periods, fishable biomass has declined by 33% from 17,131 t to 11,462 t (Table 7). The 2005 survey covered most of the fishing areas presently fished. During 2006-07, the TAC was reduced by 70% to 176.9 t. Consequently, based on the 2005 fishable biomass estimate of 11,462 t and a TAC of 176.9 t in 2007-08, the harvesting rate is estimated to have been reduced to 1.5%.

#### 4.2.4. Roe Quality (1992 versus 2005)

Sea urchin roe quality expressed as proportion of marketable roe prior to the opening of the fishery provides an indication of quality later in the year and may be important in the management of the fishery. At this time, data on roe quality from the July to September period is only available from surveys.

In order to be able to compare these data with roe quality data previously collected during the 1992 survey, only data that came from the same locations and season were used in the analysis. Data from July, August, and September 1992 and 2005 were compared (Figure 10; Table 8).

Based on survey data, roe quality had improved during 2005 in comparison to 1992, which is consistent with anecdotal information from the fishery and may reflect better growing conditions (i.e., food availability, water temperature, density dependant effects due to less crowding, etc). However, no data are available for the intervening years (Figure 10; Table 8). Traditionally, roe quality is higher during late fall and winter. Consequently, the high quality of urchin roe that was observed during the summer of 2005 emphasizes how much of an improvement occurred over the 13 years. The proportion of marketable roe increased within each location and overall from 50% to 75% between 1992 and 2005 (Table 8). Figure 9 shows the changes in categories of roe quality between 1992 and 2005 for each location individually and combined.

### 4.3. DIVER BASED SURVEYS (2006 AND 2007)

During July 2006, 7 commercial vessel days were required to complete 14 dive transects (Figure 4). Ten dive transects (G8, G9, G11, G12, G15, G18, G29, G58, G76, and G80) were located on the regular fishing grounds. One transect (G50) was located in an area where no fishing occurs and 2 other transects (G103, G104) were located in Cheney Passage and Cow Passage in areas that were closed to urchin dragging since 2006 in order to prevent conflict with dulse harvesting (Figure 4). Except for the last 2 transects (G103, G104), all the other dive transects were located at the same place as those completed in 1992 and 2005. For comparison with the 1992 and 2005 survey transects, only data from transects resurveyed in 2006 and 2007 were used in the analysis.

During July 2007, 7 commercial vessel days were required to complete 21 dive transects (Figure 4). Seventeen dive transects (G8, G9, G11, G12, G15, G16, G17, G18, G19, G29, G46, G49, G51, G52, G58, G76, and G80) were located on regular fishing grounds. Two transect (G23 and G50) were located as a “control” in areas never fished and 2 other transects (G103, G104) were located in Cheney Passage and Cow Passage, areas that were closed to urchin dragging in 2006 (Figure 4). An extra transect, G11B, was completed near G11, in order to survey an area where sub-legal urchins had been transferred during previous fishing seasons, as part of an enhancement experiment by the urchin fishers. Except for this transect (G11B), all transects were located in the same place as those either sampled in 2005 or 2006. For comparison with the 1992 and 2005 survey results, only transects resurveyed in 2006 or 2007 were used in the analysis.

### 4.3.1. Size Structure (2006 and 2007)

On the fishing grounds, the overall size structure of sea urchin sampled was similar between 2005, 2006, and 2007 (Figure 11). The overall proportion of legal size urchins (≥ 51 mm TD) in the fished areas, varied between 35% and 37% between the 3 survey years. However, the proportion of legal size urchin was much higher (varied between 67% and 71%) during 1992 in comparison to the recent years. Between 2005, 2006, and 2007, the proportion of sub-legal urchins (25 to 50 mm TD) varied between 57% and 61% (Figure 11). The proportion of sub-legal size urchin was much lower (varied between 27% and 32%) during the 1992 survey.

In the closed area (Transects G103 and G104), the proportion of legal size urchins (≥ 51 mm TD) was 93% in 2006 compared to 75% in 2007, and the proportion of sub-legal size urchins (25-50 mm TD) was 7% in 2006 compared to 25% in 2007 (Figures 4 and 11). Along transect G23 in an area that had never been fished, the proportion of legal size urchins was 90% in 1992 compared to 50% in 2005 and 44% in 2007. During 1992, the proportion of sub-legal size urchins along transect G23 was only 8%. However, there was little change in the proportion of sub-legal urchins between 2005 (50%) and 2007 (53%). Along transect G50 in an area never fished, no urchins of any size were found during 2007 in comparison to high numbers of urchins in 1992, 2005 and 2006 (Figures 4 and 11).

### 4.3.2. Density (2006 and 2007)

The overall density of sea urchins (all sizes combined) located in the fished areas was 17.4, 11.0 and 6.2 urchins/m$^2$ in 2005, 2006, and 2007, respectively (Table 9). When data from the extra transects that were sampled in 2007 were included, the overall density of urchins located in the fished areas was 19.9 urchins/m$^2$ in 2005 and 10.0 urchins/m$^2$ in 2007. The density of sea urchins estimated in 2007 (10.0 urchins/m$^2$) was similar to the density of urchins estimated in 1992 (12.2 urchins/m$^2$), (Table 9). Due to the high variability in urchin densities between transects, there was no significant difference in the overall urchin densities (all sizes combined) between survey periods (Table 12).

The density of urchins (all sizes combined) in the closed areas (G103 and G104) was 15.0 urchins/m$^2$ in 2007 as compared to 22.1 urchins/m$^2$ in 2006 (Figure 4; Table 9). Similarly, in the areas never fished, the overall density of urchins along transect G23 was 20.7 urchins/m$^2$ in 2005 compared to 13.5 urchins/m$^2$ in 2007. No urchins were found along transect G50 in 2007 where urchin densities of 18.9, 15.9 and 20.7 urchins/m$^2$ were estimated in 1992, 2005 and 2006, respectively (Figure 4; Table 9).

The overall density of legal size urchins (≥ 51 mm test diameter (TD)) located in the fished areas was significantly lower in 2006 (1.9 urchins/m$^2$) and 2007 (2.2 and 3.0 urchins/m$^2$) as compared to 1992 (6.4 and 6.7 urchins/m$^2$) and not significantly different than in 2005 (4.2 and 6.7 urchins/m$^2$), (Tables 10 and 12). The overall density of legal size urchins was not significantly different between 2005 and 1992.

The density of legal size urchins in the closed area (G103, G104) was 11.3 urchins/m$^2$ during 2007 in comparison to 20.5 urchins/m$^2$ in 2006 (Figure 4; Table 10). In 2006 and 2007, the density of legal size urchins in the closed area was higher (20.5 and 11.3 urchins/m$^2$) than the overall density of legal size urchins located in the fished areas (1.9 and 2.2 urchins/ m$^2$). The density of legal size urchins on transect G23 (area never fished) was 6.0 urchins/m$^2$ in 2007 in comparison to 6.8 urchins/m$^2$ in 1992 and 10.3 urchins/m$^2$ in 2005. During 2007, on transect G50 in another area not fished no urchins were found in comparison to significant numbers of legal size urchins in 1992 (7.7 urchins/m$^2$), 2005 (3.2 urchins/m$^2$) and 2006 (6.6 urchins/m$^2$), (Figure 4; Table 10).

Due to the high variability in urchin densities between transects there was no significant difference in the overall density of sub-legal size urchins (25-50 mm TD) between survey periods (Tables 11 and 12). The densities of sub-legal urchins was 3.1 and 5.2 urchins/m$^2$ in 1992, 12.8 and 12.3 urchins/m$^2$ in 2005, 8.3 and 13.5 urchins/m$^2$ in 2006, and 3.7 and 6.0 urchins/m$^2$ in 2007.

The density of sub-legal urchins in the closed area (G103, G104) was 1.6 urchins/m$^2$ in 2006 and 3.7 in 2007 (Figure 4; Table 11). Along transect G23 in an areas never fished, the density of sub-legal size urchins was 0.6 urchin/m$^2$ in 1992 in comparison to 10.4 urchin/m$^2$ in 2005 and 7.1 urchin/m$^2$ in 2007. Along transect G50, another area not fished, no urchins were found during 2007, even though high density of sub-legal size urchins were found during 2006 (13.5 urchin/m$^2$), 2005 (7.7 urchin/m$^2$), and 1992 (10.8 urchin/m$^2$), (Figure 4; Table 11).

### 4.4. AT-SEA OBSERVER SAMPLING (2007-08 FISHING SEASON)

During the 2007-08 urchin fishing season, at-sea observers sampled 5 fishing trips during the week of December 17 to 21, 2007 (Figure 12, see triangles), and 5 fishing trips during the week of January 7 to 11, 2008 (Figure 12, see circles). According to the observer, the urchin fishing grounds off Grand Manan Island are great feeding grounds. The area has a combination of strong tidal currents and many islands, and the bottom is mostly covered with kelp which provides a rich environment for urchin to feed on (Figure 12). According to the observer, the fishing strategy is to direct the dragging along the kelp lines where the largest urchins and best roe quality are found. These productive kelp lines are mostly located on the protected side of these small islands where eddies are created by the current rushing around these islands and creating very productive areas for kelp growth and subsequently creating prime feeding areas for urchins.

#### 4.4.1. By-catch

The limited at-sea observer sampling showed the by-catch amount varied between fishing areas but was consistent in the species type present (Table 13). In general, by-catch was low. Most of the by-catch consisted of a mixture of marine plants (mostly kelp) and shellfish which was mostly composed of blue mussels, green crab, hermit crab, and a variety of shrimp. Other shellfish consisted of rock crab, Jonah crab, and scallops. No lobsters were caught during any of the observed trips but according to fishers, the odd one is caught once in a while. A few, mostly juvenile fish, were also caught. Most of the fish captured consisted of sculpins, winter flounder, and ocean pout (Table 13).

The largest proportion of the weekly average by-catch contained kelp (36.2% and 14.1% for each sampling period, respectively) and blue mussels (3.1% and 3.2%, respectively), (Table 14). If the weight of kelp is subtracted as part of the by-catch, the proportion of blue mussel is increase to 4.9% and 3.7%, and all other species combined make up only 4.2% and 2.9% of the by-catch (Table 14). Based on observer reports, most of the by-catch, especially fish, is returned immediately to the water in good condition. Overall, the observer stated that the by-catch is very low compared to other drag fisheries and that the survival rate seemed to be high.

Based on the observer reports, although large amount of kelp is brought up in the urchin drags in some areas, fishers think that the impact of the drags on the bottom is minor. Observations based on the diving surveys during the summer shows that this may be the case. In most area surveyed, the bottom is covered with kelp and there is no evidence of dragging marks.

The relative proportion of kelp by-catch in the sea urchin trawl fishery is quite large. The kelp by-catch appears to be a combination of drift or wrack material and attached plants that are pulled off the bottom by the trawl. On a local scale, repeated trawls over the same kelp bed have the potential to reduce kelp density even if bottom 'trawl marks' are not observed. However, on a fishery-wide scale, the removal of urchin biomass can lead to greatly increased kelp cover overall due to the removal of herbivore pressure, more than compensating for local kelp loss due to the footprint of the trawl gear. The above notes need to be confirmed and quantified by future survey work.

### 4.4.2. Sea Urchin Catch Rate

Sea urchin catch rates based on the observer information varied substantially. The weekly catch rate of legal size urchins (≥ 51 mm TD) was 1,014 kg/trip (varied between 618 and 1,345 kg/trip) during December and 1,097 Kg/trip (varied between 526 and 2,210 kg/trip) in January. This variability in the catch rate was mainly due to the area fished and the availability of marketable quality roe. The proportion of the urchin catch that was discarded was 48% (41-52%) during December and 55% (37-62%) during January. Catch rates for the observed trips were approximately 1,000 kg/trip, which is similar to that of the overall catch rate for the fleet in 2007 (922 kg/trip).

### 4.4.3. Sea Urchin Size Distribution

The size distribution of sea urchin varied between trips, locations, and weekly periods. The proportion in weight of legal size urchins (≥ 51 mm TD) remained relatively high during both sampling periods. During December (17-21$^{st}$, 2007) and January (7-11$^{th}$ , 2008) a total of 1,870 and 1,586 urchins were measured, respectively (Figure 13). During December, the overall proportion in weight of legal size urchins averaged 84% and ranged from 71% to 98% between individual day trips. During January, the overall proportion in weight of legal size urchins was lower (77%), and the range was much larger (40% and 99%), (Figure 13). No juvenile urchins (5-25 mm TD) were present in any of the sampling.

## 5. CONCLUSIONS AND ADVICE

Since 1996, catch rates based on urchin dragger logbooks reached their lowest levels in the 2006-07 fishing season. During the 2007-08 fishing season, catch rates increased for the first time since 1996. However, CPUE has elements of population abundance, but is influenced by discarding due to product quality, yield, and market prices. Therefore, the CPUE series must be interpreted with caution, and cannot be used exclusively as an indicator of population abundance. Implementation of the new logbook format will facilitate collection and analysis of effort and harvesting rate data allowing the fishery to be more closely monitored on a timelier basis.

Legal sized sea urchins show no significant differences in density between the 1992 and 2005 surveys. Total biomass has changed little between the 2 survey periods and while estimated fishable biomass has declined, there is no statistically significant difference between the 2 surveys due to a high degree of variability. Survey designs biases may have been introduced because survey transect locations were not re-randomized for the most recent surveys (Waddell et al. 2003). Only 2 surveys are available, and are 13 years apart, and do not provide a time series to interpret biological characteristics. However, at a smaller scale the survey density of legal size urchins (≥ 51 mm TD) was significantly lower in 2006 (1.9 urchins/$m^2$) and 2007 (3.0 urchins/$m^2$) compared to 1992 (6.5 urchins/$m^2$).

The updated biomass, based on the 1992 survey was estimated to be 17,131 t compared to 11,462 t for the 2005 survey, a reduction of 5,669 t or 33%. No biomass survey has been conducted since 2005, so recent information is not available. However, based on the established TAC for the 2006-07 season of 176.9 t, the recent exploitation rates are estimated to be 1.5%, which is lower than the harvesting rate of 3.3% that was establish in 1996.

The 2005 survey can be used as a benchmark for the LFA 38 sea urchin fishery. The total fishable biomass that was estimated in 2005 covered most of the present day fishing grounds. Even if we assume that the harvesting rate has been low, the overall legal biomass has decreased over the last 18 years. For species that move little, there is a risk of serial depletion of the stock. This occurs when the highest density areas are fished first. Some of the lower density areas may not have been harvested because they were uneconomical to fish but still constitute part of the overall biomass. Therefore, it is possible that economic densities in fishable areas are more depleted than the total density for all the areas. A cautionary approach should be taken and a low harvesting rate should be maintained to ensure the long-term sustainability of this sea urchin fishery.

The diver based surveys are critical to the assessment of this resource and another survey including all fishing areas in LFA 38 is recommended in the next 2 to 3 years. Prior to any new survey a review of the survey design is recommended.

Fishery impacts on the ecosystem with respect to by-catch of non-urchin species and potential impact of urchin fishing on the habitat requires collection and processing of new information. At present, there is no at-sea observer coverage, which limits quantification of by-catch amounts by the dragger fleet and the ability to evaluate ecosystem impacts of the fishery by both divers and draggers.

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## 7. TABLES

*Table. 1. Lobster Fishing Area (LFA) 38 historical sea urchin landings in metric tons (t).*

| Season | Dragging | | Diving | | Total |
|---|---|---|---|---|---|
| | (t) | (% of total) | (t) | (% of total) | (t) |
| 1989-90 | | | | | 28 |
| 1990-91 | | | | | 203 |
| 1991-92 | | | | | 237 |
| 1992-93 | | | | | 428 |
| 1993-94 | | | | | 563 |
| 1994-95 | | | | | 721 |
| 1995-96 | | | | | 875 |
| 1996-97 | 872 | 100% | | 0% | 872 |
| 1997-98 | 883 | 100% | | 0% | 883 |
| 1998-99 | 581 | 100% | | 0% | 581 |
| 1999-00 | 830 | 100% | | 0% | 830 |
| 2000-01 | 734 | 100% | | 0% | 734 |
| 2001-02 | 574 | 93% | 42 | 7% | 616 |
| 2002-03 | 650 | 100% | | 0% | 650 |
| 2003-04 | 480 | 100% | | 0% | 480 |
| 2004-05 | 289 | 100% | | 0% | 289 |
| 2005-06 | 277 | 100% | | 0% | 277 |
| 2006-07 | 174 | 95% | 8 | 5% | 183 |
| 2007-08 | 165 | 97% | 5 | 3% | 170 |

*Table 2. The number of transects and the number of 10 m sections within each location surveyed during 1992 and 2005. Only locations with (*) were used for comparison with the 1992 survey.*

| Locations | 1992 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | Total bottom area fishable ($m^2$) | Total number of transects | Total number of sections | Total bottom area fishable ($m^2$) | Total number of transects | Total number of sections |
| 72 | 690,418 | 1 | 15 | | | |
| 73 | 553,234 | 2 | 28 | | | |
| 74 | 926,935 | 2 | 22 | | | |
| 75 | 1,907,005 | 1 | 15 | | | |
| **76*** | 7,165,601 | 10 | 150 | 7,165,601 | 10 | 150 |
| **77*** | 10,250,812 | 13 | 173 | 10,250,812 | 14 | 202 |
| **78*** | 4,162,613 | 3 | 45 | 4,162,613 | 3 | 45 |
| **79*** | 5,090,609 | 1 | 15 | 1,360,457 | 1 | 15 |
| **80*** | 7,647,292 | 4 | 60 | 7,647,292 | 3 | 45 |
| **81*** | 14,304,422 | 10 | 143 | 7,890,215 | 9 | 131 |
| **82*** | 8,278,504 | 5 | 64 | 8,025,818 | 5 | 75 |
| 83 | 840,352 | 1 | 15 | | | |
| 84 | 16,514,119 | 6 | 90 | | | |
| 85 | 6,847,613 | 3 | 45 | | | |
| 86 | 1,504,063 | 5 | 75 | | | |
| 87 | 17,925,261 | 4 | 49 | | | |
| 88 | 19,858,504 | | | | 1 | 15 |
| 89 | 6,224,158 | 2 | 30 | | | |
| **Total** | **130,691,515** | **73** | **1034** | **46,502,808** | **46** | **678** |

