Estimating abundance of lobsters (*Homarus americanus*) on low complexity seabeds using an underwater video system

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ABSTRACT

Methods were developed to use underwater video to estimate the density (n m^{-2}) of lobsters (*Homarus americanus*) on seabeds with low structural complexity. Lobsters were quantified on video transects over sand, mud and cobble seabeds in late summer-fall of 2005-07. Transect lengths in 2006 and 2007 averaged 713 m. Variation in seabed physical characteristics, as well as changes in orientation of the underwater video camera prevented quantification over the full transect. Thus, for each transect, intervals were identified where lobsters could be reliably counted ("countable intervals"). On average, the sum of these intervals represented 60-80% of the total length of the transect. Measurement of carapace length from the video was possible for a portion of the lobsters observed, but accuracy was +/- 10 mm at best. The 212 lobsters measured had a broader size distribution than lobsters measured from traps fished concurrent to the video. More reliable measurements would be possible with modifications to the video survey platform such as adding the capacity to take an image vertical to the seabed, and by increasing image resolution.

On predominantly sand and mud seabeds, most lobsters were completely in the open, but some were in association with pits or burrows or partially sheltered against rocks. On hard seabeds, most lobsters were again observed in the open but some were partially sheltered in pits, burrows or crevices or against rocks. For those portions of transects on harder seabeds where lobsters could be counted, density was presumably underestimated given that some lobsters were likely hidden within shelters. Surveys in 2006 and 2007 in both Lobster Bay and St. Mary's Bay in southwest Nova Scotia indicated no effect of bay or year on the mean number of lobsters m^{-2}, but a strong effect of location within the bays. Lobster abundance tended to be higher where temperatures were warmer, usually in the inner portions of the bays. Estimates of the density of lobsters from video were within the range expected based on comparison with other survey methods. Video could be a valuable tool for estimating lobster abundance on low complexity seabeds.

RÉSUMÉ

Des méthodes par vidéo sous-marine ont été développées afin d'estimer la densité (n/m^2) de homards (*Homarus americanus*) sur les fonds marins de complexité structurale minime. Les homards ont été quantifiés à partir de transectes vidéo dépeignants des fonds de sable, de boue et de galets à la fin de l'été et au début de l'automne de 2005-2007. La longueur moyenne des transectes en 2006 et en 2007 était de 713 m. Les variations dans les caractéristiques physiques du fond marin, ainsi que des changements d'orientation de la caméra sous-marine n'ont pas permis de faire une quantification sur l'ensemble d'un transecte. Par conséquent, des intervalles dénombrables ont été déterminés là où les homards pouvaient être comptés de façon fiable pour chaque transecte. En moyenne, la somme de ces intervalles représentait 60 à 80% de la longueur totale des transectes. La mesure de la longueur de carapace à partir des images vidéo a été possible pour une partie des homards observés, mais la précision était au mieux de +/-10 mm. La répartition par taille des 212 homards mesurés était plus grande que celle des homards mesurés au cours de la pêche au casier au moment de la prise des vidéos. Il serait possible d'obtenir des mesures plus fiables en modifiant la plate-forme de relevé vidéo en ajoutant une prise d'image à la verticale du fond marin ou en augmentant la résolution de l'image.

Sur les fonds marins essentiellement sablonneux ou boueux, la plupart des homards étaient entièrement à découvert, mais certains se trouvaient dans des dépressions ou des trous et d'autres étaient partiellement abrités contre les rochers. Sur les fonds marins durs, la plupart des homards ont aussi été observés à découvert, mais certains étaient partiellement abrités dans des dépressions, des trous ou des crevasses ou encore contre des rochers. Dans les sections des transectes où le fond marin est dur et où les homards ont pu être comptés, la densité établie était vraisemblablement inférieure à la réalité, car certains homards étaient probablement cachés dans des abris. Les relevés de 2006 et 2007 dans la baie Lobster et la baie St. Mary's, en Nouvelle-Écosse, ont indiqué que le nombre moyen de homards par m^2 n'est pas en fonction de la baie ou de l'année, mais bien plus en fonction de l'emplacement à l'intérieur des baies. L'abondance du homard a tendance à être plus élevée dans les régions où la température est plus chaude, généralement dans les parties intérieures des baies. Les estimations de la densité de homard obtenue par vidéo correspondaient aux valeurs prévues d'après les comparaisons avec d'autres méthodes de relevé. La vidéo pourrait être un outil de grande valeur pour l'estimation de l'abondance du homard sur les fonds marins dont la complexité structurale est minime.

INTRODUCTION

To provide the basis for management of lobster (*Homarus americanus*) stocks, fishery independent surveys are needed for indicators of abundance (Atlantic State Fisheries Commission 2006, Steneck 2006, Pezzack et al. 2006, Tremblay et al. 2013). Such indicators may be developed from surface-deployed collection devices (traps, trawls), direct underwater sampling (SCUBA divers), or remote observation (underwater video). Each approach has advantages and disadvantages.

Adolescent and adult lobsters, here taken to be those animals larger than about 50 mm carapace length, CL (Lawton and Lavalli 1995) are found on a wide variety of habitats. Sandy substrates with overlying rock support the greatest concentrations of lobster with other important inshore habitats including bedrock base with rock, mud base with burrows, eelgrass meadows and peat reefs (Cooper and Uzmann 1980, Lawton and Lavalli 1995). In shallow waters (< 20 m) the complexity of harder-seabed habitats can be increased significantly by macrophyte cover. On sand or sand-clay seabeds, lobsters are found in shallow pits or bowl shaped depressions (Stewart 1972, Campbell 1990, Tremblay and Smith 2001), that they excavate by “bulldozing” (Cobb 1971). Such pits are reported to be more common in the offshore (Cooper and Uzmann 1980).