*Table 3. Percentage of legal size sea urchins (≥ 51 mm test diameter (TD)), sub-legal size urchins (25 to 50 mm TD), and immature urchins (< 25 mm TD) for each location during the 1992 and 2005 surveys (weighted by the bottom area represented in each location).*

| **1992 Survey Locations** | Legals (≥ 51 mm TD) | | | Sub-legals (25-50 mm TD) | | | Immature (< 25 mm TD) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m |
| 76 | 46% | 57% | 2% | 47% | 39% | 77% | 7% | 4% | 21% |
| 77 | 49% | 62% | 20% | 45% | 36% | 64% | 6% | 1% | 17% |
| 78 | 29% | 36% | 4% | 69% | 62% | 90% | 3% | 2% | 7% |
| 79 | 29% | 29% | | 67% | 67% | | 4% | 4% | |
| 80 | 31% | 78% | 2% | 68% | 22% | 97% | 1% | 1% | 2% |
| 81 | 92% | 92% | | 7% | 7% | | 0.2% | 0.2% | |
| 82 | 96% | 96% | | 2% | 2% | | 3% | 3% | |
| **Total** | **42%** | **60%** | **8%** | **53%** | **38%** | **83%** | **4%** | **2%** | **9%** |

| **2005 Survey Locations** | Legals (≥ 51 mm TD) | | | Sub-legals (25-50 mm TD) | | | Immature (< 25 mm TD) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m |
| 76 | 20% | 20% | 0% | 71% | 71% | 39% | 9% | 8% | 61% |
| 77 | 34% | 39% | 7% | 56% | 54% | 67% | 10% | 7% | 26% |
| 78 | 8% | 10% | 0% | 60% | 62% | 48% | 32% | 28% | 52% |
| 79 | 4% | 4% | | 75% | 75% | | 22% | 22% | |
| 80 | 17% | 30% | 2% | 62% | 67% | 56% | 21% | 3% | 42% |
| 81 | 59% | 59% | | 39% | 39% | | 2% | 2% | |
| 82 | 90% | 90% | | 8% | 8% | | 3% | 3% | |
| **Total** | **24%** | **29%** | **3%** | **61%** | **62%** | **59%** | **14%** | **9%** | **38%** |

*Table 4A. Mean densities (# urchins/m$^2$) of legal size urchins (≥ 51 mm test diameter (TD)), sub-legal size urchins (25 to 50 mm TD), and immature urchins (< 25 mm TD) for each location during the 1992 and 2005 surveys.*

| 1992 Survey | Total | | | Legals (≥ 51 mm TD) | | | Sub-legals (25-50 mm TD) | | | Immature (< 25 mm TD) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locations | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m |
| 76 | 11.2 | 11.1 | 11.6 | 5.1 | 6.4 | 0.2 | 5.3 | 4.4 | 8.9 | 0.8 | 0.4 | 2.5 |
| 77 | 16.2 | 14.3 | 22.5 | 7.9 | 8.9 | 4.4 | 7.3 | 5.2 | 14.3 | 1.0 | 0.2 | 3.7 |
| 78 | 10.3 | 17.2 | 4.4 | 2.9 | 6.2 | 0.2 | 7.1 | 10.7 | 4.0 | 0.3 | 0.3 | 0.3 |
| 79 | 20.4 | 20.4 | | 5.9 | 5.9 | | 3.6 | 13.6 | | 0.2 | 0.8 | |
| 80 | 17.1 | 12.4 | 22.4 | 5.3 | 9.6 | 0.3 | 11.5 | 2.7 | 21.7 | 0.2 | 0.1 | 0.3 |
| 81 | 2.4 | 2.4 | | 2.2 | 2.2 | | 0.2 | 0.2 | | 0.0 | 0.0 | |
| 82 | 0.2 | 0.2 | | 0.2 | 0.2 | | 0.0 | 0.0 | | 0.0 | 0.0 | |
| **Total** | **10.1** | **8.4** | **16.6** | **4.3** | **5.0** | **1.6** | **5.4** | **3.2** | **13.6** | **0.4** | **0.2** | **1.5** |

| 2005 Survey | Total | | | Legals (≥ 51 mm TD) | | | Sub-legals (25-50 mm TD) | | | Immature (< 25 mm TD) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locations | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m | Total | 0 to10 m | 11-20 m |
| 76 | 15.5 | 19.2 | 0.7 | 3.1 | 3.9 | 0.0 | 11.0 | 13.7 | 0.3 | 1.4 | 1.6 | 0.4 |
| 77 | 21.5 | 23.8 | 13.7 | 7.3 | 9.3 | 1.0 | 12.0 | 12.8 | 9.1 | 2.2 | 1.7 | 3.6 |
| 78 | 6.8 | 12.0 | 2.4 | 0.6 | 1.2 | 0.0 | 4.1 | 7.5 | 1.1 | 2.2 | 3.3 | 1.2 |
| 79 | 40.1 | 40.1 | | 1.4 | 1.4 | | 30.0 | 30.0 | | 8.7 | 8.7 | |
| 80 | 20.2 | 19.7 | 20.7 | 3.4 | 6.0 | 0.4 | 12.5 | 13.2 | 11.6 | 4.3 | 0.5 | 8.7 |
| 81 | 3.6 | 3.6 | | 2.1 | 2.1 | | 1.4 | 1.4 | | 0.06 | 0.06 | |
| 82 | 0.2 | 0.2 | | 0.2 | 0.2 | | 0.01 | 0.01 | | 0.0 | 0.00 | |
| **Total** | **12.9** | **13.2** | **11.7** | **3.1** | **3.8** | **0.4** | **7.9** | **8.1** | **6.9** | **1.9** | **1.2** | **4.4** |

*Table 4B. ANOVA analysis comparing urchin densities between the 1992 and 2005 survey periods for each size categories and depth strata (shallow < 10 m , deep 10-20 m; top) and between depth strata (bottom). *Urchin densities are significantly different at p < .05.*

| Survey Period | 1992 | | | | | All Sizes Combine | | 2005 | | | Anova | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nb of Samples | Mean Urchins /m² | Standard Error | 95% Confidence limit Lower | Upper | Nb of Samples | Mean Urchins /m² | Standard Error | 95% Confidence limit Lower | Upper | F | *Significantly different at p < .05 |
| **Shalow (0 -10 m)** | 7 | 11.1 | 2.8 | 4.3 | 18.0 | 7 | 16.9 | 5.1 | 4.5 | 29.3 | 1.0 | 0.336 |
| **Deep (> 10 m)** | 4 | 15.2 | 4.4 | 1.1 | 29.3 | 4 | 9.4 | 4.8 | -5.7 | 24.5 | 0.8 | 0.402 |
| **All Depth Combine** | 7 | 11.1 | 2.9 | 4.1 | 18.1 | 7 | 15.4 | 5.2 | 2.8 | 28.0 | 0.5 | 0.480 |
| **Legal ≥ 51 mmTD** | | | | | | | | | | | | |
| **Shalow (0 -10 m)** | 7 | 5.6 | 1.3 | 2.5 | 8.8 | 7 | 3.4 | 1.2 | 0.5 | 6.4 | 1.5 | 0.240 |
| **Deep (> 10 m)** | 4 | 1.3 | 1.0 | -2.0 | 4.6 | 4 | 0.4 | 0.2 | -0.4 | 1.1 | 0.8 | 0.420 |
| **All Depth Combine** | 7 | 4.2 | 1.0 | 1.8 | 6.6 | 7 | 2.6 | 0.9 | 0.4 | 4.8 | 1.5 | 0.246 |
| **Sub-Legal 25-50 mmTD** | | | | | | | | | | | | |
| **Shalow (0 -10 m)** | 7 | 5.3 | 2.0 | 0.5 | 10.0 | 7 | 11.2 | 3.8 | 2.0 | 20.5 | 2.0 | 0.186 |
| **Deep (> 10 m)** | 4 | 12.2 | 3.8 | 0.1 | 24.3 | 4 | 5.5 | 2.8 | -3.5 | 14.6 | 2.0 | 0.207 |
| **All Depth Combine** | 7 | 5.0 | 1.6 | 1.2 | 8.8 | 7 | 10.1 | 3.8 | 0.7 | 19.5 | 1.5 | 0.238 |
| **Immature 5-25 mm TD** | | | | | | | | | | | | |
| **Shalow (0 -10 m)** | 7 | 0.3 | 0.1 | 0.0 | 0.5 | 7 | 2.3 | 1.2 | -0.6 | 5.1 | 3.0 | 0.110 |
| **Deep (> 10 m)** | 4 | 1.7 | 0.8 | -1.0 | 4.4 | 4 | 3.5 | 1.9 | -2.5 | 9.4 | 0.7 | 0.420 |
| **All Depth Combine** | 7 | 0.4 | 0.1 | 0.0 | 0.7 | 7 | 2.7 | 1.1 | -0.1 | 5.5 | 4.1 | 0.066 |

| Survey Period | Shallow | | | | | All Sizes Combine | | Deep | | | Anova | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nb of Samples | Mean Urchins /m² | Standard Error | 95% Confidence limit Lower | Upper | Nb of Samples | Mean Urchins /m² | Standard Error | 95% Confidence limit Lower | Upper | F | *Significantly different at p < .05 |
| **1992** | 4 | 13.8 | 1.3 | 9.5 | 18.0 | 4 | 15.2 | 4.4 | 1.1 | 29.3 | 0.1 | 0.760 |
| **2005** | 4 | 18.7 | 2.5 | 10.9 | 26.5 | 4 | 9.4 | 4.8 | -5.7 | 24.5 | 3.0 | 0.133 |
| **Legal (≥ 51 mmTD)** | | | | | | | | | | | | |
| **1992** | 4 | 7.8 | 0.9 | 5.0 | 10.5 | 4 | 1.3 | 1.0 | -2.0 | 4.6 | 23.1 | ***0.003** |
| **2005** | 4 | 5.1 | 1.7 | -0.3 | 10.5 | 4 | 0.4 | 0.2 | -0.4 | 1.1 | 7.6 | ***0.033** |
| **Sub-Legal (25-50 mmTD)** | | | | | | | | | | | | |
| **1992** | 4 | 5.8 | 1.7 | 0.2 | 11.3 | 4 | 12.2 | 3.8 | 0.1 | 24.3 | 2.4 | 0.172 |
| **2005** | 4 | 11.8 | 1.4 | 7.2 | 16.4 | 4 | 5.5 | 2.8 | -3.5 | 14.6 | 3.9 | 0.096 |
| **Juvenile (5-25 mm TD)** | | | | | | | | | | | | |
| **1992** | 4 | 0.3 | 0.1 | 0.0 | 0.5 | 4 | 1.7 | 0.8 | -1.0 | 4.4 | 2.9 | 0.138 |
| **2005** | 4 | 1.8 | 0.6 | -0.1 | 3.6 | 4 | 3.5 | 1.9 | -2.5 | 9.4 | 0.8 | 0.418 |

*Table 5. Estimates of the mean, minimum and maximum number of sea urchins for individual locations according to the 0 to 10 m depth strata (A), the 11 to 20 m depth strata (B), and the sum of both depths strata (C), based on the 1992 and 2005 survey data.*

| (**A**) Locations | No of | Mean | Standard | 95 % CL | | Area m² | Number of urchins | 95 % CL | |
|---|---|---|---|---|---|---|---|---|---|
| (0 to 10 m) | Sections | #/m² | Error | Min.#/m² | Max. #/m² | | Total No. | Min. No. | Max. No. |
| 76 | 142 | 11.1 | 0.9 | 9.3 | 12.9 | 5,727,969 | 63,830,550 | 53,270,112 | 73,890,800 |
| 77 | 164 | 14.3 | 1.1 | 12.2 | 16.4 | 7,849,075 | 112,514,576 | 95,758,715 | 128,724,830 |
| 78 | 36 | 17.2 | 1.6 | 14.0 | 20.4 | 1,917,527 | 32,952,169 | 26,845,378 | 39,117,551 |
| 79 | 15 | 20.4 | 2.2 | 15.7 | 25.1 | 1,360,457 | 27,721,579 | 21,359,175 | 34,147,471 |
| 80 | 52 | 12.4 | 2.3 | 7.7 | 17.1 | 4,089,994 | 50,676,599 | 31,492,954 | 69,938,897 |
| 81 | 125 | 2.4 | 0.5 | 1.4 | 3.4 | 7,890,215 | 19,084,852 | 11,046,301 | 26,826,731 |
| 82 | 64 | 0.2 | 0.1 | -0.2 | 0.4 | 8,025,818 | 1,724,297 | -1,605,164 | 3,210,327 |
| **Total 1992** | **598** | **8.4** | **0.9** | **6.5** | **10.2** | **36,861,055** | **308,504,621** | **238,167,471** | **375,856,607** |
| 76 | 141 | 19.2 | 1.9 | 15.4 | 23.0 | 5,727,969 | 109,804,353 | 88,210,723 | 131,743,287 |
| 77 | 174 | 23.8 | 1.9 | 20.0 | 27.6 | 7,849,075 | 187,164,351 | 156,981,500 | 216,634,470 |
| 78 | 39 | 12.0 | 2.2 | 7.5 | 16.5 | 1,917,527 | 23,079,158 | 14,381,453 | 31,639,196 |
| 79 | 15 | 40.1 | 2.6 | 34.5 | 45.7 | 1,360,457 | 54,572,465 | 46,935,767 | 62,172,885 |
| 80 | 35 | 19.7 | 2.6 | 14.4 | 25.0 | 4,089,994 | 80,672,210 | 58,895,914 | 102,249,850 |
| 81 | 131 | 3.6 | 0.9 | 1.9 | 5.3 | 7,890,215 | 28,257,209 | 14,991,409 | 41,818,140 |
| 82 | 75 | 0.2 | 0.1 | 0.1 | 0.3 | 8,025,818 | 1,449,998 | 802,582 | 2,407,745 |
| **Total 2005** | **610** | **13.2** | **1.4** | **10.3** | **16.0** | **36,861,055** | **484,999,745** | **381,199,346** | **588,665,572** |

| (**B**) Locations | No of | Mean | Standard | 95 % CL | | Area m² | Number of urchins | 95 % CL | |
|---|---|---|---|---|---|---|---|---|---|
| (11 to 20 m) | Sections | #/m² | Error | Min.#/m² | Max. #/m² | | Total No. | Min. No. | Max. No. |
| 76 | 8 | 11.6 | 2.9 | 4.8 | 18.4 | 1,437,632 | 16,712,472 | 6,900,634 | 26,452,429 |
| 77 | 9 | 22.5 | 8.0 | 4.0 | 41.0 | 2,401,737 | 53,972,368 | 9,606,948 | 98,471,217 |
| 78 | 9 | 4.4 | 2.1 | -0.5 | 9.3 | 2,245,086 | 9,965,687 | -1,122,543 | 20,879,300 |
| 79 | | | | | | | | | |
| 80 | 8 | 22.4 | 2.1 | 17.5 | 27.3 | 3,557,298 | 79,794,641 | 62,252,715 | 97,114,235 |
| 81 | | | | | | | | | |
| 82 | | | | | | | | | |
| **Total 1992** | **34** | **16.6** | **3.7** | **8.1** | **25.2** | **9,641,753** | **160,445,168** | **77,637,754** | **242,917,181** |
| 76 | 9 | 0.7 | 0.4 | -0.3 | 1.7 | 1,437,632 | 974,395 | -431,290 | 2,443,974 |
| 77 | 28 | 13.7 | 4.3 | 5.0 | 22.4 | 2,401,737 | 32,946,685 | 12,008,685 | 53,798,909 |
| 78 | 6 | 2.4 | 1.9 | -2.4 | 7.2 | 2,245,086 | 5,313,370 | -5,388,206 | 16,164,619 |
| 79 | | | | | | | | | |
| 80 | 10 | 20.7 | 5.9 | 7.4 | 34.0 | 3,557,298 | 73,671,642 | 26,324,005 | 120,948,132 |
| 81 | | | | | | | | | |
| 82 | | | | | | | | | |
| **Total 2005** | **53** | **11.7** | **3.7** | **3.4** | **20.1** | **9,641,753** | **112,906,092** | **32,513,194** | **193,355,634** |

| (**C**) Locations | No of | Mean | Standard | 95 % CL | | Area m² | Number of urchins | 95 % CL | |
|---|---|---|---|---|---|---|---|---|---|
| (combined) | Sections | #/m² | Error | Min.#/m² | Max. #/m² | | Total No. | Min. No. | Max. No. |
| 76 | 150 | 11.2 | 1.4 | 8.4 | 14.0 | 7,165,601 | 80,543,022 | 60,170,745 | 100,343,229 |
| 77 | 173 | 16.2 | 3.0 | 10.3 | 22.2 | 10,250,812 | 166,486,943 | 105,365,663 | 227,196,047 |
| 78 | 45 | 10.3 | 2.1 | 6.4 | 14.4 | 4,162,613 | 42,917,856 | 25,722,835 | 59,996,851 |
| 79 | 15 | 20.4 | -6.8 | 4.2 | 6.7 | 1,360,457 | 27,721,579 | 21,359,175 | 34,147,471 |
| 80 | 60 | 17.1 | 2.4 | 12.3 | 21.8 | 7,647,292 | 130,471,239 | 93,745,669 | 167,053,133 |
| 81 | 125 | 2.4 | -0.1 | 0.8 | 2.3 | 7,890,215 | 19,084,852 | 11,046,301 | 26,826,731 |
| 82 | 64 | 0.2 | 0.1 | -0.2 | 0.4 | 8,025,818 | 1,724,297 | -1,605,164 | 3,210,327 |
| **Total 1992** | **632** | **10.1** | **1.2** | **6.8** | **13.3** | **46,502,808** | **468,949,789** | **315,805,224** | **618,773,788** |
| 76 | 150 | 15.5 | 1.6 | 12.3 | 18.7 | 7,165,601 | 110,778,748 | 87,779,433 | 134,187,261 |
| 77 | 202 | 21.5 | 2.5 | 16.5 | 26.4 | 10,250,812 | 220,111,036 | 168,990,185 | 270,433,379 |
| 78 | 45 | 6.8 | 2.3 | 2.2 | 11.5 | 4,162,613 | 28,392,529 | 8,993,246 | 47,803,815 |
| 79 | 15 | 40.1 | -14.0 | 9.2 | 12.2 | 1,360,457 | 54,572,465 | 46,935,767 | 62,172,885 |
| 80 | 45 | 20.2 | 4.5 | 11.1 | 29.2 | 7,647,292 | 154,343,852 | 85,219,919 | 223,197,982 |
| 81 | 131 | 3.6 | -0.3 | 1.0 | 2.9 | 7,890,215 | 28,257,209 | 14,991,409 | 41,818,140 |
| 82 | 75 | 0.2 | 0.1 | 0.1 | 0.3 | 8,025,818 | 1,449,998 | 802,582 | 2,407,745 |
| **Total 2005** | **663** | **12.9** | **1.3** | **8.9** | **16.8** | **46,502,808** | **597,905,837** | **413,712,540** | **782,021,207** |