The range of habitats for adolescent and adult lobsters presents a challenge for estimating lobster abundance. Complex habitats such as boulders with macrophytes can only be intensively surveyed by SCUBA divers. These surveys are usually restricted to shallow waters because of diver depth limitations. Surveying a significant portion of the inshore habitat by SCUBA is an expensive undertaking although it is feasible for some lobster species (Pitcher et al. 1997). Underwater video offers the potential of fishery-independent estimates of density for low complexity seabeds--- those that are predominantly mud, sand, gravel or cobble, with little macrophyte cover. The possibility of video surveys for lobster abundance is substantiated by existing video surveys for *Nephrops norvegicus*, which make indirect abundance estimates by enumerating burrows (Tuck et al. 1997, Smith et al. 2003).

A surface-deployed underwater video system (“URCHIN”), described in Strong and Lawton (2004), has been used for several recent coastal habitat inventory projects within DFO’s Maritimes Region. Lawton et al. (2009) used URCHIN as one survey approach in an assessment of biological effects of ocean dredge spoil disposal in the harbor approaches at Saint John, NB. They assessed lobster distribution using URCHIN, but did not attempt lobster density estimates. URCHIN was also utilized to document seabed habitat and fauna at a number of survey stations along the Atlantic Coast of Nova Scotia (DFO, 2007), and in Bras d’Or Lakes (Tremblay et al. 2005). Neither of these studies provided estimates of lobster density from the video.

Here we describe an application of URCHIN to estimate lobster abundance in some rich fishing grounds in Lobster Fishing Area (LFA) 34, off southwest Nova Scotia. We estimate density (number m^{-2}) of lobster on seabeds with low structural complexity in two bays.

METHODS

Study areas

Study areas were selected that were expected to have a high abundance of lobsters. Lobster Bay and St. Mary's Bay (Fig. 1) are productive lobster fishing grounds. Landings per grid as reported in lobster logs for these areas are historically amongst the highest in LFA 34 (Fig. 1, Tremblay et al. 2013).

Video system

The surface-deployed underwater video camera system URCHIN (Fig. 2) was used (Strong and Lawton 2004; Lawton et al 2009; Tremblay et al. 2005) to enumerate lobsters along transects. Class-Event software enabled the interactive logging of "events" such as a lobster sighting, and "classes" which are user-defined categories of seabed or habitat type (Strong and Lawton 2004). Although initial lobster counts were done in real time (see below) we found that post-analysis in the laboratory gave more precise counts and better evaluation of shelter use and habitat type. The black and white underwater camera (standard definition) was mounted on a light tripod easily deployed from small vessels. URCHIN's surface equipment package included a video monitor for real-time viewing, GIS (geographic information system) software to track the precise location of the vessel through GPS (Global Positioning System), and automated recording of location information to a computer file. The video image was recorded on mini-DV format video tape using a Sony Digital Camera recorder (Handicam). In addition to the camera, an auxiliary light source and a temperature and depth recorder were located on the tripod. The black and white underwater camera had sufficient resolution for discriminating seabed type and identifying lobsters. Due to its low light capability the auxiliary light was often not required, which also helped to reduce backscatter. To provide a size reference on the seabed, two laser lights were fixed to the tripod so that the beams were 25 cm apart.

URCHIN deployment and survey methods – A small-scale study in Lobster Bay was undertaken Aug 30-31, 2005 to test the use of the gear for quantitative estimates of lobster density. In this initial year the transect directions were pre-determined and achieved by the boat captain taking advantage of the wind and tide and engaging the engine as necessary to travel in a north or south direction (tidal currents are predominantly north-south). The disadvantage of this approach was that URCHIN tended to come up off the seabed as the engine was engaged. In 2006, we employed a different strategy---use of the wind and the tide to drift across a predetermined grid square in whatever direction worked best. This was achieved by positioning the boat at the beginning of the transect to account for the prevailing boat drift.

In 2005, multiple transects were done in close proximity to evaluate sampling variability. Based on what was learned in 2005, larger areas of Lobster Bay and St. Mary's Bay were surveyed in 2006 and 2007 within grid blocks (see below). Sampling days and dates were as follows: Lobster Bay 2006 - 10 days from Aug 29 to Sep 15; St. Mary's Bay 2007 - 5 days from Sep 21 to Oct 4; Lobster Bay 2007 - 5 days from Aug 27 to 31; St. Mary's Bay 2007 - 5 days from Sep 10 to 16.

The URCHIN system worked well overall. An operator monitored the video image showing the relationship of the camera with respect to the seabed and occasionally needed to manually raise or lower the tripod if the depth was changing or if obstacles were encountered (e.g. large boulders or fishing gear). This aspect, together with variations in current and speed over ground, meant that the tripod was not always close to the seabed or oriented correctly. In addition, rough seabeds or poor visibility sometimes prevented accurate counts. As such, counts of lobster for full transects were not usually possible; instead a strategy was adopted of analyzing transect intervals where certain conditions were met.

Calibrations and "enumeration box" - The camera on URCHIN is oriented to look forward and when deployed in a drift mode, the tripod itself is typically tilted to the rear such that the rear legs are on or just above the seabed and the front leg is a variable distance off the seabed. This forward view was derived in the initial URCHIN design (Lawton and Strong 2004) to support its primary application in identifying coastal seabed type, and also to enable the surface operator to avoid entanglement on the seabed. As a result the field of view on the recorded image is distorted such that it is wider at the top than at the bottom. Lab calibrations were done to evaluate this distortion and to adopt criteria for counting such that the transect width was as uniform as possible. These calibrations showed that the width of the viewing window at the horizon defined by the position of the base of the front leg varied according to the tilt (defined by the height of the front leg above the surface) as in the table below.

Tilt -Front leg height off surface (cm)	Width at position of front leg (cm)	Width at bottom of window (cm)	Position of lasers dots (fraction of window height)
0	83	67	Not visible
10	97	74	Not visible
20	120	84	0.25
30	145	96	0.4

During underwater deployments, the position of the laser dots indicated how the tripod was tilted on the seabed. Counts were restricted to periods when the video was oriented such that the lasers were in the lower half of the window. Lobsters were counted only if they were within the window below the horizon defined by the front pod ("the enumeration box"). As such, transect width ranged from 1.0 to 1.5 m and the average width of transects under these conditions was taken to be 1.25 m. In addition to the above constraint, only intervals where there was high confidence that all lobsters were seen were identified as class "A". This eliminated intervals where the video was oriented correctly, but there was low visibility or counts were unreliable due to high seabed complexity (e.g. boulders or macrophytes). A second interval type ("Class B") was reserved for sections where lobsters were apparent and could be counted, but where seabed complexity was high and counts could potentially be underestimates.

Total transect lengths in the field were provided by the MapInfo GIS system.

Processing of video

Initial counts of lobsters were made in the field, as were assessments of seabed type. All videos were then reviewed in the lab to identify class A and class B intervals. Once these intervals were identified, recounts of lobsters were done to ensure none were missed and that all lobsters counted were in fact within the enumeration box.

Seabed types, characterized by a combination of sediment grain size and macrophytic cover, were assigned to each interval in a manner similar to Strong and Lawton (2004). Grain size was categorized visually from the video image using the Wentworth scale and based on the presence/absence of boulders (> 26 cm), cobble (C) (6-25 cm), gravel, (0.4 -6 cm) or sand/mud (< 0.4 cm). Discrimination of mud from sand was attempted based on the extent to which the sediment was re-suspended after contact with the video tripod (greater re-suspension = mud), but for analysis mud and sand were combined into one category. The 5 seabed type categories analyzed are listed below:

1. Mud or sand only;
2. Gravel with or without sand or mud;
3. Cobble with or without sand or mud;
4. Boulder with or without cobble or gravel;
5. Boulder with kelp.

In addition to the characterization of the predominant seabed type for intervals, shelter status of lobsters was categorized as below:

1. In open, not associated with burrow or shelter, on mud or sand;
2. Associated with pit or burrow, on sand or mud;
3. Partially sheltered against rock on sand or mud;
4. In open on hard seabed (gravel, cobble, boulder);

5. Partially sheltered in pit or against rock on hard seabed;
6. Primarily sheltered in pit, burrow or crevice on hard seabed.

Transect interval lengths and lobster abundance estimation - Initial total transect lengths were determined from the polylines created in GIS software (MapInfo) based on real-time GPS tracking during the transects. Ship positions came from the GPS on deck; differences between this and the position of URCHIN on the seabed caused unknown errors in the estimates of the transect track and length. The GPS antenna was placed within 2 m of the block where URCHIN was deployed. As long as the angle of the wire deploying URCHIN did not vary during transects, the plotted positions of the boat would not differ from the actual track of URCHIN. Attempts were made to minimize the wire angle during transects although that was not always possible in conditions of strong tide.

To estimate the length of intervals within transects, the program "Segment length" was used. Developed at the Bedford Institute of Oceanography by D. McKeown (Personal Communication) this program calculates the track length between specified start and end times for a time series of positions via two different methods: (i) Point-To-Point and (ii) Curve fit. The point-to-point method computes and sums the distance between the actual fixes. This method is satisfactory only if the positions were recorded at a very high resolution and do not contain random noise. The Curve Fit method fits a curve through successive groups of fixes then interpolates fitted positions along these curves. It is the most appropriate method to use if the fixes have been recorded at too low a resolution or are contaminated by random noise. This method was most appropriate for the URCHIN data. The Curve fit method functions as follows:

1. For a user specified curve fit time interval T, it fits third order equations separately to the northing and easting components of the actual fixes over this period.
2. Computes fitted (interpolated) northing and easting components from these fitted curves.
3. Computes the distance over the mid-third of the fitted curve from T/3 to 2T/3.
4. Shifts along the input data time series by a period T/3 and then repeats this process.
5. Adds in the track length from the first fitted curve from 0 to T/3 and from the last fitted curve from 2T/3 to T.

Once the lengths of the countable intervals were determined, the number of lobsters per m^2 per transect was estimated as:

N lobsters on all countable intervals / area of countable intervals

where the area of an interval was length * average width (1.25 m).