*Table 6. Biomass calculations using mean numbers of urchins from Table 5 for individual location according to the 0 to 10 m depth strata (A), the 11 to 20 m depth strata (B) and all depths combined (C), based on the 1992 and 2005 survey data.*

| A | Total no. | Mean | Total Biomass (t) | | | Percent | Total Number of | Legal | Legal Size Biomass (t) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Locations | of urchins | Weight | | 95 % CL | | Fishable | Legal Size Urchins | Mean | | 95 % CL | |
| (0 to 10 m) | | (g) | Total (t) | Min (t) | Max (t) | % | (≥ 51 mm TD) | Wt. (g) | Total (t) | Min (t) | Max (t) |
| 76 | 63,830,550 | 64 | 4,055 | 3,384 | 4,694 | 57 | 36,468,740 | 90 | 3,278 | 2,735 | 3,794 |
| 77 | 112,514,576 | 64 | 7,187 | 6,117 | 8,223 | 62 | 70,187,963 | 82 | 5,770 | 4,910 | 6,601 |
| 78 | 32,952,169 | 48 | 1,572 | 1,281 | 1,866 | 36 | 11,895,940 | 76 | 909 | 741 | 1,080 |
| 79 | 27,721,579 | 41 | 1,145 | 882 | 1,411 | 29 | 8,037,618 | 73 | 585 | 450 | 720 |
| 80 | 50,676,599 | 75 | 3,796 | 2,359 | 5,238 | 78 | 39,401,212 | 86 | 3,373 | 2,096 | 4,654 |
| 81 | 19,084,852 | 114 | 2,172 | 1,257 | 3,053 | 92 | 17,629,228 | 120 | 2,117 | 1,225 | 2,976 |
| 82 | 1,724,297 | 138 | 237 | -221 | 442 | 96 | 1,648,859 | 143 | 236 | -220 | 440 |
| **Total 1992** | **308,504,621** | **65** | **20,164** | **15,567** | **24,566** | **60** | **185,269,560** | **88** | **16,267** | **12,558** | **19,819** |
| 76 | 109,804,353 | 36 | 3,936 | 3,162 | 4,723 | 20 | 22,322,431 | 69 | 1,534 | 1,232 | 1,840 |
| 77 | 187,164,351 | 49 | 9,199 | 7,715 | 10,647 | 39 | 72,731,663 | 82 | 5,965 | 5,003 | 6,905 |
| 78 | 23,079,158 | 22 | 497 | 310 | 681 | 10 | 2,307,916 | 67 | 154 | 96 | 211 |
| 79 | 54,572,465 | 22 | 1,186 | 1,020 | 1,351 | 4 | 1,936,442 | 68 | 132 | 113 | 150 |
| 80 | 80,672,210 | 45 | 3,613 | 2,638 | 4,579 | 30 | 24,597,485 | 75 | 1,856 | 1,355 | 2,353 |
| 81 | 28,257,209 | 63 | 1,783 | 946 | 2,639 | 59 | 16,680,761 | 85 | 1,420 | 753 | 2,101 |
| 82 | 1,449,998 | 107 | 155 | 86 | 257 | 90 | 1,301,280 | 115 | 150 | 83 | 249 |
| **Total 2005** | **484,999,745** | **42** | **20,369** | **16,010** | **24,723** | **29** | **141,877,978** | **79** | **11,211** | **8,811** | **13,607** |

| B | Total no. | Mean | Total Biomass (t) | | | Percent | Total Number of | Legal | Legal Size Biomass (t) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Locations | of urchins | Weight | | 95 % CL | | Fishable | Legal Size Urchins | Mean | | 95 % CL | |
| (11 to 20 m) | | (g) | Total (t) | Min (t) | Max (t) | % | (≥ 51 mm TD) | Wt. (g) | Total (t) | Min (t) | Max (t) |
| 76 | 16,712,472 | 15 | 248 | 103 | 393 | 2 | 332,036 | 69 | 23 | 9 | 36 |
| 77 | 53,972,368 | 27 | 1453 | 259 | 2,652 | 20 | 10,645,069 | 69 | 733 | 130 | 1,337 |
| 78 | 9,965,687 | 19 | 190 | -21 | 398 | 4 | 369,100 | 64 | 24 | -3 | 49 |
| 79 | | | | | | | | | | | |
| 80 | 79,794,641 | 22 | 1729 | 1,349 | 2,104 | 2 | 1,233,938 | 69 | 85 | 66 | 103 |
| 81 | | | | | | | | | | | |
| 82 | | | | | | | | | | | |
| **Total 1992** | **160,445,168** | **23** | **3,621** | **1,689** | **5,547** | **8** | **12,580,142** | **69** | **864** | **418** | **1,308** |
| 76 | 974,395 | 6 | 6 | -3 | 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| 77 | 32,946,685 | 20 | 661 | 241 | 1,079 | 7 | 2,376,915 | 67 | 159 | 58 | 259 |
| 78 | 5,313,370 | 7 | 38 | -39 | 117 | 0 | 0 | 0 | 0 | 0 | 0 |
| 79 | | | | | | | | | | | |
| 80 | 73,671,642 | 13 | 942 | 337 | 1,547 | 2 | 1,466,102 | 63 | 93 | 33 | 153 |
| 81 | | | | | | | | | | | |
| 82 | | | | | | | | | | | |
| **Total 2005** | **112,906,092** | **15** | **1,647** | **536** | **2,758** | **3** | **3,843,017** | **66** | **252** | **72** | **431** |

| C | Total no. | Mean | Total Biomass (t) | | | Percent | Total Number of | Legal | Legal Size Biomass (t) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Locations | of urchins | Weight | | 95 % CL | | Fishable | Legal Size Urchins | Mean | | 95 % CL | |
| (combined) | | (g) | Total (t) | Min (t) | Max (t) | % | (≥ 51 mm TD) | Wt. (g) | Total (t) | Min (t) | Max (t) |
| 76 | 80,543,022 | 53 | 4,303 | 3,213 | 5,358 | 46 | 36,800,776 | 90 | 3,301 | 2,466 | 4,112 |
| 77 | 166,486,943 | 52 | 8,641 | 5,466 | 11,786 | 49 | 80,833,032 | 80 | 6,502 | 4,115 | 8,873 |
| 78 | 42,917,856 | 41 | 1,762 | 1,057 | 2,466 | 29 | 12,265,040 | 76 | 933 | 559 | 1,304 |
| 79 | 27,721,579 | 41 | 1,145 | 882 | 1,410 | 29 | 8,037,618 | 73 | 585 | 450 | 720 |
| 80 | 130,471,239 | 42 | 5,525 | 3,974 | 7,082 | 31 | 40,635,150 | 85 | 3,457 | 2,484 | 4,427 |
| 81 | 19,084,852 | 121 | 2,172 | 1,333 | 3,236 | 92 | 17,629,228 | 120 | 2,117 | 1,225 | 2,976 |
| 82 | 1,724,297 | 138 | 237 | -221 | 442 | 96 | 1,648,859 | 143 | 236 | -220 | 440 |
| **Total 1992** | **468,949,789** | **51** | **23,785** | **15,704** | **31,781** | **42** | **197,849,702** | **87** | **17,131** | **11,537** | **22,604** |
| 76 | 110,778,748 | 36 | 3,942 | 3,119 | 4,768 | 20 | 22,322,431 | 69 | 1,534 | 1,215 | 1,858 |
| 77 | 220,111,036 | 45 | 9,859 | 7,563 | 12,104 | 34 | 75,108,578 | 82 | 6,124 | 4,702 | 7,524 |
| 78 | 28,392,529 | 19 | 535 | 169 | 898 | 8 | 2,307,916 | 67 | 154 | 49 | 259 |
| 79 | 54,572,465 | 22 | 1,186 | 1,019 | 1,349 | 4 | 1,936,442 | 68 | 132 | 113 | 150 |
| 80 | 154,343,852 | 30 | 4,555 | 2,516 | 6,589 | 17 | 26,063,587 | 75 | 1,949 | 1,076 | 2,819 |
| 81 | 28,257,209 | 63 | 1,783 | 946 | 2,639 | 59 | 16,680,761 | 85 | 1,420 | 753 | 2,101 |
| 82 | 1,449,998 | 107 | 155 | 86 | 257 | 90 | 1,301,280 | 115 | 150 | 83 | 249 |
| **Total 2005** | **597,905,837** | **37** | **22,016** | **15,417** | **28,604** | **24** | **145,720,995** | **79** | **11,462** | **7,931** | **14,992** |

*Table 7. Summary of biomass estimates in metric tons (t) and 95% confidence limits (95% CL) for each individual location according to the 0 to 10 m depth strata (A), the 11 to 20 m depth strata (B), and all depths combined (C), based on the 1992 and 2005 survey data.*

| | Total Biomass (t) | | | | | |
|---|---|---|---|---|---|---|
| | 1992 | | | 2005 | | |
| **Locations** | **0 to 10 m** | **11 to 20 m** | **Total** | **0 to 10 m** | **11 to 20 m** | **Total** |
| **76** | 4,055 | 248 | 4,303 | 3,936 | 6 | 3,942 |
| **77** | 7,187 | 1,453 | 8,641 | 9,199 | 661 | 9,860 |
| **78** | 1,572 | 190 | 1,762 | 497 | 38 | 535 |
| **79** | 1,145 | | 1,145 | 1,186 | | 1,186 |
| **80** | 3,796 | 1,729 | 5,525 | 3,613 | 942 | 4,555 |
| **81** | 2,172 | | 2,172 | 1,783 | | 1,783 |
| **82** | 237 | | 237 | 155 | | 155 |
| **Total** | **20,164** | **3,621** | **23,785** | **20,369** | **1,647** | **22,016** |

| | Legal Biomass (≥ 51 mm TD) (t) | | | | | |
|---|---|---|---|---|---|---|
| | 1992 | | | 2005 | | |
| **Locations** | **0 to 10 m** | **11 to 20 m** | **Total** | **0 to 10 m** | **11 to 20 m** | **Total** |
| **76** | 3,278 | 23 | 3,301 | 1,534 | 0 | 1,534 |
| **77** | 5,770 | 733 | 6,502 | 5,965 | 159 | 6,124 |
| **78** | 909 | 24 | 933 | 154 | 0 | 154 |
| **79** | 585 | | 585 | 132 | | 132 |
| **80** | 3,373 | 85 | 3,457 | 1,856 | 93 | 1,949 |
| **81** | 2,117 | | 2,117 | 1,420 | | 1,420 |
| **82** | 236 | | 236 | 150 | | 150 |
| **Total** | **16,267** | **864** | **17,131** | **11,211** | **252** | **11,462** |

*Table 8. Roe quality expressed as the percent of marketable legal size sea urchins sampled for each location and depth strata. Egg stages 1 to 4 classified as marketable.*

| 1992 | 0 - 10 meters | | 10-20 meters | | Combined | |
|---|---|---|---|---|---|---|
| **Locations** | **Total No. of Urchins Sampled** | **Percent Marketable** | **Total No. of Urchins Sampled** | **Percent Marketable** | **Total No. of Urchins Sampled** | **Percent Marketable** |
| 76 | 817 | 61% | 3 | 0% | 820 | 61% |
| 77 | 901 | 54% | 33 | 52% | 934 | 54% |
| 78 | 147 | 27% | | | 147 | 27% |
| 79 | 71 | 30% | | | 71 | 30% |
| 80 | 256 | 30% | 10 | 30% | 266 | 30% |
| 81 | 397 | 42% | 25 | 60% | 422 | 43% |
| 82 | 62 | 58% | | | 62 | 58% |
| **Total** | **2651** | **50%** | **71** | **49%** | **2722** | **50%** |

| 2005 | 0 - 10 meters | | 10-20 meters | | Combined | |
|---|---|---|---|---|---|---|
| **Locations** | **Total No. of Urchins Sampled** | **Percent Marketable** | **Total No. of Urchins Sampled** | **Percent Marketable** | **Total No. of Urchins Sampled** | **Percent Marketable** |
| 76 | 476 | 89% | | | 476 | 89% |
| 77 | 615 | 67% | 55 | 93% | 670 | 69% |
| 78 | 40 | 83% | | | 40 | 83% |
| 79 | 19 | 58% | | | 19 | 58% |
| 80 | 170 | 65% | 9 | 33% | 179 | 63% |
| 81 | 198 | 80% | | | 198 | 80% |
| 82 | 89 | 69% | 11 | 18% | 100 | 63% |
| **Total** | **1607** | **75%** | **75** | **75%** | **1682** | **75%** |

*Table 9. Calculation of mean densities (#/m$^2$) and the estimated number of sea urchins of all sizes for each transects and for combined transects during the 2005 (A), 2006 (B), 2007 (C), and 1992 (D) dive surveys.*

| (A) 2005 | No of | Mean | | STD | | Min | Max | Area | Estimated # of urchins | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | Sections | #/m² | SD | ERROR | 95% CL | #/m² | #/m² | m² | Total No. | Min. No | Max. No |
| G8 | 15 | 55.2 | 13.9 | 3.6 | 7.7 | 47.5 | 62.9 | 300 | 16,560 | 14,250 | 18,870 |
| G9 | 15 | 10.6 | 12.4 | 3.2 | 6.9 | 3.7 | 17.5 | 300 | 3,180 | 1,110 | 5,250 |
| G11 | 15 | 16.2 | 13.9 | 3.6 | 7.7 | 8.5 | 23.9 | 300 | 4,860 | 2,550 | 7,170 |
| G12 | 15 | 3.6 | 7.3 | 1.9 | 4.0 | -0.4 | 7.6 | 300 | 1,080 | -120 | 2,280 |
| G15 | 15 | 5.1 | 3.9 | 1.0 | 2.2 | 2.9 | 7.3 | 300 | 1,530 | 870 | 2,190 |
| ***G16** | 15 | 1.5 | 1.9 | 0.5 | 1.1 | 0.4 | 2.6 | 300 | 450 | 120 | 780 |
| ***G17** | 15 | 5.6 | 7.3 | 1.9 | 4.1 | 1.5 | 9.7 | 300 | 1,680 | 450 | 2,910 |
| G18 | 15 | 21.9 | 11.2 | 2.9 | 6.2 | 15.7 | 28.1 | 300 | 6,570 | 4,710 | 8,430 |
| ***G19** | 15 | 30.6 | 26.7 | 6.9 | 14.8 | 15.8 | 45.4 | 300 | 9,180 | 4,740 | 13,620 |
| G29 | 15 | 0.3 | 1.2 | 0.3 | 0.7 | -0.4 | 1.0 | 300 | 90 | -120 | 300 |
| G46 | 15 | 41.3 | 20.3 | 5.3 | 11.3 | 30.0 | 52.6 | 300 | 12,390 | 9,000 | 15,780 |
| ***G49** | 7 | 44.5 | 29.6 | 8.9 | 21.8 | 22.7 | 66.3 | 140 | 6,230 | 3,178 | 9,282 |
| ***G51** | 15 | 62.6 | 50.0 | 12.9 | 27.7 | 34.9 | 90.3 | 300 | 18,780 | 10,470 | 27,090 |
| ***G52** | 15 | 14.4 | 6.7 | 1.7 | 3.7 | 10.7 | 18.1 | 300 | 4,320 | 3,210 | 5,430 |
| G58 | 11 | 29.4 | 18.8 | 5.7 | 12.6 | 16.8 | 42.0 | 220 | 6,468 | 3,696 | 9,240 |
| G76 | 15 | 11.1 | 5.3 | 1.40 | 3.0 | 8.1 | 14.1 | 300 | 3,330 | 2,430 | 4,230 |
| G80 | 15 | 0.3 | 0.6 | 0.1 | 0.3 | 0.0 | 0.6 | 300 | 90 | 0 | 180 |
| **Total Fished Area (2005-06)** | **161** | **17.4** | **20.5** | **1.6** | **3.2** | **14.2** | **20.6** | **3220** | **56,148** | **45,844** | **66,452** |
| ***Total Fished Area (2005-07)** | **243** | **19.9** | **25.7** | **1.6** | **3.2** | **16.7** | **23.1** | **4860** | **96,788** | **81,236** | **112,340** |
| **G50 Area Not Fished** | **15** | **15.9** | **19.3** | **5.0** | **10.7** | **5.2** | **26.6** | **300** | **4,770** | **1,560** | **7,980** |
| **G23 Area Not Fished** | **15** | **20.7** | **10.3** | **2.7** | **5.7** | **15.0** | **26.4** | **300** | **6,210** | **4,500** | **7,920** |

| (B) 2006 | No of | Mean | | STD | | Min | Max | Area | Estimated # of urchins | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | Sections | #/m² | SD | ERROR | 95% CL | #/m² | #/m² | m² | Total No. | Min. No | Max. No |
| G8 | 15 | 39.8 | 7.3 | 1.9 | 4.1 | 35.7 | 43.9 | 300 | 11,940 | 10,710 | 13,170 |
| G9 | 15 | 6.5 | 8.2 | 2.1 | 4.5 | 2.0 | 11.0 | 300 | 1,950 | 600 | 3,300 |
| G11 | 15 | 1.1 | 2.7 | 1.1 | 1.5 | -0.4 | 2.6 | 300 | 330 | -120 | 780 |
| G12 | 15 | 1.6 | 5.6 | 1.4 | 3.1 | -1.5 | 4.7 | 300 | 480 | -450 | 1,410 |
| G15 | 14 | 4.4 | 5.9 | 1.6 | 3.4 | 1.0 | 7.8 | 280 | 1,232 | 280 | 2,184 |
| G18 | 14 | 24.3 | 22.4 | 6.0 | 12.9 | 11.4 | 37.2 | 280 | 6,804 | 3,192 | 10,416 |
| G29 | 12 | 2.3 | 3.6 | 1.0 | 2.3 | 0.0 | 4.6 | 240 | 552 | 0 | 1,104 |
| G46 | 15 | 31.1 | 20.1 | 5.2 | 11.1 | 20.0 | 42.2 | 300 | 9,330 | 6,000 | 12,660 |
| G58 | 15 | 0.9 | 1.9 | 0.5 | 1.0 | -0.1 | 1.9 | 300 | 270 | -30 | 570 |
| G76 | 15 | 7.4 | 4.7 | 1.20 | 2.6 | 4.8 | 10.0 | 300 | 2,220 | 1,440 | 3,000 |
| G80 | 15 | 0.6 | 0.9 | 0.2 | 0.5 | 0.1 | 1.1 | 300 | 180 | 30 | 330 |
| G103 (Closed) | 10 | 23.3 | 4.4 | 1.4 | 3.2 | 20.1 | 26.5 | 200 | 4,660 | 4,020 | 5,300 |
| G104 (Closed) | 11 | 21.1 | 6.6 | 2.0 | 4.4 | 16.7 | 25.5 | 220 | 4,642 | 3,674 | 5,610 |
| **Total Area Fished** | **160** | **11.0** | **16.7** | **1.3** | **2.6** | **8.4** | **13.6** | **3200** | **35,288** | **26,968** | **43,608** |
| **G50 Area Not Fished** | **15** | **20.7** | **26.0** | **6.7** | **14.4** | **6.3** | **35.1** | **300** | **6,210** | **1,890** | **10,530** |
| **Total Close Area G103+G104** | **21** | **22.1** | **5.6** | **1.2** | **2.6** | **19.5** | **24.7** | **420** | **9,302** | **8,210** | **10,394** |