Measurements of lobsters - The distance between the laser dots on the video image (25 cm) provided a reference for lobster measurements, but the lobsters were often oriented such that the long axis of the animal was not aligned along the same plane as the laser dots. Individual video frames were captured and converted to digital still images; however, the resulting 0.1 MB images were often of low quality and as a result measurements were not precise. Measurements of known sized lobsters from video taken in the lab gave confidence that measurement was possible to within +/- 10 mm using the laser dots as a reference.

To estimate the approximate size of lobsters observed in the field surveys, 212 lobsters were measured from video frame grabs using image analysis software. All lobsters were from Lobster Bay in 2006. Only lobsters that were in the enumeration box were measured. The proportion of lobsters in the enumeration box that could be measured was not quantified, but was less than half. Lobsters could not be measured if they were oriented incorrectly or if image resolution was low. In some cases, total length could be measured and was converted to carapace length (CL) using the relationship in Wilder (1953). In other cases, claws or carapace widths could be measured. To develop relationships between these body parts and CL, measurements were made on 160 trap-caught animals from Lobster Bay. Relationships were then developed between CL and (i) carapace width (at the cervical groove) (ii) crusher claw length and (iii) cutter claw length. These relationships are below:

CL = 1.285*(Carapace width) + 19.134 (R^2 = 0.896)
CL = 0.527*(Crusher claw length) + 29.896 (R^2 = 0.836)
CL = 0.518*(Cutter claw length) + 25.825 (R^2 = 0.836)

The sizes of lobsters measured in the video were compared with the sizes of lobsters collected by 20 commercial traps set in the area concurrent with the video transects in 2006. The traps were baited and set on the seabed on Sept. 5 and hauled on Sept. 6; the size measurements from video were obtained from transects completed on Aug. 29, 31 or Sept. 8.

RESULTS

Deployment to establish protocols - 2005

In 2005, 26 transects were completed in Lobster Bay (Table 1). Transects were in 4 “transect blocks” south of Whitehead Island (Fig. 3). One block had 11 transects 460-980 m in length (mean=717 m), while the other three blocks had 15 transects 410-580 m in length (mean=473 m). Some transects were interrupted due to rough seabed, low visibility, or obstacles on the seabed. Transect intervals for which there was a high confidence that all lobsters were encountered (Class A), accounted for 65% of the total transect lengths. On average there were 2.6 of these intervals per transect. Average speed over the seabed within the intervals was 2.2 km hr^{-1} (SE=0.48, range = 1.1 to 3.0). Higher speeds generally coincided with stronger tidal currents. At higher speeds, video resolution was reduced and it was more difficult to count accurately in real time. Higher speeds also increased the chances of collision with boulders or with obstacles on the seabed. Such collisions were infrequent and the video frame was hooked on the seabed only once during the survey. It was retrieved when the vessel slowly backtracked over the transect.

A total of 629 lobsters were counted within the Class A intervals of the 26 transects (Table 1). The mean density of lobsters per transect was 0.047 m^{-2} (SE=0.004). There was a significant effect of transect block on density (Table 2) with higher densities for the inner-most transect block compared to the other 3 transect blocks (Fig. 4). The inner-most block was sampled on one day while the other blocks were sampled on the second day. No day effect is expected since weather conditions were good on both days.

Transects in Lobster Bay and St. Mary's Bay - 2006 and 2007

In 2006 and 2007, the project was expanded within Lobster Bay (Fig. 5) and to a new area, St. Mary's Bay (Fig. 6). In each bay, a 1 km^2 grid was established and based on the results from 2005, strata were set up to evaluate potential differences in abundance within the bays. Grid cell selection was primarily random but approximately 20% of the grid cells were selected because local knowledge and sounder transects indicated seabed types were primarily low complexity (mud, sand or gravel). Transects were completed on 26 sampling days over the two years in Lobster Bay and St. Mary's Bay. Transect lengths in 2006 and 2007 averaged 713 m (SE=8.5 m). An attempt was made to sample more than one grid block per day to avoid potential day effects on lobster density estimates. Two to four grid blocks were sampled on 19 of 26 days; on the other 7 days only one grid block was sampled.

The total length of transects was consistent across strata within the two bays (Fig. 7). Mean estimated speed over the seabed during transects in Lobster Bay was 1.6 km hr^{-1} in 2006 and 2.2 km hr^{-1} in 2007, while in St. Mary's Bay mean speeds were lower (1.6 and 1.4 km hr^{-1}). Given a speed of 1.5 km h^{-1}, the average duration for a 700 m transect was approximately 30 minutes. Total number of transects in a work day depended on the distance between transects, and length of the work day. The work day was usually 8-9 hours but was sometimes interrupted by weather (rough sea conditions) or gear issues (infrequent). In 2006 and 2007, the average number of transects per day was 7.6 for Lobster Bay, and 9.8 for St. Mary's Bay.

The estimated numbers of lobsters m^{-2} were based on class A intervals, which included 93% of lobsters counted within the enumeration box (7% of lobsters were counted within Class B intervals). The sum of class A interval lengths varied by area and stratum (Fig. 8) and the overall proportion of transects represented by these intervals was lower in Lobster Bay (0.63-0.65) than in St. Mary's Bay (0.71-0.77). This variation was due to several factors including visibility, depth (greater depth, less light and fewer countable intervals) and seabed complexity.

In 2006 and 2007, a total of 114 transects were completed and 2180 lobsters counted in Lobster Bay (Table 3). In St. Mary's Bay, 108 transects were completed and 1787 lobsters counted.

Estimates of lobster abundance tended to be higher in the inner strata in Lobster Bay (Fig. 9). This was also the case for St. Mary's Bay in 2007, but not in 2006. Proceeding from the inner strata to the outer strata, a clear environmental gradient was present as depths increased (Fig. 10) and temperatures decreased (Fig. 11). Analysis of variance (Table 4) indicated that stratum and temperature were significant, but area, year and depth were not. A sampling day effect was not evaluated because of the unbalanced design.

Seabed type and shelter status

Seabed type for the Class A transect intervals was predominantly mud, sand or gravel (types 1 and 2) (Table 5). St. Mary's Bay had a slightly higher proportion in these two seabed types compared to Lobster Bay. Inclusion of Class B interval data increased the number of lobsters observed to 2387 for Lobster Bay and 1851 for St. Mary's Bay. Lobster counts in both Lobster Bay and St. Mary's Bay were distributed across the 5 seabed types in proportion to the frequency of the seabed types (Fig. 12).

On sand or mud habitats, most lobsters were observed in the open, rather than in association with burrows or shelters (Fig. 13). In Lobster Bay the percentage in the open for all strata combined was 57%; in St. Mary's Bay 78% of lobsters counted were in the open. At the other extreme of shelter, 10% (n=240) of lobsters in Lobster Bay were on hard seabeds in pits against rocks or partially hidden (shelter status 5 and 6). In St. Mary's Bay just 3.5% of lobsters (n=66) were in categories 5 and 6.

Lobster Sizes

Carapace length (CL, 20 mm bins) was estimated for lobsters observed on video transects and compared with the CLs of lobsters measured from trap catches. All trapped lobsters were obtained from the inner portion of Lobster Bay in 2006 (Fig. 14). Of the 212 measured from video transects, the size range was approximately 40 to 180 mm CL. The mean size of these lobsters (calculated from the midpoint of the 20 mm bins) was 98.9 mm CL. Lobsters collected in the 20 traps in inner Lobster Bay (n=435) had a mean CL of 85.7 mm (range = 50-148 mm) (Fig. 15). Compared to the trap-caught size frequency, the size frequency from the videos included a higher portion of smaller lobsters (< 80 mm CL) and large lobsters (> 120 mm CL). Restriction of the video data to those 4 transects closest to the traps reduced the data set to 112 lobsters, but the size frequency remained very similar (mean=97.5 mm CL).

DISCUSSION

Use of video as a survey tool for lobsters

In general URCHIN worked well for estimating lobster abundance on low complexity seabeds, and the estimates were within the range expected based on comparison with other methods (see below). The system was deployable from a lobster boat, which is advantageous both in terms of cost and in engaging fishermen in science. The precision of the system was not directly quantifiable, as it was affected by variability in the position of the video camera relative to the seabed, the wire angle of the suspension cable, water clarity and seabed roughness, all of which varied in undocumented ways across the survey data set. Although the precision of the lobster abundance estimates was very likely less than that from SCUBA transects, time in the field to collect data was substantially less than what could be expected from SCUBA transects. As such video allows for greater spatial coverage and increased data acquisition per unit time in comparison with SCUBA.

The video system was much more capable of working in deeper water and in rough surface conditions than a team of SCUBA divers. Routine SCUBA surveys at depths greater than 15-20 m become increasingly limited due to the reduced bottom times of divers. In addition surface conditions can make it unsafe for divers to enter and exit the water. Even if weather and depths were suitable, it would be more expensive to have a dive team conduct the number of dive transects comparable to the video transects completed here. With a team of three people on board for the video transects (including vessel captain), 8-10 transects of 500-800 m in length were possible per day (total daily coverage approximately = 6000 m^2). The dive transects completed in Lobster Bay for another study (Tremblay and Smith 2001) were 150 m in length and 2 m wide, for an area covered of 300 m^2. Thus, 20 dive transects would give coverage of 6000 m^2, equal to that in a day of video transects. This number of dive transects would usually take a team of three (2 divers, one boat person) 4-6 days, or a team of five 2-3 days.

Another advantage of video over other methods (SCUBA, trawl) is that an archivable record exists of the transect conditions including lobsters, other benthic fauna, and seabed type, in the form of a video tape, or a digital video file. With SCUBA and trawls, counts and measurements are more or less final on the day the field work is complete, and there is no way to resample the transect beyond the original information collected, or obtain additional descriptors of conditions. With video, counts are not final until the videos are considered to be fully reviewed for the original survey intent. However, this does come with the cost of additional resources (image analysis and computer facilities, personnel time) to process the video footage. For this project, we found that for every hour of video tape, at least 2 hours of processing time was needed. This processing time could be considerably greater if more data are to be extracted and quantified from video.

A disadvantage of video that is shared by other methods (SCUBA, trawl) is the inability to get accurate estimates of abundance on complex seabeds. While SCUBA allows better estimates on these seabeds, divers are still unlikely to count all lobsters when there are stacked or large boulders, particularly when combined with heavy macrophyte cover.

A disadvantage of the URCHIN video system design, as used for this survey application, was the difficulty in measuring lobsters. Sex, egg status, shell condition and other biological attributes could also not be assessed. The ability to measure lobsters from video could be improved over the URCHIN system used here. URCHIN provided for low resolution images (original standard definition video image; image frame grabs), and lobsters were often oriented such that measurement using the laser dots was difficult or inappropriate. Images from video could be improved with newer technology; some of these improvements are discussed below. It should be noted that improvements to the video system will still not allow for determination of sex and other biological attributes of lobsters since only the dorsal view is available, and the lobster cannot be physically manipulated. In SCUBA transects or trawls lobsters can be grasped, turned over and physically examined.