| (C) 2007 | No of | Mean | | STD | | Min | Max | Area | Estimated # of urchins | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | Sections | #/m² | SD | ERROR | 95% CL | #/m² | #/m² | m² | Total No. | Min. No | Max. No |
| G8 | 15 | 7.1 | 3.4 | 0.9 | 1.9 | 5.2 | 9.0 | 300 | 2,130 | 1,560 | 2,700 |
| G9 | 15 | 0.4 | 0.7 | 0.2 | 0.4 | 0.0 | 0.8 | 300 | 120 | 0 | 240 |
| G11 | 15 | 0.3 | 0.4 | 0.1 | 0.2 | 0.1 | 0.5 | 300 | 90 | 30 | 150 |
| G12 | 15 | 2.0 | 6.4 | 1.7 | 3.5 | -1.5 | 5.5 | 300 | 600 | -450 | 1,650 |
| G15 | 15 | 8.2 | 3.8 | 1.0 | 2.1 | 6.1 | 10.3 | 300 | 2,460 | 1,830 | 3,090 |
| ***G16** | 15 | 1.1 | 1.5 | 0.4 | 0.8 | 0.3 | 1.9 | 300 | 330 | 90 | 570 |
| ***G17** | 15 | 8.8 | 3.9 | 1.0 | 2.2 | 6.6 | 11.0 | 300 | 2,640 | 1,980 | 3,300 |
| G18 | 15 | 21.6 | 8.5 | 2.2 | 4.7 | 16.9 | 26.3 | 300 | 6,480 | 5,070 | 7,890 |
| ***G19** | 10 | 42.8 | 23.0 | 7.3 | 16.5 | 26.3 | 59.3 | 200 | 8,560 | 5,260 | 11,860 |
| G29 | 15 | 3.1 | 5.4 | 1.4 | 3.0 | 0.1 | 6.1 | 300 | 930 | 30 | 1,830 |
| G46 | 15 | 14.8 | 9.7 | 2.5 | 5.4 | 9.4 | 20.2 | 300 | 4,440 | 2,820 | 6,060 |
| ***G49** | 15 | 22.0 | 13.2 | 3.4 | 7.3 | 14.7 | 29.3 | 300 | 6,600 | 4,410 | 8,790 |
| ***G51** | 15 | 20.9 | 8.7 | 2.3 | 4.8 | 16.1 | 25.7 | 300 | 6,270 | 4,830 | 7,710 |
| ***G52** | 11 | 17.9 | 13.8 | 4.2 | 9.3 | 8.6 | 27.2 | 220 | 3,938 | 1,892 | 5,984 |
| G58 | 15 | 7.7 | 5.0 | 1.3 | 2.8 | 4.9 | 10.5 | 300 | 2,310 | 1,470 | 3,150 |
| G76 | 15 | 1.6 | 1.5 | 0.40 | 0.8 | 0.8 | 2.4 | 300 | 480 | 240 | 720 |
| G80 | 15 | 3.4 | 5.5 | 1.4 | 3.1 | 0.3 | 6.5 | 300 | 1,020 | 90 | 1,950 |
| **Total Fished Area (2007-06)** | **165** | **6.4** | **8.2** | **0.6** | **1.3** | **5.1** | **7.7** | **3300** | **21060** | **16,770** | **25,350** |
| ***Total Fished Area (2007-05)** | **246** | **10.0** | **12.8** | **0.8** | **1.6** | **8.4** | **11.6** | **4920** | **49398** | **41,526** | **57,270** |
| **G50 Area Not Fished** | **15** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **300** | **0** | **0** | **0** |
| **G23 Area Not Fished** | **15** | **13.5** | **11.4** | **2.9** | **6.3** | **7.2** | **19.8** | **300** | **4,050** | **2,160** | **5,940** |
| **Total Close Area G103+G104** | **21** | **15.0** | **6.0** | **1.3** | **2.7** | **12.3** | **17.7** | **420** | **6,298** | **5,164** | **7,432** |

*Table 9. Continued.*

| (D) 1992 | No of | Mean | | STD | | Min | Max | Area | Estimated # of urchins | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Transect** | **Sections** | **#/m²** | **SD** | **ERROR** | **95% CL** | **#/m²** | **#/m²** | **m²** | **Total No.** | **Min. No** | **Max. No** |
| G8 | 15 | 20.6 | 12.4 | 3.2 | 6.9 | 13.7 | 27.5 | 300 | 6,180 | 4,110 | 8,250 |
| G9 | 15 | 17.6 | 5.5 | 1.4 | 3.1 | 14.5 | 20.7 | 300 | 5,280 | 4,350 | 6,210 |
| G11 | 15 | 6.6 | 4.7 | 1.2 | 2.6 | 4.0 | 9.2 | 300 | 1,980 | 1,200 | 2,760 |
| G12 | 15 | 7.7 | 3.3 | 0.9 | 1.8 | 0.0 | 9.5 | 300 | 2,310 | 0 | 2,850 |
| G15 | 15 | 10.3 | 6.1 | 1.6 | 3.4 | 6.9 | 13.7 | 300 | 3,090 | 2,070 | 4,110 |
| ***G16** | 15 | 1.1 | 1.0 | 0.2 | 0.5 | 0.6 | 1.6 | 300 | 330 | 180 | 480 |
| ***G17** | 15 | 15.1 | 7.0 | 1.8 | 3.9 | 11.2 | 19.0 | 300 | 4,530 | 3,360 | 5,700 |
| G18 | 15 | 9.1 | 2.5 | 0.6 | 1.4 | 7.7 | 10.5 | 300 | 2,730 | 2,310 | 3,150 |
| ***G19** | 15 | 8.5 | 2.5 | 0.6 | 1.4 | 7.1 | 9.9 | 300 | 2,550 | 2,130 | 2,970 |
| G29 | 15 | 0.2 | 0.2 | 0.1 | 0.2 | 0.0 | 0.4 | 300 | 60 | 0 | 120 |
| G46 | 15 | 2.6 | 3.2 | 0.8 | 1.8 | 0.8 | 4.4 | 300 | 780 | 240 | 1,320 |
| ***G49** | 15 | 45.8 | 16.3 | 4.2 | 9.0 | 36.8 | 54.8 | 300 | 13,740 | 11,040 | 16,440 |
| ***G51** | 15 | 21.3 | 10.8 | 2.8 | 6.0 | 15.3 | 27.3 | 300 | 6,390 | 4,590 | 8,190 |
| ***G52** | 15 | 6.7 | 3.2 | 0.8 | 1.8 | 4.9 | 8.5 | 300 | 2,010 | 1,470 | 2,550 |
| G58 | 15 | 15.6 | 9.2 | 2.4 | 5.1 | 10.5 | 20.7 | 300 | 4,680 | 3,150 | 6,210 |
| G76 | 15 | 8.9 | 1.8 | 0.50 | 1.0 | 7.9 | 9.9 | 300 | 2,670 | 2,370 | 2,970 |
| G80 | 4 | 2.0 | 2.2 | 1.1 | 3.4 | -1.4 | 5.4 | 80 | 160 | -112 | 432 |
| **Total Fished Area (1992-2006)** | **154** | **9.7** | **8.4** | **0.7** | **1.3** | **8.4** | **11.0** | **3080** | **29,920** | **25,916** | **33,924** |
| ***Total Fished Area (1992-2007)** | **244** | **12.2** | **12.7** | **0.8** | **1.6** | **10.6** | **13.8** | **4880** | **59,470** | **51,662** | **67,278** |
| **G50 Area Not Fished** | **15** | **18.9** | **7.6** | **2.0** | **4.2** | **14.7** | **23.1** | **300** | **5,670** | **4,410** | **6,930** |
| **G23 Area Not Fished** | **15** | **7.6** | **2.1** | **0.5** | **1.2** | **6.4** | **8.8** | **300** | **2,280** | **1920** | **2640** |

**Includes the equivalent extra transects that were surveyed in 2007.*

*Table 10. Calculation of mean densities (#/$m^2$) and the estimated number of legal size urchins (≥ 51 mm test diameter (TD)) for each transects and for combined transects during the 2005 (A), 2006 (B), 2007 (C), and 1992 (D) dive surveys.*

| (A) 2005 | All size urchins | | Percent | Legal size urchins (≥ 51 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 16,560 | 2,310 | 10 | 1,722 | 240 | 300 | 5.7 | 4.9 | 6.5 |
| G9 | 3,180 | 2,070 | 45 | 1,444 | 940 | 300 | 4.8 | 1.7 | 7.9 |
| G11 | 4,860 | 2,310 | 22 | 1,074 | 511 | 300 | 3.6 | 1.9 | 5.3 |
| G12 | 1,080 | 1,200 | 45 | 489 | 544 | 300 | 1.6 | -0.2 | 3.4 |
| G15 | 1,530 | 660 | 88 | 1,348 | 581 | 300 | 4.5 | 2.6 | 6.4 |
| ***G16** | 450 | 330 | 96 | 434 | 318 | 300 | 1.4 | 0.4 | 2.5 |
| ***G17** | 1,680 | 1,230 | 77 | 1,295 | 948 | 300 | 4.3 | 1.2 | 7.5 |
| G18 | 6,570 | 1,860 | 13 | 861 | 244 | 300 | 2.9 | 2.1 | 3.7 |
| ***G19** | 9,180 | 4,440 | 7 | 606 | 293 | 300 | 2.0 | 1.0 | 3.0 |
| G29 | 90 | 210 | 94 | 85 | 198 | 300 | 0.3 | -0.4 | 0.9 |
| G46 | 12,390 | 3,390 | 8 | 1,004 | 275 | 300 | 3.3 | 2.4 | 4.3 |
| ***G49** | 6,230 | 3,052 | 14 | 872 | 427 | 140 | 6.2 | 3.2 | 9.3 |
| ***G51** | 18,780 | 8,310 | 76 | 14,216 | 6,291 | 300 | 47.4 | 26.4 | 68.4 |
| ***G52** | 4,320 | 1,110 | 31 | 1,326 | 341 | 300 | 4.4 | 3.3 | 5.6 |
| G58 | 6,468 | 2,772 | 79 | 5,084 | 2,179 | 220 | 23.1 | 13.2 | 33.0 |
| G76 | 3,330 | 900 | 13 | 426 | 115 | 300 | 1.4 | 1.0 | 1.8 |
| G80 | 90 | 90 | 86 | 77 | 77 | 300 | 0.3 | 0.0 | 0.5 |
| **Total Fished Area (2005-06)** | **56,148** | **10,304** | **24** | **13,613** | **2,498** | **3220** | **4.2** | **3.5** | **5.0** |
| ***Total Fished Area (2005-07)** | **96,788** | **15,552** | **33** | **32,363** | **5,200** | **4860** | **6.7** | **5.6** | **7.7** |
| **G50 Area Not Fished** | **4,770** | **3,210** | **20** | **949** | **639** | **300** | **3.2** | **1.0** | **5.3** |
| **G23 Area Not Fished** | **6,210** | **1,710** | **50** | **3,086** | **850** | **300** | **10.3** | **7.5** | **13.1** |

| (B) 2006 | All size urchins | | Percent | Legal size urchins (≥ 51 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 11,940 | 1,230 | 6 | 752 | 77 | 300 | 2.5 | 2.2 | 2.8 |
| G9 | 1,950 | 1,350 | 59 | 1,151 | 797 | 300 | 3.8 | 1.2 | 6.5 |
| G11 | 330 | 450 | 39 | 128 | 174 | 300 | 0.4 | -0.2 | 1.0 |
| G12 | 480 | 930 | 56 | 268 | 520 | 300 | 0.9 | -0.8 | 2.6 |
| G15 | 1,232 | 952 | 95 | 1,174 | 907 | 280 | 4.2 | 1.0 | 7.4 |
| G18 | 6,804 | 3,612 | 16 | 1,068 | 567 | 280 | 3.8 | 1.8 | 5.8 |
| G29 | 552 | 552 | 68 | 374 | 374 | 240 | 1.6 | 0.0 | 3.1 |
| G46 | 9,330 | 3,330 | 8 | 700 | 250 | 300 | 2.3 | 1.5 | 3.2 |
| G58 | 270 | 300 | 89 | 241 | 268 | 300 | 0.8 | -0.1 | 1.7 |
| G76 | 2,220 | 780 | 4 | 80 | 28 | 300 | 0.3 | 0.2 | 0.4 |
| G80 | 180 | 150 | 80 | 145 | 121 | 300 | 0.5 | 0.1 | 0.9 |
| G103 (Closed) | 4,660 | 640 | 97 | 4,506 | 619 | 200 | 22.5 | 19.4 | 25.6 |
| G104 (Closed) | 4,642 | 968 | 89 | 4,117 | 859 | 220 | 18.7 | 14.8 | 22.6 |
| **Total Fished** | **35,288** | **8,320** | **17** | **6,080** | **1,434** | **3200** | **1.9** | **1.5** | **2.3** |
| **G50 Area Not Fished** | **6,210** | **4,320** | **32** | **1,993** | **1,387** | **300** | **6.6** | **2.0** | **11.3** |
| **Total Close Area G103+G104** | **9,302** | **1,092** | **93** | **8,624** | **1,012** | **420** | **20.5** | **18.1** | **22.9** |

| (C) 2007 | All size urchins | | Percent | Legal size urchins (≥ 51 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 2,130 | 570 | 13 | 281 | 75 | 300 | 0.9 | 0.7 | 1.2 |
| G9 | 120 | 120 | 62 | 75 | 75 | 300 | 0.2 | 0.0 | 0.5 |
| G11 | 90 | 60 | 25 | 23 | 15 | 300 | 0.1 | 0.0 | 0.1 |
| G12 | 600 | 1,050 | 43 | 259 | 454 | 300 | 0.9 | -0.6 | 2.4 |
| G15 | 2,460 | 630 | 95 | 2,327 | 596 | 300 | 7.8 | 5.8 | 9.7 |
| ***G16** | 330 | 240 | 88 | 292 | 212 | 300 | 1.0 | 0.3 | 1.7 |
| ***G17** | 2,640 | 660 | 81 | 2,138 | 535 | 300 | 7.1 | 5.3 | 8.9 |
| G18 | 6,480 | 1,410 | 15 | 998 | 217 | 300 | 3.3 | 2.6 | 4.1 |
| ***G19** | 8,560 | 3,300 | 3 | 214 | 83 | 200 | 1.1 | 0.7 | 1.5 |
| G29 | 930 | 900 | 70 | 653 | 632 | 300 | 2.2 | 0.1 | 4.3 |
| G46 | 4,440 | 1,620 | 1 | 58 | 21 | 300 | 0.2 | 0.1 | 0.3 |
| ***G49** | 6,600 | 2,190 | 31 | 2,066 | 685 | 300 | 6.9 | 4.6 | 9.2 |
| ***G51** | 6,270 | 1,440 | 38 | 2,370 | 544 | 300 | 7.9 | 6.1 | 9.7 |
| ***G52** | 3,938 | 2,046 | 13 | 492 | 256 | 220 | 2.2 | 1.1 | 3.4 |
| G58 | 2,310 | 840 | 77 | 1,769 | 643 | 300 | 5.9 | 3.8 | 8.0 |
| G76 | 480 | 240 | 30 | 146 | 73 | 300 | 0.5 | 0.2 | 0.7 |
| G80 | 1,020 | 930 | 71 | 725 | 661 | 300 | 2.4 | 0.2 | 4.6 |
| **Total Fished Area (2007-06)** | **21060** | **4,290** | **35** | **7314** | **1,490** | **3300** | **2.2** | **1.8** | **2.7** |
| ***Total Fished Area (2007-05)** | **49398** | **7,872** | **30** | **14887** | **2,372** | **4920** | **3.0** | **2.5** | **3.5** |
| **G50 Area Not Fished** | **0** | **0** | **0** | **0** | **0** | **300** | **0.0** | **0.0** | **0.0** |
| **G23 Area Not Fished** | **4,050** | **1,890** | **44** | **1,790** | **835** | **300** | **6.0** | **3.2** | **8.8** |
| **Total Close Area G103+G104** | **6,298** | **1,134** | **75** | **4,736** | **853** | **420** | **11.3** | **9.2** | **13.3** |

*Table 10. Continued.*

| (D) 1992 | All size urchins | | Percent | Legal size urchins (≥ 51 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 6,180 | 2,070 | 41 | 2,530 | 848 | 300 | 8.4 | 5.6 | 11.3 |
| G9 | 5,280 | 930 | 44 | 2,300 | 405 | 300 | 7.7 | 6.3 | 9.0 |
| G11 | 1,980 | 780 | 97 | 1,927 | 759 | 300 | 6.4 | 3.9 | 9.0 |
| G12 | 2,310 | 540 | 96 | 2,215 | 518 | 300 | 7.4 | 5.7 | 9.1 |
| G15 | 3,090 | 1,020 | 97 | 2,999 | 990 | 300 | 10.0 | 6.7 | 13.3 |
| ***G16** | 330 | 150 | 97 | 321 | 146 | 300 | 1.1 | 0.6 | 1.6 |
| ***G17** | 4,530 | 1,170 | 91 | 4,107 | 1,061 | 300 | 13.7 | 10.2 | 17.2 |
| G18 | 2,730 | 420 | 56 | 1,524 | 234 | 300 | 5.1 | 4.3 | 5.9 |
| ***G19** | 2,550 | 420 | 44 | 1,119 | 184 | 300 | 3.7 | 3.1 | 4.3 |
| G29 | 60 | 60 | 0 | 0 | 0 | 300 | 0.0 | 0.0 | 0.0 |
| G46 | 780 | 540 | 94 | 737 | 510 | 300 | 2.5 | 0.8 | 4.2 |
| ***G49** | 13,740 | 2,700 | 13 | 1,764 | 347 | 300 | 5.9 | 4.7 | 7.0 |
| ***G51** | 6,390 | 1,800 | 61 | 3,866 | 1,089 | 300 | 12.9 | 9.3 | 16.5 |
| ***G52** | 2,010 | 540 | 81 | 1,634 | 439 | 300 | 5.4 | 4.0 | 6.9 |
| G58 | 4,680 | 1,530 | 86 | 4,011 | 1,311 | 300 | 13.4 | 9.0 | 17.7 |
| G76 | 2,670 | 300 | 54 | 1,446 | 162 | 300 | 4.8 | 4.3 | 5.4 |
| G80 | 160 | 272 | 93 | 148 | 252 | 80 | 1.9 | -1.3 | 5.0 |
| **Total Fished Area (1992-2006)** | **29,920** | **4,004** | **66** | **19,838** | **2,655** | **3,080** | **6.4** | **5.6** | **7.3** |
| ***Total Fished Area (1992-2007)** | **59,470** | **7,808** | **55** | **32,650** | **4,287** | **4,880** | **6.7** | **5.8** | **7.6** |
| **G50 Area Not Fished** | **5,670** | **1,260** | **41** | **2,302** | **512** | **300** | **7.7** | **6.0** | **9.4** |
| **G23 Area Not Fished** | **2,280** | **360** | **90** | **2,042** | **322** | **300** | **6.8** | **5.7** | **7.9** |

**Includes the equivalent extra transects that were surveyed in 2007.*

*Table 11. Calculation of mean densities (#/m$^2$) and the estimated number of sub-legal size urchins (25 to 50 mm test diameter (TD)) for each transects and for combined transects during the 2005 (A), 2006 (B), 2007 (C), and 1992 (D) dive surveys.*

| (A) 2005 | Number of Urchins | | Percent | Sub-legal size urchins (25 to 50 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Sub-legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 16,560 | 2,310 | 85 | 13,993 | 1,952 | 300 | 46.6 | 40.1 | 53.2 |
| G9 | 3,180 | 2,070 | 54 | 1,724 | 1,122 | 300 | 5.7 | 2.0 | 9.5 |
| G11 | 4,860 | 2,310 | 77 | 3,762 | 1,788 | 300 | 12.5 | 6.6 | 18.5 |
| G12 | 1,080 | 1,200 | 44 | 470 | 522 | 300 | 1.6 | -0.2 | 3.3 |
| G15 | 1,530 | 660 | 12 | 182 | 79 | 300 | 0.6 | 0.3 | 0.9 |
| ***G16** | 450 | 330 | 4 | 16 | 12 | 300 | 0.1 | 0.0 | 0.1 |
| ***G17** | 1,680 | 1,230 | 23 | 385 | 282 | 300 | 1.3 | 0.3 | 2.2 |
| G18 | 6,570 | 1,860 | 87 | 5,709 | 1,616 | 300 | 19.0 | 13.6 | 24.4 |
| ***G19** | 9,180 | 4,440 | 62 | 5,646 | 2,731 | 300 | 18.8 | 9.7 | 27.9 |
| G29 | 90 | 210 | 6 | 5 | 12 | 300 | 0.02 | 0.0 | 0.1 |
| G46 | 12,390 | 3,390 | 90 | 11,139 | 3,048 | 300 | 37.1 | 27.0 | 47.3 |
| ***G49** | 6,230 | 3,052 | 82 | 5,090 | 2,493 | 140 | 36.4 | 18.5 | 54.2 |
| ***G51** | 18,780 | 8,310 | 24 | 4,564 | 2,019 | 300 | 15.2 | 8.5 | 21.9 |
| ***G52** | 4,320 | 1,110 | 69 | 2,981 | 766 | 300 | 9.9 | 7.4 | 12.5 |
| G58 | 6,468 | 2,772 | 21 | 1,384 | 593 | 220 | 6.3 | 3.6 | 9.0 |
| G76 | 3,330 | 900 | 84 | 2,787 | 753 | 300 | 9.3 | 6.8 | 11.8 |
| G80 | 90 | 90 | 10 | 9 | 9 | 300 | 0.03 | 0.0 | 0.1 |
| **Total Fished Area (2005-06)** | **56,148** | **10,304** | **73** | **41164** | **7,554** | **3220** | **12.8** | **10.4** | **15.1** |
| ***Total Fished Area (2005-07)** | **96,788** | **15,552** | **62** | **59845** | **9,616** | **4860** | **12.3** | **10.3** | **14.3** |
| **G50 Area Not Fished** | **4,770** | **3,210** | **49** | **2,323** | **1,563** | **300** | **7.7** | **2.5** | **13.0** |
| **G23 Area Not Fished** | **6,210** | **1,710** | **50** | **3,124** | **860** | **300** | **10.4** | **7.5** | **13.3** |

| (B) 2006 | Number of Urchins | | Percent | Sub-legal size urchins (25 to 50 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Sub-legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 11,940 | 1,230 | 80 | 9,600 | 989 | 300 | 32.0 | 28.7 | 35.3 |
| G9 | 1,950 | 1,350 | 40 | 782 | 541 | 300 | 2.6 | 0.8 | 4.4 |
| G11 | 330 | 450 | 61 | 202 | 276 | 300 | 0.7 | -0.2 | 1.6 |
| G12 | 480 | 930 | 44 | 212 | 410 | 300 | 0.7 | -0.7 | 2.1 |
| G15 | 1,232 | 952 | 5 | 58 | 45 | 280 | 0.2 | 0.0 | 0.4 |
| G18 | 6,804 | 3,612 | 80 | 5,409 | 2,872 | 280 | 19.3 | 9.1 | 29.6 |
| G29 | 552 | 552 | 32 | 175 | 175 | 240 | 0.7 | 0.0 | 1.5 |
| G46 | 9,330 | 3,330 | 85 | 7,968 | 2,844 | 300 | 26.6 | 17.1 | 36.0 |
| G58 | 270 | 300 | 11 | 29 | 32 | 300 | 0.1 | 0.0 | 0.2 |
| G76 | 2,220 | 780 | 90 | 1,987 | 698 | 300 | 6.6 | 4.3 | 9.0 |
| G80 | 180 | 150 | 20 | 35 | 29 | 300 | 0.1 | 0.0 | 0.2 |
| G103 (Closed) | 4,660 | 640 | 3 | 154 | 21 | 200 | 0.8 | 0.7 | 0.9 |
| G104 (Closed) | 4,642 | 968 | 11 | 525 | 109 | 220 | 2.4 | 1.9 | 2.9 |
| **Total Fished** | **35,288** | **8,320** | **75** | **26,457** | **6,238** | **3200** | **8.3** | **6.3** | **10.2** |
| **G50 Area Not Fished** | **6,210** | **4,320** | **65** | **4,061** | **2,825** | **300** | **13.5** | **4.1** | **23.0** |
| **Total Close Area G103+G104** | **9,302** | **1,092** | **7** | **678** | **80** | **420** | **1.6** | **1.4** | **1.8** |

| (C) 2007 | Number of Urchins | | Percent | Sub-legal size urchins (25 to 50 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Sub-legal % | Total Number | 95 % CI | Area m² | Mean #/m² | Min #/m² | Max #/m² |
| G8 | 2,130 | 570 | 85 | 1,808 | 484 | 300 | 6.0 | 4.4 | 7.6 |
| G9 | 120 | 120 | 37 | 44 | 44 | 300 | 0.1 | 0.0 | 0.3 |
| G11 | 90 | 60 | 73 | 66 | 44 | 300 | 0.2 | 0.1 | 0.4 |
| G12 | 600 | 1,050 | 51 | 307 | 538 | 300 | 1.0 | -0.8 | 2.8 |
| G15 | 2,460 | 630 | 5 | 133 | 34 | 300 | 0.4 | 0.3 | 0.6 |
| ***G16** | 330 | 240 | 12 | 38 | 28 | 300 | 0.1 | 0.0 | 0.2 |
| ***G17** | 2,640 | 660 | 19 | 494 | 123 | 300 | 1.6 | 1.2 | 2.1 |
| G18 | 6,480 | 1,410 | 79 | 5,145 | 1,120 | 300 | 17.2 | 13.4 | 20.9 |
| ***G19** | 8,560 | 3,300 | 62 | 5,333 | 2,056 | 200 | 26.7 | 16.4 | 36.9 |
| G29 | 930 | 900 | 29 | 269 | 260 | 300 | 0.9 | 0.0 | 1.8 |
| G46 | 4,440 | 1,620 | 73 | 3,241 | 1,183 | 300 | 10.8 | 6.9 | 14.7 |
| ***G49** | 6,600 | 2,190 | 66 | 4,363 | 1,448 | 300 | 14.5 | 9.7 | 19.4 |
| ***G51** | 6,270 | 1,440 | 62 | 3,869 | 888 | 300 | 12.9 | 9.9 | 15.9 |
| ***G52** | 3,938 | 2,046 | 85 | 3,339 | 1,735 | 220 | 15.2 | 7.3 | 23.1 |
| G58 | 2,310 | 840 | 23 | 531 | 193 | 300 | 1.8 | 1.1 | 2.4 |
| G76 | 480 | 240 | 67 | 322 | 161 | 300 | 1.1 | 0.5 | 1.6 |
| G80 | 1,020 | 930 | 29 | 292 | 266 | 300 | 1.0 | 0.1 | 1.9 |
| **Total Fished Area (2007-06)** | **21060** | **4,290** | **58** | **12158** | **2,477** | **3300** | **3.7** | **2.9** | **4.4** |
| ***Total Fished Area (2007-05)** | **49398** | **7,872** | **60** | **29593** | **4,716** | **4920** | **6.0** | **5.1** | **7.0** |
| **G50 Area Not Fished** | **0** | **0** | **0** | **0** | **0** | **300** | **0.0** | **0.0** | **0.0** |
| **G23 Area Not Fished** | **4,050** | **1,890** | **53** | **2,138** | **998** | **300** | **7.1** | **3.8** | **10.5** |
| **Total Close Area G103+G104** | **6,298** | **1,134** | **25** | **1,543** | **278** | **420** | **3.7** | **3.0** | **4.3** |

*Table 11. Continued.*

| (D) 1992 | Number of Urchins | | Percent | Sub-legal size urchins (25 to 50 mm TD) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | Total Number | 95 % CI | Sub-legal % | Total Number | 95 % CI | Area $m^2$ | Mean $\#/m^2$ | Min $\#/m^2$ | Max $\#/m^2$ |
| G8 | 6,180 | 2,070 | 56 | 3,435 | 1,151 | 300 | 11.5 | 7.6 | 15.3 |
| G9 | 5,280 | 930 | 56 | 2,965 | 522 | 300 | 9.9 | 8.1 | 11.6 |
| G11 | 1,980 | 780 | 2 | 47 | 19 | 300 | 0.2 | 0.1 | 0.2 |
| G12 | 2,310 | 540 | 4 | 83 | 19 | 300 | 0.3 | 0.2 | 0.3 |
| G15 | 3,090 | 1,020 | 2 | 61 | 20 | 300 | 0.2 | 0.1 | 0.3 |
| ***G16** | 330 | 150 | 0 | 0 | 0 | 300 | 0.0 | 0.0 | 0.0 |
| ***G17** | 4,530 | 1,170 | 8 | 370 | 96 | 300 | 1.2 | 0.9 | 1.6 |
| G18 | 2,730 | 420 | 42 | 1,136 | 175 | 300 | 3.8 | 3.2 | 4.4 |
| ***G19** | 2,550 | 420 | 55 | 1,396 | 230 | 300 | 4.7 | 3.9 | 5.4 |
| G29 | 60 | 60 | 0 | 0 | 0 | 300 | 0.0 | 0.0 | 0.0 |
| G46 | 780 | 540 | 1 | 8 | 5 | 300 | 0.0 | 0.0 | 0.0 |
| ***G49** | 13,740 | 2,700 | 84 | 11,535 | 2,267 | 300 | 38.4 | 30.9 | 46.0 |
| ***G51** | 6,390 | 1,800 | 38 | 2,444 | 689 | 300 | 8.1 | 5.9 | 10.4 |
| ***G52** | 2,010 | 540 | 18 | 365 | 98 | 300 | 1.2 | 0.9 | 1.5 |
| G58 | 4,680 | 1,530 | 14 | 657 | 215 | 300 | 2.2 | 1.5 | 2.9 |
| G76 | 2,670 | 300 | 40 | 1,071 | 120 | 300 | 3.6 | 3.2 | 4.0 |
| G80 | 160 | 272 | 3 | 5 | 8 | 80 | 0.1 | 0.0 | 0.2 |
| **Total Fished Area (1992-2006)** | **29,920** | **4,004** | **32** | **9,467** | **1,267** | **3,080** | **3.1** | **2.7** | **3.5** |
| ***Total Fished Area (1992-2007)** | **59,470** | **7,808** | **43** | **25,577** | **3,358** | **4,880** | **5.2** | **4.6** | **5.9** |
| **G50 Area Not Fished** | **5,670** | **1,260** | **57** | **3,226** | **717** | **300** | **10.8** | **8.4** | **13.1** |
| **G23 Area Not Fished** | **2,280** | **360** | **9** | **195** | **31** | **300** | **0.6** | **0.5** | **0.8** |

**Includes the equivalent extra transects that were surveyed in 2007.*

*Table 12. ANOVA analysis comparing the average urchin densities between survey periods (1992, 2005, 2006, and 2007) for each size categories. Only include transects which were sampled in the same location during all 4 sampling periods. *Urchin densities are significantly different at p < .05.*

| Survey Period | All Size Combine | | | | | | | | | | Anova | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nb of Samples | Mean Urchins /m² | Standard Error | 95% Confidence limit Lower | 95% Confidence limit Upper | Nb of Samples | Mean Urchins /m² | Standard Error | 95% Confidence limit Lower | 95% Confidence limit Upper | F | *Significantly different at p < .05 |
| **1992 vs 2005** | 17 | 11.7 | 2.7 | 6.1 | 17.4 | 17 | 20.8 | 4.8 | 10.6 | 31.1 | 2.7 | 0.109 |
| **1992 vs 2006** | 17 | 11.7 | 2.7 | 6.1 | 17.4 | 11 | 10.9 | 4.2 | 1.5 | 20.3 | 0.0 | 0.860 |
| **1992 vs 2007** | 17 | 11.7 | 2.7 | 6.1 | 17.4 | 17 | 10.8 | 2.8 | 5.0 | 16.6 | 0.1 | 0.807 |
| **2005 vs 2006** | 17 | 20.8 | 4.8 | 10.6 | 31.1 | 11 | 10.9 | 4.2 | 1.5 | 20.3 | 2.1 | 0.163 |
| **2005 vs 2007** | 17 | 20.8 | 4.8 | 10.6 | 31.1 | 17 | 10.8 | 2.8 | 5.0 | 16.6 | 3.3 | 0.080 |
| **2006 vs 2007** | 11 | 10.9 | 4.2 | 1.5 | 20.3 | 17 | 10.8 | 2.8 | 5.0 | 16.6 | 0.0 | 0.983 |
| **Legal ≥ 51 mmTD** | | | | | | | | | | | | |
| **1992 vs 2005** | 17 | 6.5 | 1.0 | 4.3 | 8.6 | 17 | 6.9 | 2.8 | 0.9 | 12.9 | 0.0 | 0.893 |
| **1992 vs 2006** | 17 | 6.5 | 1.0 | 4.3 | 8.6 | 11 | 1.9 | 0.4 | 0.9 | 2.9 | 12.0 | ***0.002** |
| **1992 vs 2007** | 17 | 6.5 | 1.0 | 4.3 | 8.6 | 17 | 3.0 | 0.7 | 1.5 | 4.5 | 8.0 | ***0.008** |
| **2005 vs 2006** | 17 | 6.9 | 2.8 | 0.9 | 12.9 | 11 | 1.9 | 0.4 | 0.9 | 2.9 | 2.0 | 0.173 |
| **2005 vs 2007** | 17 | 6.9 | 2.8 | 0.9 | 12.9 | 17 | 3.0 | 0.7 | 1.5 | 4.5 | 1.8 | 0.188 |
| **2006 vs 2007** | 11 | 1.9 | 0.4 | 0.9 | 2.9 | 17 | 3.0 | 0.7 | 1.5 | 4.5 | 1.2 | 0.277 |
| **Sub-Legal 25-50 mmTD** | | | | | | | | | | | | |
| **1992 vs 2005** | 17 | 5.0 | 2.3 | 0.2 | 9.8 | 17 | 13.0 | 3.5 | 5.5 | 20.4 | 3.6 | 0.067 |
| **1992 vs 2006** | 17 | 5.0 | 2.3 | 0.2 | 9.8 | 11 | 8.1 | 3.6 | 0.1 | 16.2 | 0.6 | 0.446 |
| **1992 vs 2007** | 17 | 5.0 | 2.3 | 0.2 | 9.8 | 17 | 6.6 | 2.0 | 2.4 | 10.7 | 0.3 | 0.612 |
| **2005 vs 2006** | 17 | 13.0 | 3.5 | 5.5 | 20.4 | 11 | 8.1 | 3.6 | 0.1 | 16.2 | 0.8 | 0.368 |
| **2005 vs 2007** | 17 | 13.0 | 3.5 | 5.5 | 20.4 | 17 | 6.6 | 2.0 | 2.4 | 10.7 | 2.5 | 0.122 |
| **2006 vs 2007** | 11 | 8.1 | 3.6 | 0.1 | 16.2 | 17 | 6.6 | 2.0 | 2.4 | 10.7 | 0.2 | 0.678 |
| **Immature 5-25 mm TD** | | | | | | | | | | | | |
| **1992 vs 2005** | 17 | 0.2 | 0.1 | 0.0 | 0.4 | 17 | 1.0 | 0.6 | -0.3 | 2.2 | 1.5 | 0.230 |
| **1992 vs 2006** | 17 | 0.2 | 0.1 | 0.0 | 0.4 | 11 | 0.8 | 0.5 | -0.3 | 1.9 | 2.3 | 0.144 |
| **1992 vs 2007** | 17 | 0.2 | 0.1 | 0.0 | 0.4 | 17 | 1.3 | 0.9 | -0.6 | 3.2 | 1.3 | 0.261 |
| **2005 vs 2006** | 17 | 1.0 | 0.6 | -0.3 | 2.2 | 11 | 0.8 | 0.5 | -0.3 | 1.9 | 0.0 | 0.897 |
| **2005 vs 2007** | 17 | 1.0 | 0.6 | -0.3 | 2.2 | 17 | 1.3 | 0.9 | -0.6 | 3.2 | 0.1 | 0.777 |
| **2006 vs 2007** | 11 | 0.8 | 0.5 | -0.3 | 1.9 | 17 | 1.3 | 0.9 | -0.6 | 3.2 | 0.1 | 0.730 |