The lobster measurements that were done had a wider size range than those done on lobsters from traps fished concurrent to the video transects. This illustrates the high size selectivity of lobster traps, a feature also demonstrated in comparisons between measurements done on lobsters collected by SCUBA and those collected in traps (Tremblay and Smith 2001). Compared to traps, video has the potential to give a more complete picture of lobster size structure on the bottom.

Trends in abundance and comparisons with other methods

Within the range of conditions where lobster counts were possible (Class A and B intervals), lobsters were distributed in proportion to the frequency of observed seabed types. We are confident of this finding with regard to sand and cobble, but it is likely that we underestimated the density of lobsters on rougher seabeds (e.g. most in Class B intervals), given that in these areas some lobsters would have been hidden in shelters.

No bay or year effect on abundance was detected in 2006 and 2007. Both Lobster Bay and St. Mary's Bay have similar high abundance of lobsters present in late summer and early fall. The analysis of variance detected an effect of stratum and temperature. The effect of day sampled was not evaluated but is thought to be unimportant since at least two strata were sampled on most days. Trends within bays corresponded to gradients in both depth and bottom temperature, although only temperature was a significant factor in the analysis of variance. Lobster abundance tended to be higher in the inner portions of the bays where temperatures were warmer. Temperature is often cited as a causal mechanism of lobster distribution (e.g. Campbell 1990, Cowan et al. 2007).

Comparisons of video estimates of abundance with those from other methods are hampered by the lack of samples co-occurring in time and space. Some comparisons with estimates using other methods in Lobster Bay and St. Mary's Bay at different times are described below. They indicate that the lobster abundance estimates from video are in the expected range. Lobster density estimates for the inner portion of Lobster Bay using SCUBA in September of 1998 (Tremblay and Smith 2001) are similar to the estimates from video in 2006 and 2007. On sand- and mud-dominated seabeds, the mean number of lobsters > 50 mm CL per 300 m^2 dive transect was 15.9 lobsters (= 0.053 m^{-2}). The video estimates of abundance for this area (Stratum A) were 0.04-0.05 lobsters m^{-2} (Fig. 9). Based on increased landings, commercial catch rates and trawl catch rates, we would expect that densities in 2006-07 were higher than the earlier period, so the video transects may have underestimated the abundance in 2006 and 2007, but this cannot be confirmed.

Abundance estimates from trawl tows are available from July 2006 and 2007 for a few locations in Lobster Bay and St. Mary's Bay (Table 6, Fig. 16). These were part of a survey done by industry in cooperation with DFO. Termed the "ITQ Survey" (ITQ = Individual Transferrable Quota), it was directed at groundfish, but also recorded lobsters. For comparison with these tows (done in July of each year), we selected those video transects conducted in September that were within 2.5 km of the ITQ tow locations two months earlier. In most cases the estimates of abundance from video were higher than those from the ITQ survey (Table 6, Fig. 17), as might be expected given that not all lobsters in the path of the trawl are captured.

Potential future applications of video for estimating lobster abundance

Estimates of abundance of lobsters on low complexity seabeds are possible with video transects conducted in a manner similar to that described here. This approach has the advantage of lower cost and a greater range of bottom depths than is possible with underwater censuses by divers, and more accurate estimates of abundance than those possible from trawl surveys. Video transects could be used to get highly resolved estimates of abundance in low complexity seabed habitats. Such an approach would be particularly useful when the questions are related to smaller geographic scales such as coastal embayments, estuaries etc.

Since the original URCHIN system was documented (Strong and Lawton 2004), high definition video standards have replaced standard definition technology, both in terms of video camera image resolution, and also video recording formats. However, in terms of simply providing the surface operator with a forward view of the survey device transit across the seabed (and thus ability to avoid oncoming obstacles) existing hardware equipment and video system configurations based on standard definition still remain useful, as of 2014.

Development of an easily deployed video platform based on two cameras could provide a more effective lobster video survey package particularly if accurate carapace length measurements were possible. One camera would be dedicated to a forward oblique survey operations view, and could use existing standard definition cameras, particularly low-light capable cameras. The second camera would be mounted separately on the platform and would have a fully vertical view with better resolution for measuring carapace length. Trials are currently underway at the Saint Andrews Biological Station (P. Lawton, Personal Communication) to integrate a high definition color camera system with laser scaling into an updated video survey platform. One benefit of this new camera system is that it can be powered from a battery pack on the platform that also powers a video light/still image flash. The camera itself can be set up either to record continuous high definition video, sequential still images, or combinations of the two. Alternative designs with two camera systems could involve cable systems that allow for remote triggering of a vertically-oriented camera from the surface.

Survey design is an area that requires further work should video transects be employed for lobster abundance estimation. Ideally, high resolution seabed type maps would be available for the area to be surveyed and transect locations would be randomly selected from several strata; using this approach density estimates could be converted to estimates of population abundance. For the present study, scaling up the abundance estimates from transects was not possible because comprehensive seabed maps for these areas do not exist, and the selection of transects was not completely random.