*Table 13. Statistics on the daily catch per trip of urchins and the by-catch recorded in kilograms by observers onboard various fishing vessels during the week of December 17-21, 2007, and the week of January 7-11, 2008.*

| Trip Number<br>Landing Date | J07-0756A<br>17-Dec-07 | J07-0756B<br>18-Dec-07 | J07-0756C<br>19-Dec-07 | J07-0756D<br>20-Dec-07 | J07-0756E<br>21-Dec-07 |
|---|---|---|---|---|---|
| Number of tows | 17 | 23 | 26 | 12 | 20 |
| Average tow time (min.) | 18 | 15 | 11 | 15 | 17 |
| Sea Urchins Caught (Kg) | 1282 | 1940 | 2127 | 2290 | 2161 |
| Sea Urchins Discarded (kg) | 664 | 995 | 1000 | 945 | 1125 |
| **Sea Urchins Kept (Kg/Trip)** | **618** | **945** | **1127** | **1345** | **1036** |
| **Kg/tow** | **36** | **41** | **43** | **112** | **52** |
| **Kg/hour** | **120** | **170** | **233** | **456** | **182** |
| Blue Mussels | 150 | 86 | 141 | 17 | 130 |
| Ocean Pout | | 1 | 2 | | |
| Green Crab | 65 | 8 | 8 | | 9 |
| Hermit Crabs | 22 | 23 | 23 | 11 | 20 |
| Hyas coarctaus | | | | | |
| Jonah Crab | 4 | | | | |
| Lumpfish | | 1 | | | |
| Rock Crab | 31 | 13 | 8 | | 6 |
| Sabinea sp. | | | | | |
| Sand Lance | | | | | |
| Scallops | 5 | 9 | 3 | 2 | 3 |
| Sculpin | 16 | 14 | 12 | 3 | 7 |
| Sea Mouse | | 2 | 1 | | |
| Sea Raven | 2 | 2 | 2 | | 2 |
| Seaweed (Kelp) | 1833 | 2170 | 939 | 150 | 1012 |
| Shrimp | 22 | 23 | 23 | 4 | 20 |
| Winter Flounder | 11 | 3 | 2 | | |

| Trip Number<br>Landing Date | J08-0008A<br>07-Jan-08 | J08-0008B<br>08-Jan-08 | J08-0008C<br>09-Jan-08 | J08-0008D<br>10-Jan-08 | J08-0008E<br>11-Jan-08 |
|---|---|---|---|---|---|
| Number of tows | 24 | 22 | 28 | 24 | 16 |
| Average tow time (min.) | 13 | 19 | 11 | 20 | 23 |
| Sea Urchins Caught (Kg) | 1865 | 2467 | 2314 | 4784 | 828 |
| Sea Urchins Discarded (kg) | 1156 | 1478 | 1261 | 2574 | 303 |
| **Sea Urchins Kept (Kg/Trip)** | **708** | **990** | **1053** | **2210** | **526** |
| **Kg/tow** | **30** | **45** | **38** | **92** | **33** |
| **Kg/hour** | **140** | **144** | **204** | **283** | **84** |
| Blue Mussels | 241 | 71 | 68 | 109 | |
| Ocean Pout | 1 | | 1 | | |
| Green Crab | 17 | 6 | 21 | 3 | |
| Hermit Crabs | 22 | 17 | 25 | 22 | 13 |
| Hyas coarctaus | 4 | | | | |
| Jonah Crab | 2 | | | | 39 |
| Lumpfish | 1 | | | | |
| Rock Crab | 4 | 12 | 1 | | 13 |
| Sabinea sp. | | | 21 | | 63 |
| Sand Lance | 1 | | 1 | | 4 |
| Scallops | 0 | | | | |
| Sculpin | 8 | 1 | | 3 | |
| Sea Raven | 1 | | 1 | 1 | 1 |
| Seaweed (Kelp) | 853 | 349 | 423 | 338 | 200 |
| Shrimp | 30 | 17 | | | |
| Winter Flounder | 5 | 3 | 2 | | 2 |

*Table 14. Statistics on the percent of the by-catch for each species for all the fishing trips combined during the week of December 17-21, 2007, and the week of January 7-11, 2008.*

| | 17-21 Dec. 2007 | | | 7-11 Jan. 2008 | | |
|---|---|---|---|---|---|---|
| | **Catch (Kg)** | **Percent of catch (with Kelp)** | **Percent of catch (no Kelp)** | **Catch (Kg)** | **Percent of catch (with Kelp)** | **Percent of catch (no Kelp)** |
| **Total weekly catch** | **16876** | 100% | | **15296** | 100% | |
| **Total weekly catch (No Kelp)** | **10772** | | 100% | **13134** | | 100% |
| **Sea Urchins Discarded** | 4729 | 28.0% | 43.9% | 6772 | 44.3% | 51.6% |
| **Sea Urchins Kept** | 5071 | 30.0% | 47.1% | 5487 | 35.9% | 41.8% |
| **Blue Mussels** | 524 | 3.1% | 4.9% | 489 | 3.2% | 3.7% |
| **Ocean Pout** | 3 | 0.02% | 0.03% | 2 | 0.01% | 0.01% |
| **Green Crab** | 90 | 0.5% | 0.8% | 47 | 0.3% | 0.4% |
| **Hermit Crabs** | 99 | 0.6% | 0.9% | 99 | 0.6% | 0.8% |
| **Hyas coarctaus** | 0 | 0.0% | 0.0% | 4 | 0.0% | 0.0% |
| **Jonah Crab** | 4 | 0.0% | 0.0% | 41 | 0.3% | 0.3% |
| **Lumpfish** | 1 | 0.0% | 0.0% | 1 | 0.0% | 0.0% |
| **Rock Crab** | 58 | 0.3% | 0.5% | 29 | 0.2% | 0.2% |
| **Sabinea sp.** | 0 | 0.0% | 0.0% | 84 | 0.6% | 0.6% |
| **Sand Lance** | 0 | 0.0% | 0.0% | 5 | 0.0% | 0.0% |
| **Scallops** | 22 | 0.1% | 0.2% | 0 | 0.0% | 0.0% |
| **Sculpin** | 52 | 0.3% | 0.5% | 12 | 0.1% | 0.1% |
| **Sea Mouse** | 3 | 0.0% | 0.0% | 4 | 0.0% | 0.0% |
| **Sea Raven** | 8 | 0.0% | 0.1% | 0 | 0.0% | 0.0% |
| **Seaweed (Kelp)** | 6104 | 36.2% | | 2162 | 14.1% | |
| **Shrimp** | 92 | 0.5% | 0.9% | 47 | 0.3% | 0.4% |
| **Winter Flounder** | 16 | 0.1% | 0.1% | 12 | 0.1% | 0.1% |

## 8. FIGURES

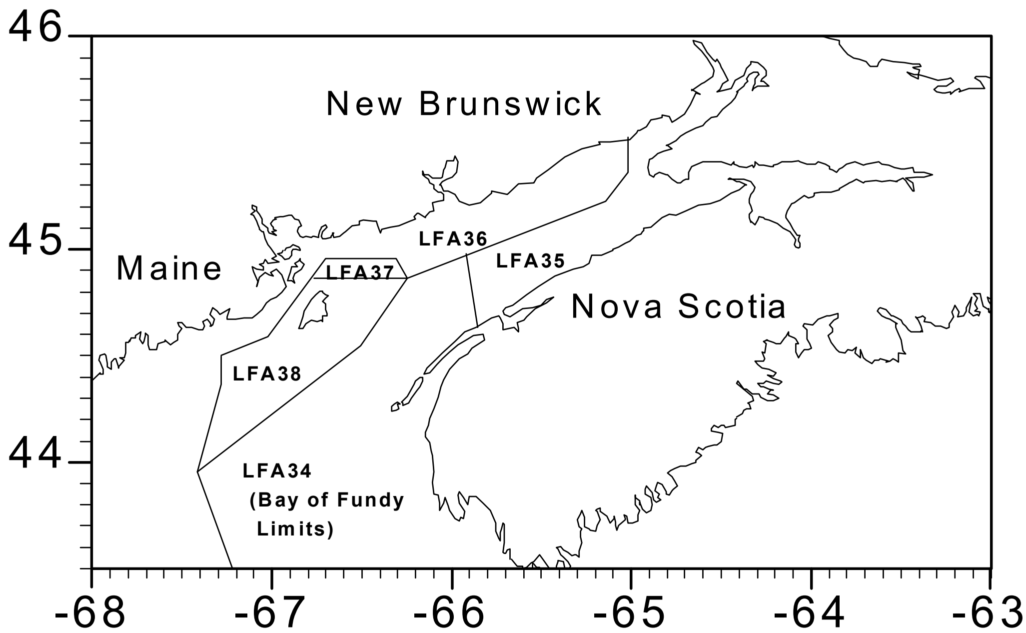


*Figure 1. Bay of Fundy/Gulf of Maine map showing Lobster Fishing Areas (LFAs) 35, 36, 37, and, 38, and adjacent LFA 34.*

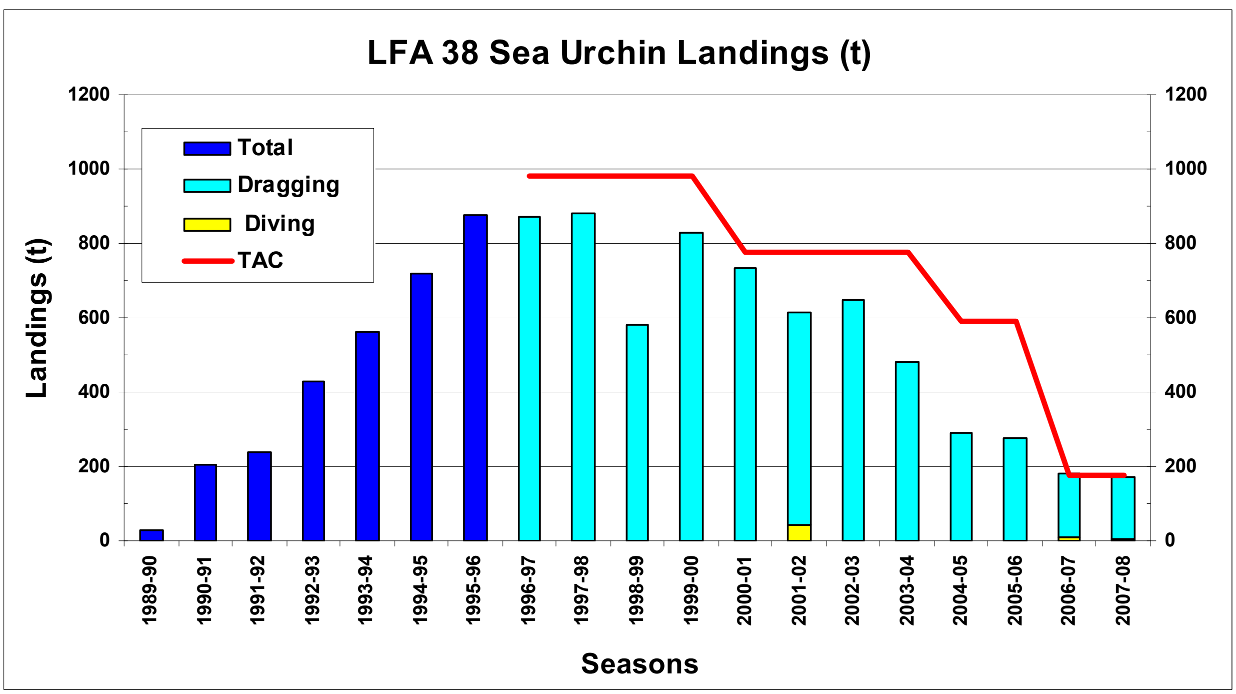


*Figure 2. LFA 38 historical urchin landings and total allowable catch (TAC) in metric tons (t). In 2006-07 and 2007-08, the sparse landings that came from Zone 2 was all from diving operations. The TAC for Zone 2 landings was the same as Zone 1.*

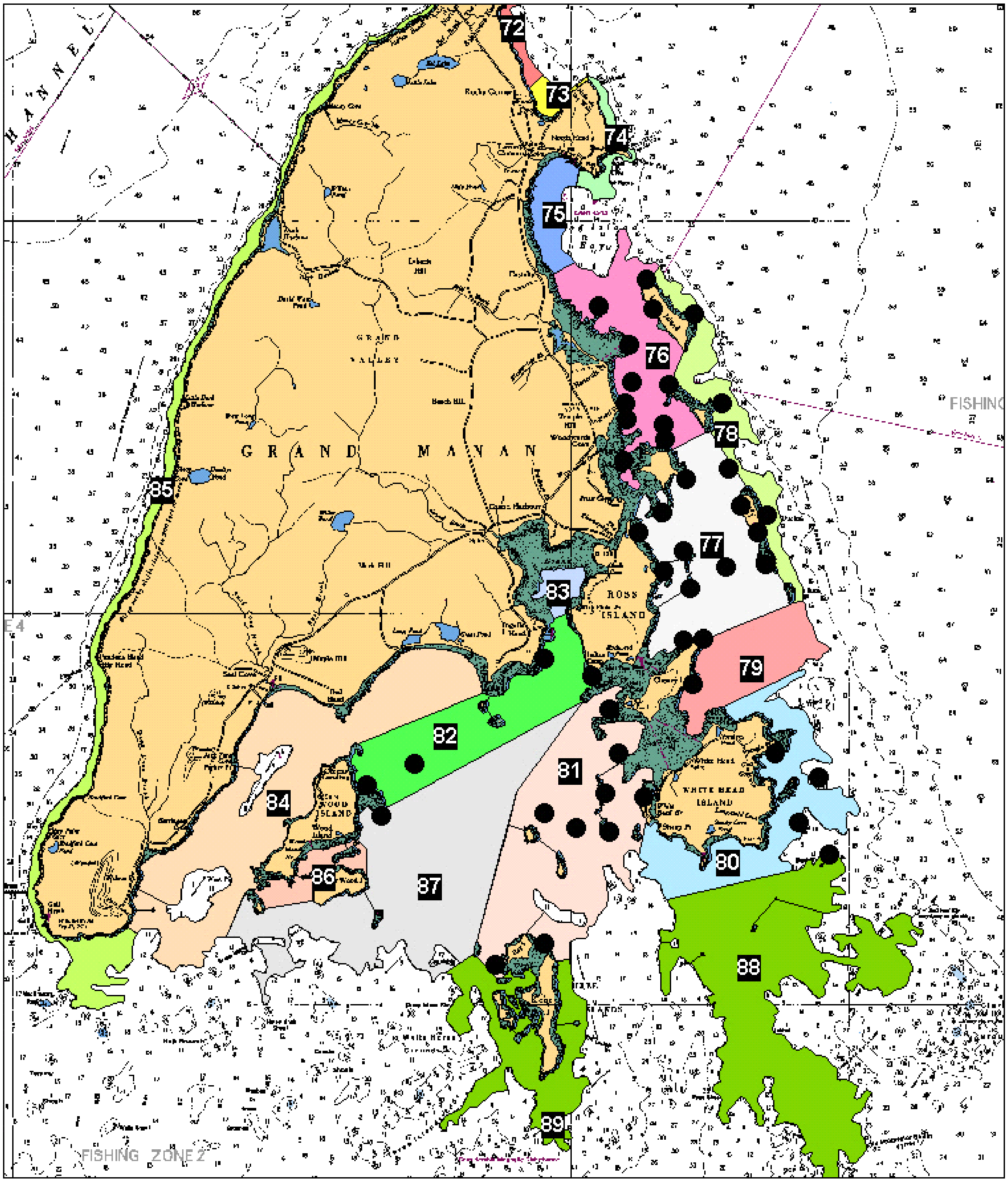


*Figure 3. Map showing the locations (shaded area) and the position of each transect sampled (●) around Grand Manan Island during 2005.*

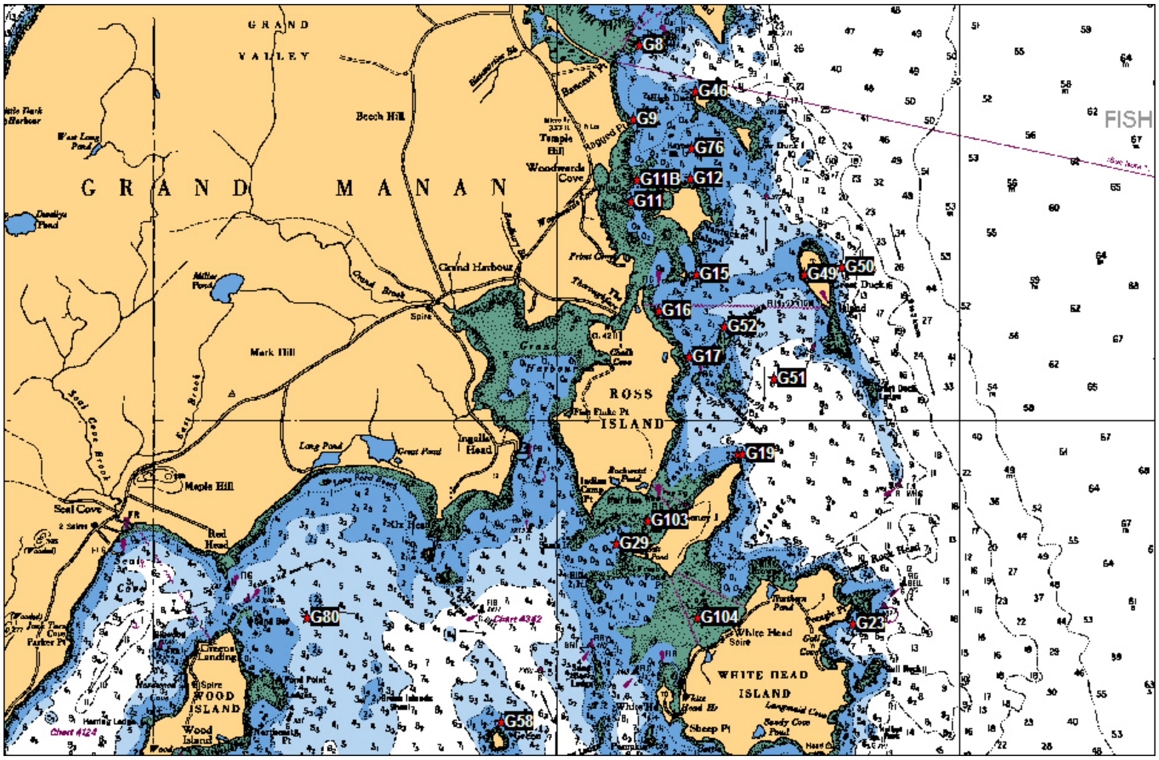


*Figure 4. Map showing the position of each transect sampled around Grand Manan Island during 2005, 2006, and 2007.*