With regard to developing a routine abundance survey for lobsters in the Maritimes Region at larger scales, the current focus is on a trawl survey. Although a trawl survey will never equal a video survey in potential for direct estimates of density, accurate length measurements and other biological data are readily obtained from trawl catches. A video survey has potentially higher costs in terms of staff technical skills, post-survey processing and equipment maintenance. The best approach may be the use of video in combination with trawls. An enhanced video survey tool would be a valuable complement to a trawl survey and could be used not only to characterize habitat in the area of the trawl survey, but to estimate the catchability of lobsters in the trawl.

ACKNOWLEDGEMENTS

This project was possible only with the participation of several key people. For operating the fishing vessels and providing expert advice on deploying the video, and on local seabed habitat, we thank Carl Spinney and Stacey Denton. Mike Strong worked with Peter Lawton in the original development of the URCHIN system, and we thank him and other DFO staff (Stephen Nolan) who assisted in running and maintaining the URCHIN system during this project. We thank Dave McKeown for providing software and advice for processing the navigational data, and for the software for estimating transect interval lengths. For many hours of video analysis in the lab, we thank Julie Sperl, Samantha Hamilton and Megan Wilson. For comments that improved the manuscript, we thank Julien Gaudette, Manon Cassista-Da Ros and Scott Coffen-Smout.

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Table 1. Lobster counts and density estimates for 2005 by transect block (see Fig. 3). Counts are totals for countable intervals (Class A). Mean number calculated as the average of transect number m^{-2}, rather than the total number of lobsters over all transects divided by the sum of all interval lengths.

Transect Block	Number of transects	Number of countable intervals	Sum of interval lengths (m)	Total number of lobsters counted	Mean number m^{-2}
1	11	29	5831	437	0.065
2	5	12	1728	88	0.034
3	5	10	1433	61	0.024
4	5	17	1055	43	0.034
Total	26	68	10048	629	0.046

Table 2. Analysis of variance table for effect of transect block on number of lobsters m^{-2}. Numbers were log transformed for analysis.

	Df	Sum Squares	Mean Square	F value	Probability > F
Block	3	1.738	0.579	5.185	0.0073
Residuals	22	2.459	0.112		

Table 3. Number of transects, intervals and lobster counts by area, year and stratum. Only countable intervals (Class A) included.

Area	Year	Stratum	Number of transects	Number of intervals	Sum of lobsters
Lobster	2006	A	23	55	767
Bay		B	16	30	275
		C	10	19	205
		D	11	37	162
		E	11	48	65
		All	**71**	**189**	**1474**
	2007	A	10	15	238
		B	11	16	185
		C	11	30	163
		D	5	9	55
		E	6	13	65
		All	**43**	**83**	**706**
	2006-07	All	**114**		**2180**
Saint	2006	A	8	25	97
Mary's		B	12	26	182
Bay		C	13	16	205
		D	13	17	318
		E	13	23	161
		All	**59**	**107**	**963**
	2007	A	3	5	100
		B	7	8	220
		C	9	16	193
		D	12	16	164
		E	18	31	147
		All	**49**	**76**	**824**
	2006-07	All	**108**		**1787**

Table 4. Analysis of variance of lobsters m^{-2} in Lobster Bay and St. Mary's Bay in 2006 and 2007. Seven transects were eliminated because they had zero lobsters; 2 transects were eliminated because temperature and depth data were not available.

Effect	Df	Sum Squares	Mean Square	F value	Probability > F
Stratum	4	26.99	6.75	10.27	***0.0000
Year	1	1.04	1.04	1.59	0.2092
Area	1	0.21	0.21	0.32	0.5755
Temperature	1	5.97	5.97	9.08	**0.0029
Depth	1	0.82	0.82	1.25	0.2642
Residuals	204	134.01	0.66		

Table 5. Interval lengths by area and strata, together with proportion of lengths assigned to each seabed type. Only countable intervals (class A) included. Seabed types were as follows: 1) Mud or sand only; 2) Gravel with or without sand or mud; 3) Cobble with or without sand or mud; 4) Boulder with or without cobble or gravel; 5) Boulder with kelp.

			Seabed type				
Area		**Total interval length (m)**	**1**	**2**	**3**	**4**	**5**
Lobster Bay	All strata	59276	**46%**	**22%**	**15%**	**15%**	**2%**
	A	17733	55%	27%	8%	6%	4%
	B	15402	77%	4%	6%	11%	2%
	C	10375	30%	29%	28%	11%	2%
	D	7749	10%	22%	20%	48%	0%
	E	8017	17%	38%	29%	15%	2%
St. Mary's Bay	All strata	**57378**	**52%**	**26%**	**10%**	**8%**	**4%**
	A	5110	35%	54%	8%	0%	3%
	B	10730	50%	25%	8%	13%	4%
	C	12624	71%	13%	1%	16%	0%
	D	13631	65%	17%	12%	4%	2%
	E	15282	32%	34%	19%	6%	8%

Table 6. Estimates of lobster abundance off southwest NS from video transects, and trawls. Trawls were from a July 2006 and 2007 trawl survey conducted by the Individual Transferrable Quota (ITQ) groundfish fleet in cooperation with DFO (unpublished). The survey was conducted with balloon trawl with rock hopper gear. Video transects (Set) completed in late August and September 2006 and 2007 were selected for comparison with a trawling station (Sta) if the centre of the video transect was within 2.5 km of the centre of the trawl track. Length for the video transects is the sum of the countable intervals. Fig. 16 shows locations of video transects and trawls.