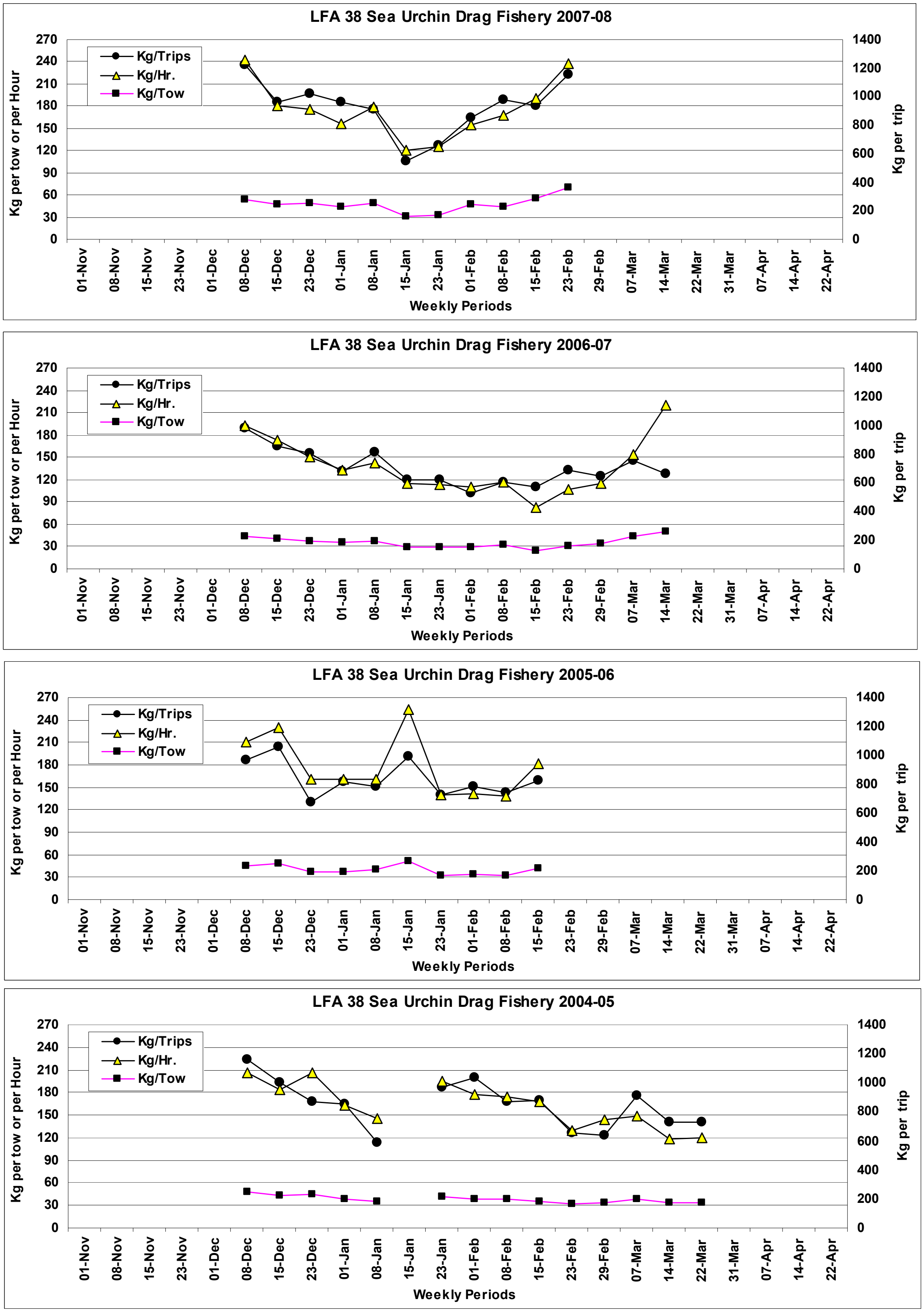


*Figure 5. Comparison of different catch per unit of effort (CPUE) by weekly periods based on logbook information collected seasonally for the last 4 fishing season. The catch rates are in kilograms per day trip (kg/trip; legend on right), in kg per tow and in kg per hour of towing (legend on left).*

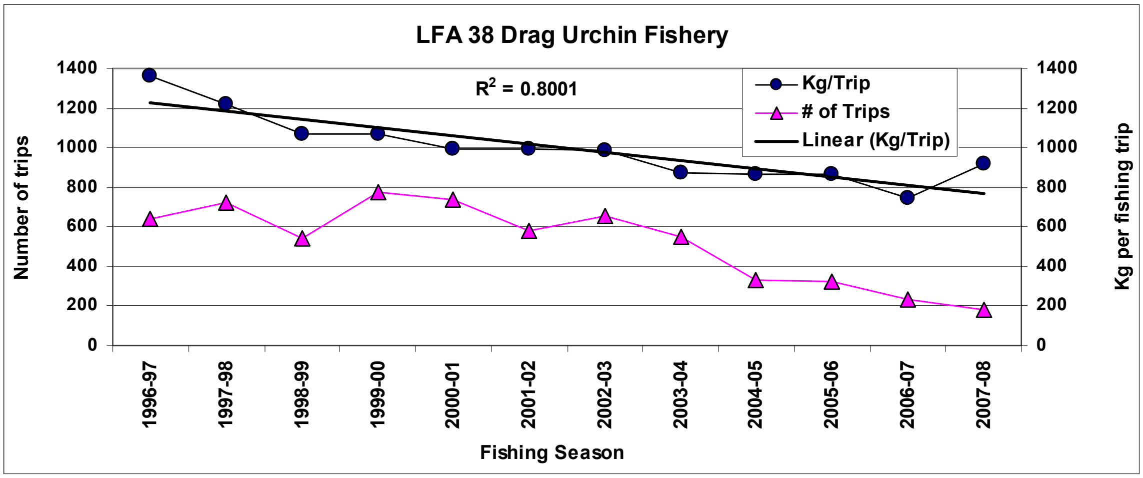


*Figure 6. The average catch in kilograms per fishing trip (kg/trip) and the number of trips per fishing season for the Lobster Fishing Area (LFA) 38 urchin drag fishery from the 1996-97 to 2007-08 fishing seasons.*

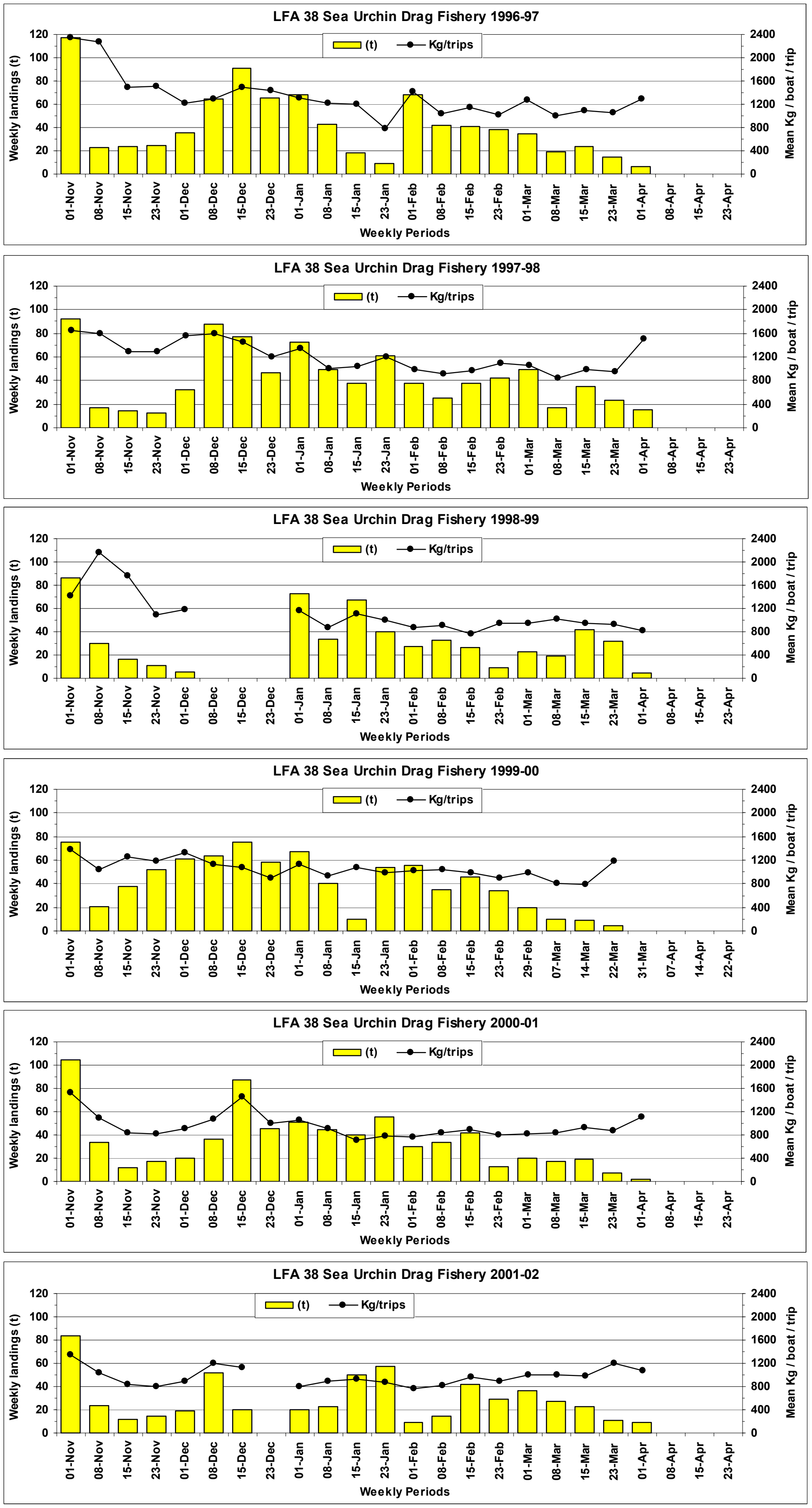


*Figure 7. Urchin weekly landings in metric tons (t) and daily catch rate in kilograms per boat per day trip (kg/trip), from logbook information between the 1996-97 and 2007-08 fishing seasons.*

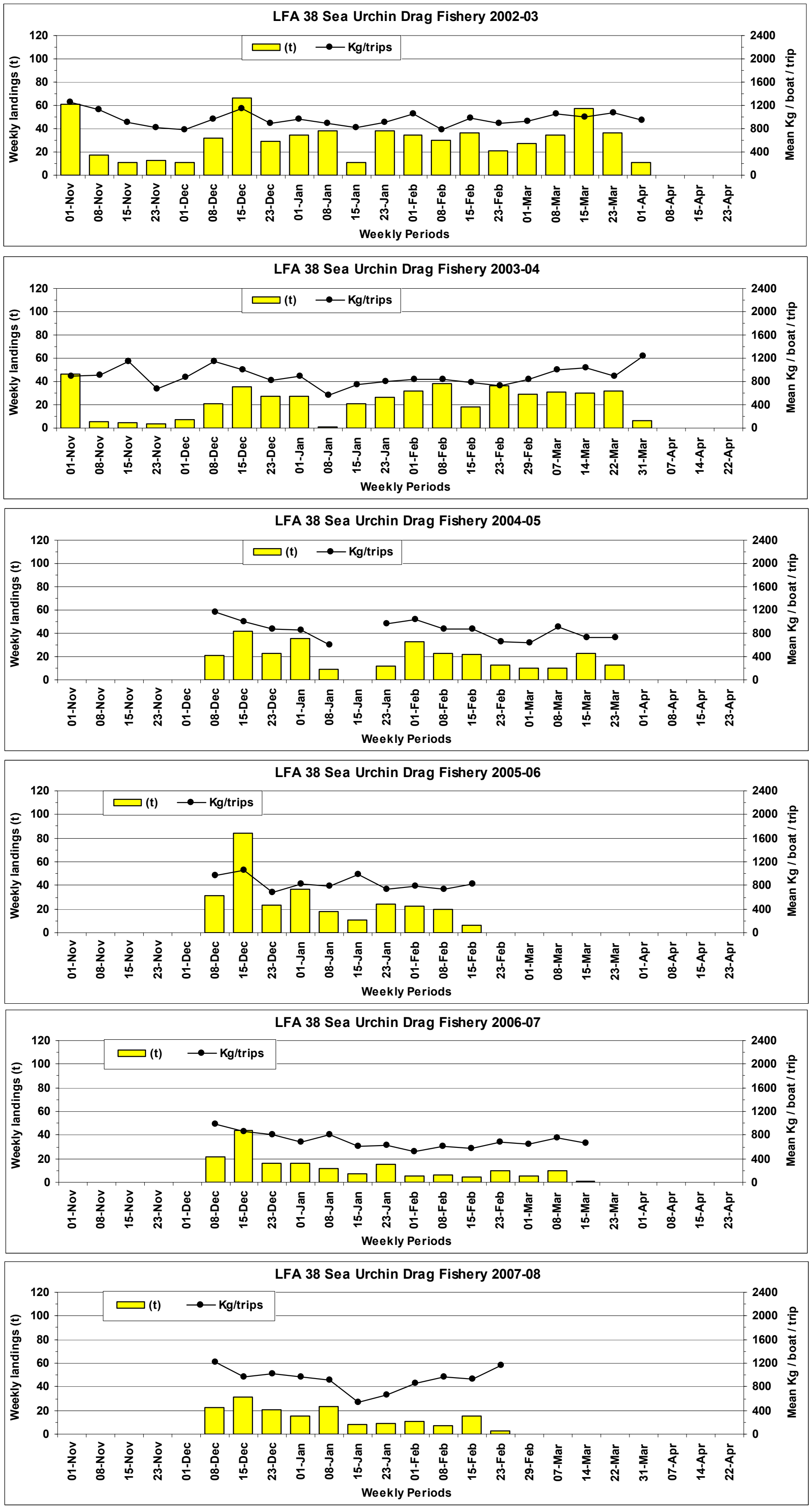


*Figure 7. Continued.*

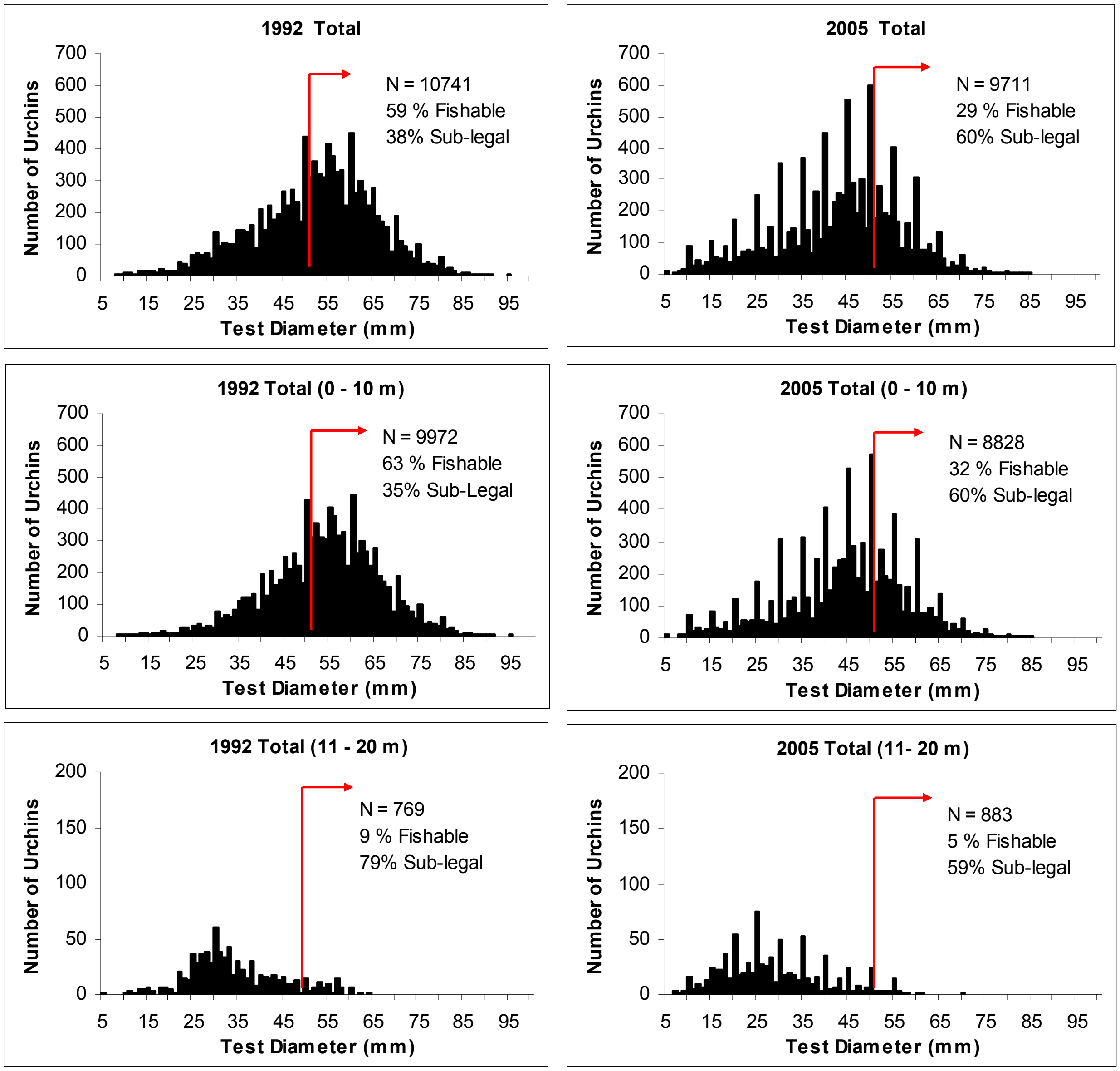


*Figure 8. Size frequency distribution of the total number of sea urchins sampled off Grand Manan during 1992 (left) and 2005 (right) for all depths combined (top), 0 to 10 m depth strata (middle), and the 11 to 20 m depth strata (bottom). The central line and arrow indicate the legal size urchin ≥ 51 mm test diameter (TD)).*

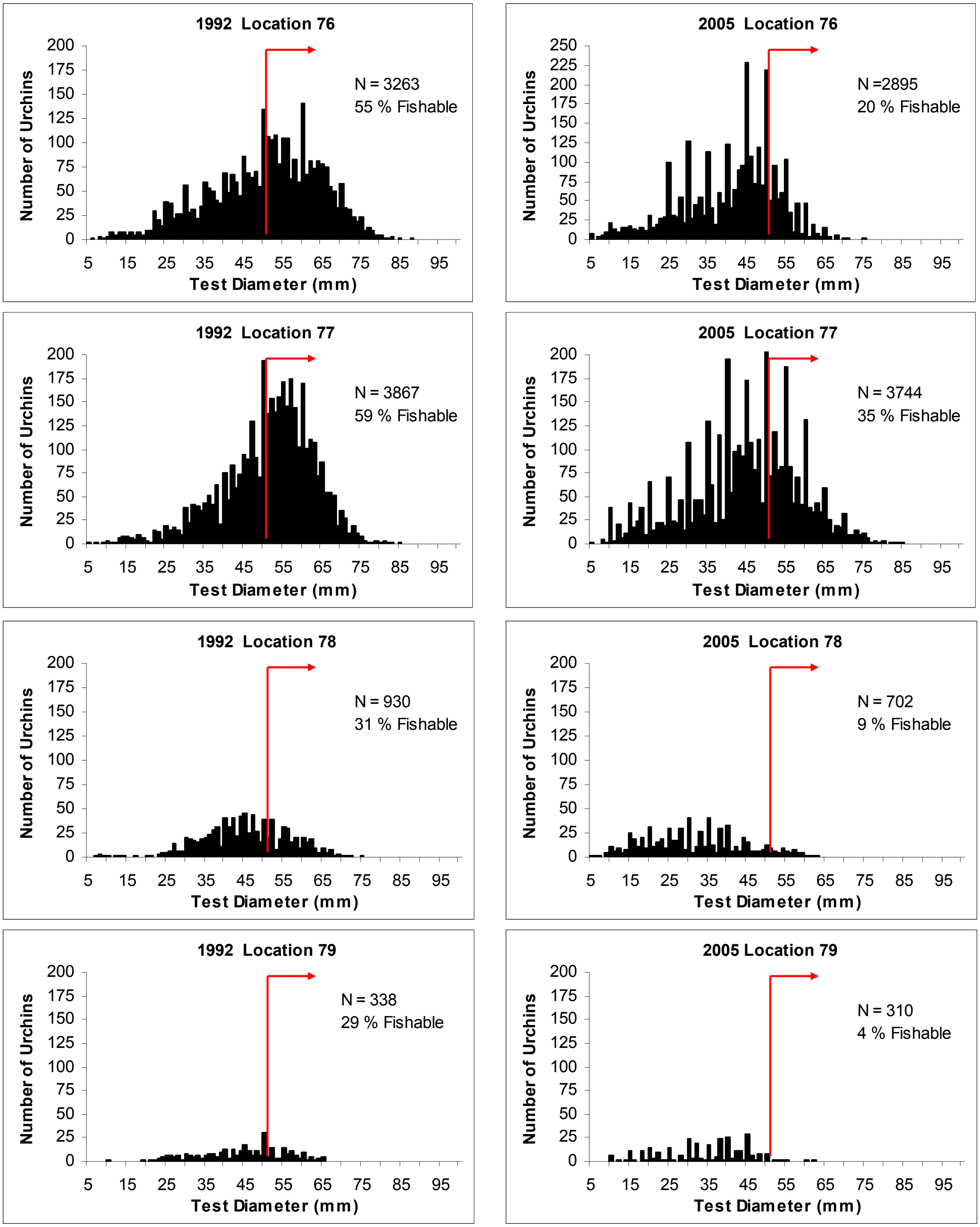


*Figure 9. Size frequency distribution of the total number of sea urchins sampled in each location off Grand Manan for all depths combined during 1992 (left) and 2005 (right). The central line and arrow indicate the legal size urchin ≥ 51 mm test diameter (TD)).*

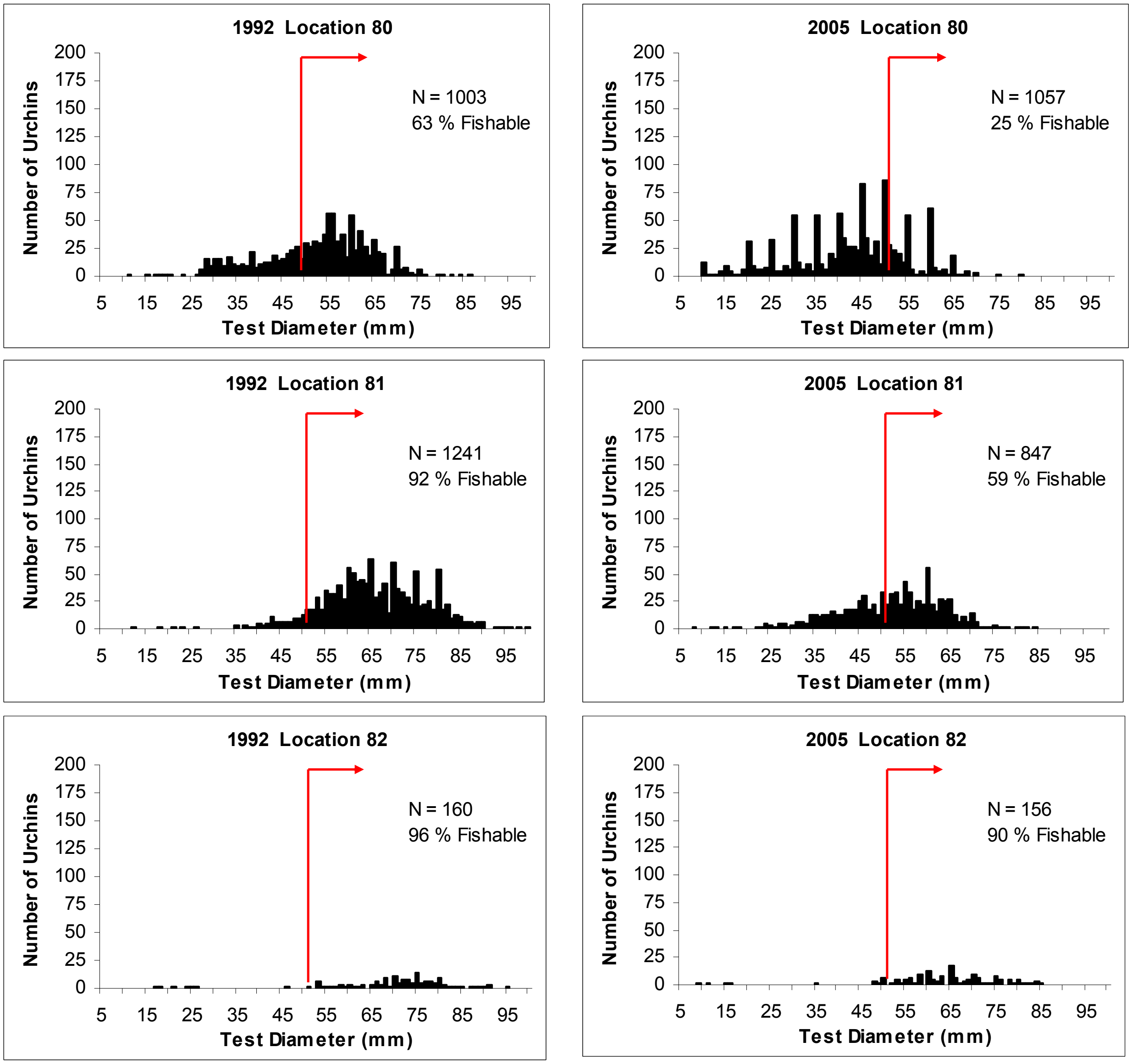


*Figure 9. Continued.*

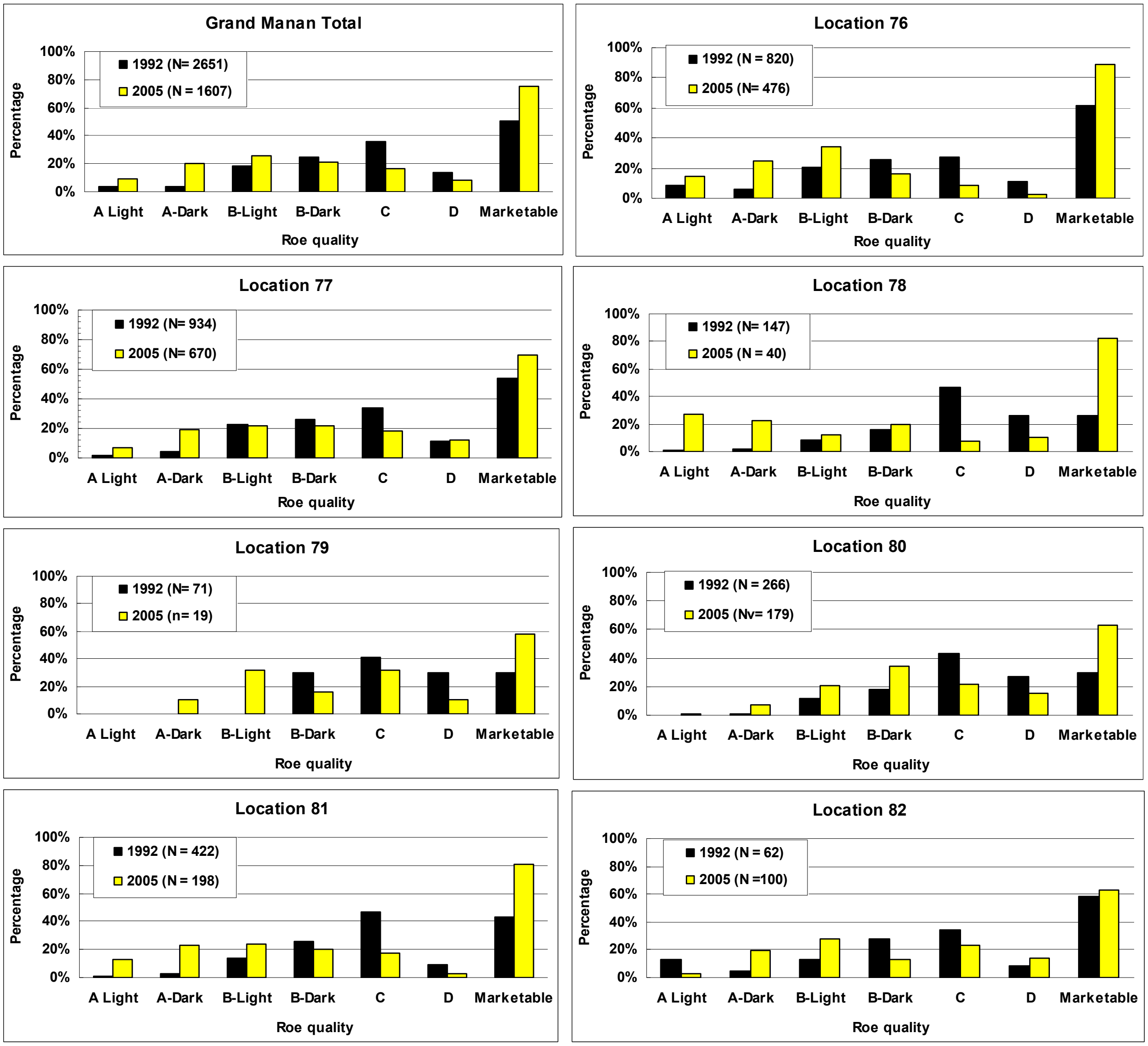


*Figure 10. Roe quality by categories as a percentage of the total number of legal size urchins tested during the 1992 and 2005 surveys. The number of legal size urchin tested within each location is also shown. Only roe quality that falls within the categories A and B are considered marketable.*

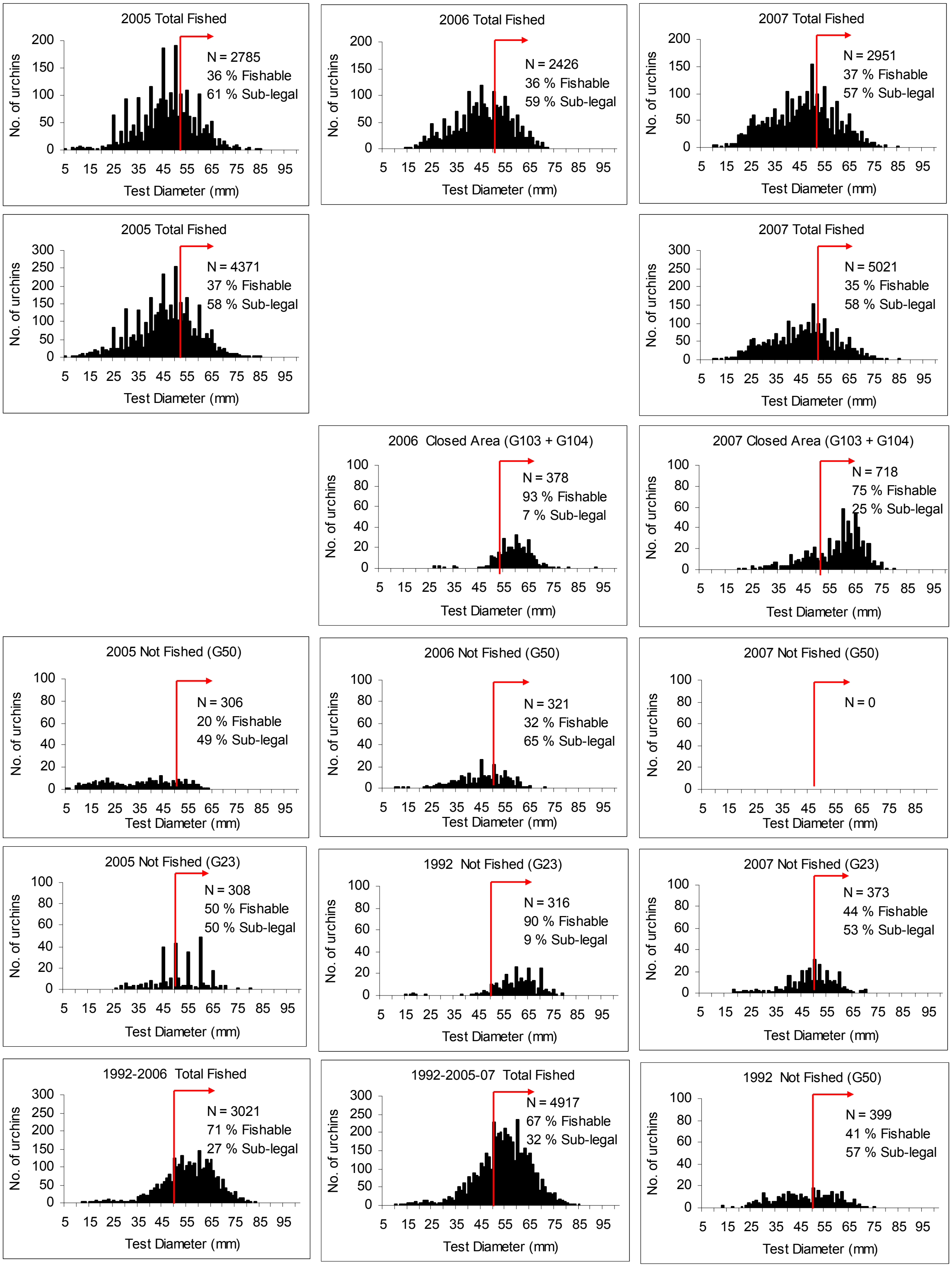


*Figure 11. Size frequency distribution of sea urchins sampled during 2005 (left), 2006 (middle), 2007 (right), and 1992 (bottom). The central line and arrow indicate the legal size urchin ≥ 51 mm test diameter (TD)). The proportion of legal size urchins and sub-legal size urchins (25-50 mm TD) is indicated on the right.*

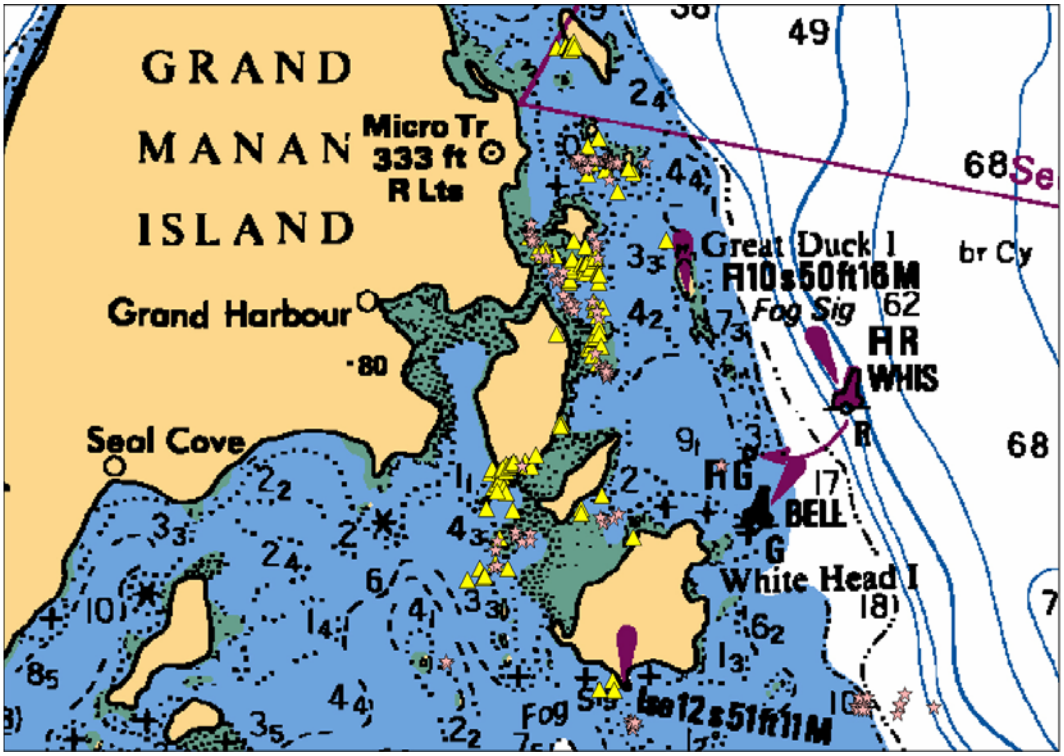


*Figure 12. Location of urchin dragging throughout the observer monitored fishing trips during the week of December 17-21, 2007 (triangles), and January 7-11, 2008 (circles).*

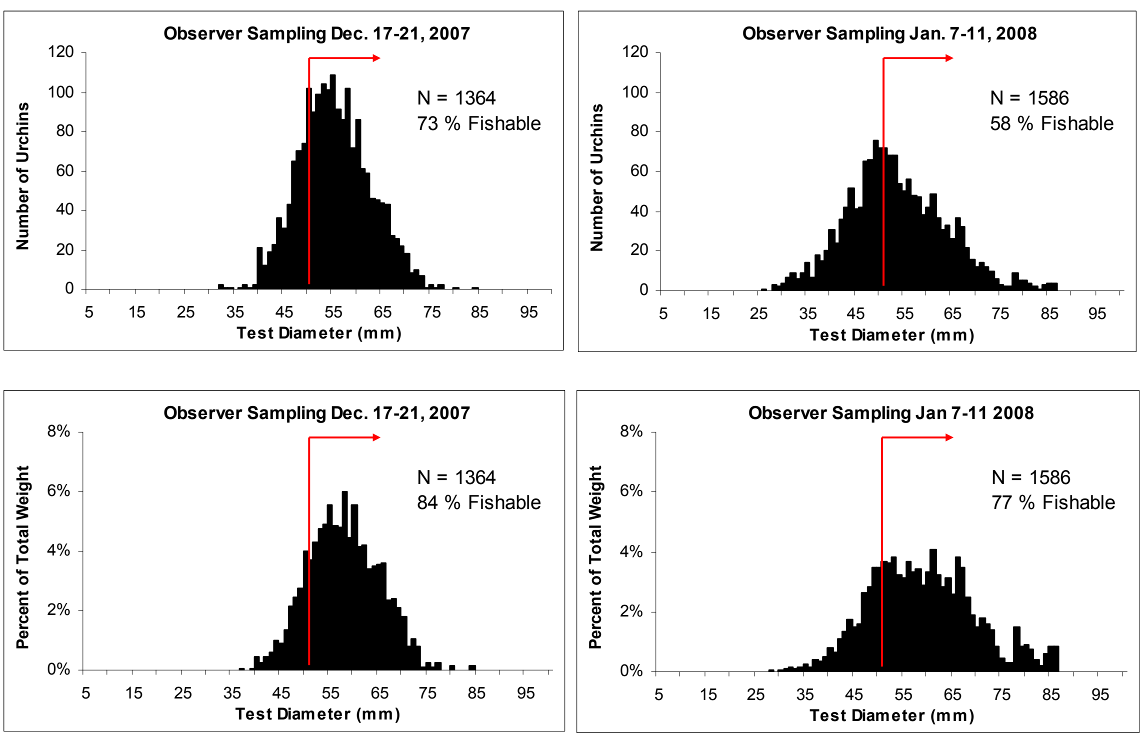


*Figure 13. Size frequency distribution of sea urchins (top) and proportion of weight at size (bottom) sampled by observers during the week of December 17-21, 2007, and the week of January 7-11, 2008.*

## 9. APPENDIX

*Appendix 1. Map showing the location of fishing areas as recorded by fishers in the new area based urchin logbook which was introduced during fall 2008.*