Location	Date	Method	Length (m),	Depth (m)	Number of lobsters	Density No m^{-2}
Inner Lobster Bay	2006	ITQ - Sta 58	1878	14-15	219	0.0069
Inner Lobster Bay	2006	Video – Set 308	600	16-17	5	0.0067
		Video – Set 309	623	13-14	7	0.0090
Outer Lobster Bay	2006	ITQ - Sta 59	1848	11-17	1112	0.0354
	2006	Video - Set 292	587	18-23	33	0.0450
	2007	ITQ - Sta 59	1865	6-10	301	0.0095
	2007	Video - Set 452	534	13-22	41	0.0614
St. Mary's Bay	2006	ITQ - Sta 46a	1878	33-35	116	0.0036
		Video - Set 364	600	42-43	11	0.0147
		Video - Set 365	395	33-35	5	0.0101
	2007	ITQ - Sta 46a	1867	36	341	0.0107
		Video - Set 493	738	34-35	10	0.0108
		Video – Set 494	589	33-36	11	0.0149
		Video - Set 495	593	33-36	11	0.0148
	2007	ITQ - Sta 46b	1898	31-35	24	0.0007
		Video - Set 464	643	25-32	6	0.0075
		Video - Set 476	576	34-35	7	0.0097

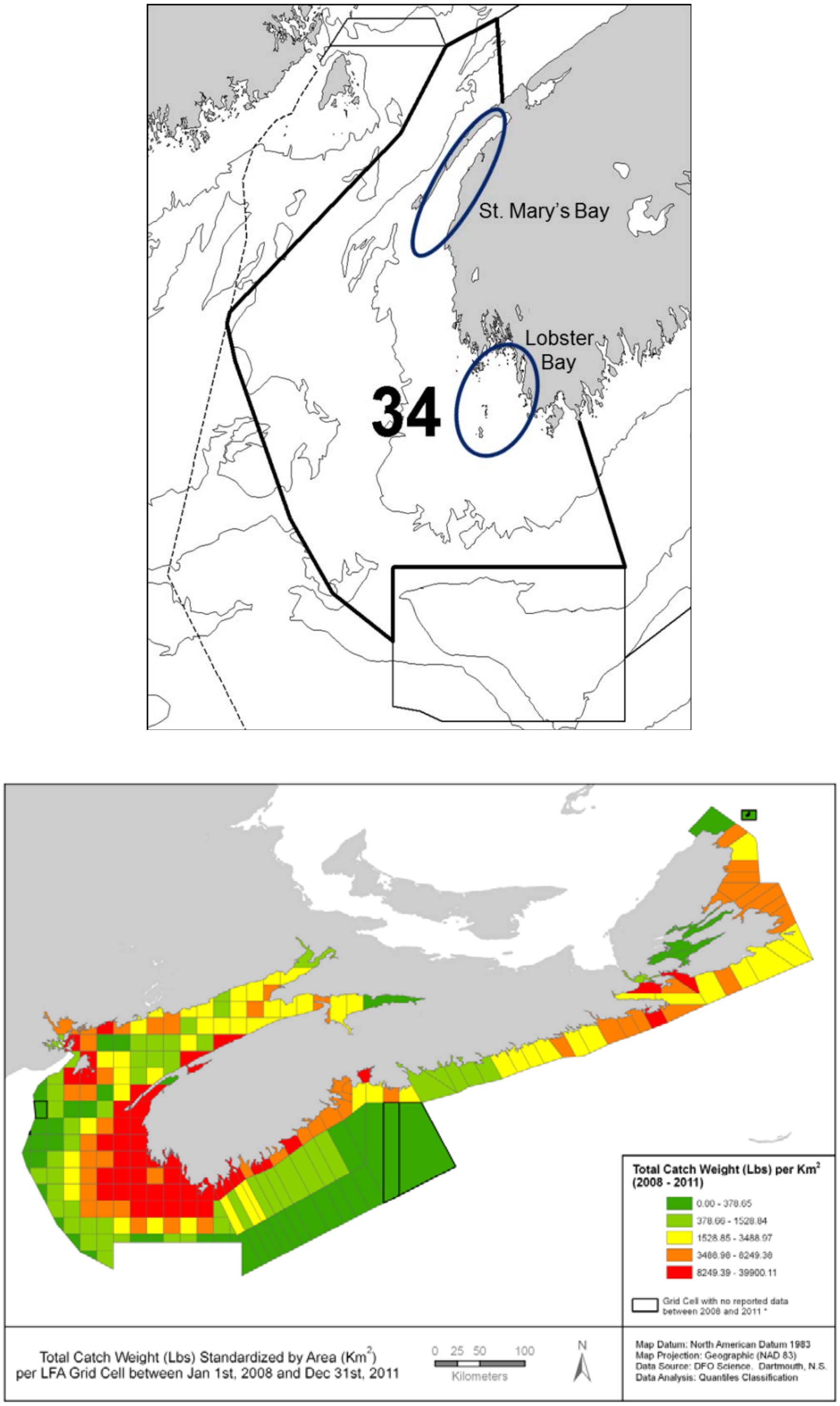

Figure 1. Location of study areas in LFA 34 (upper panel), together with the spatial distribution of lobster landings by commercial fishing fleets (lower panel). The lower panel shows colour-coded weight per km^2 by reporting cell for all LFAs in the Scotia-Fundy fisheries management area (2008-11, from Coffen-Smout et al. 2013).

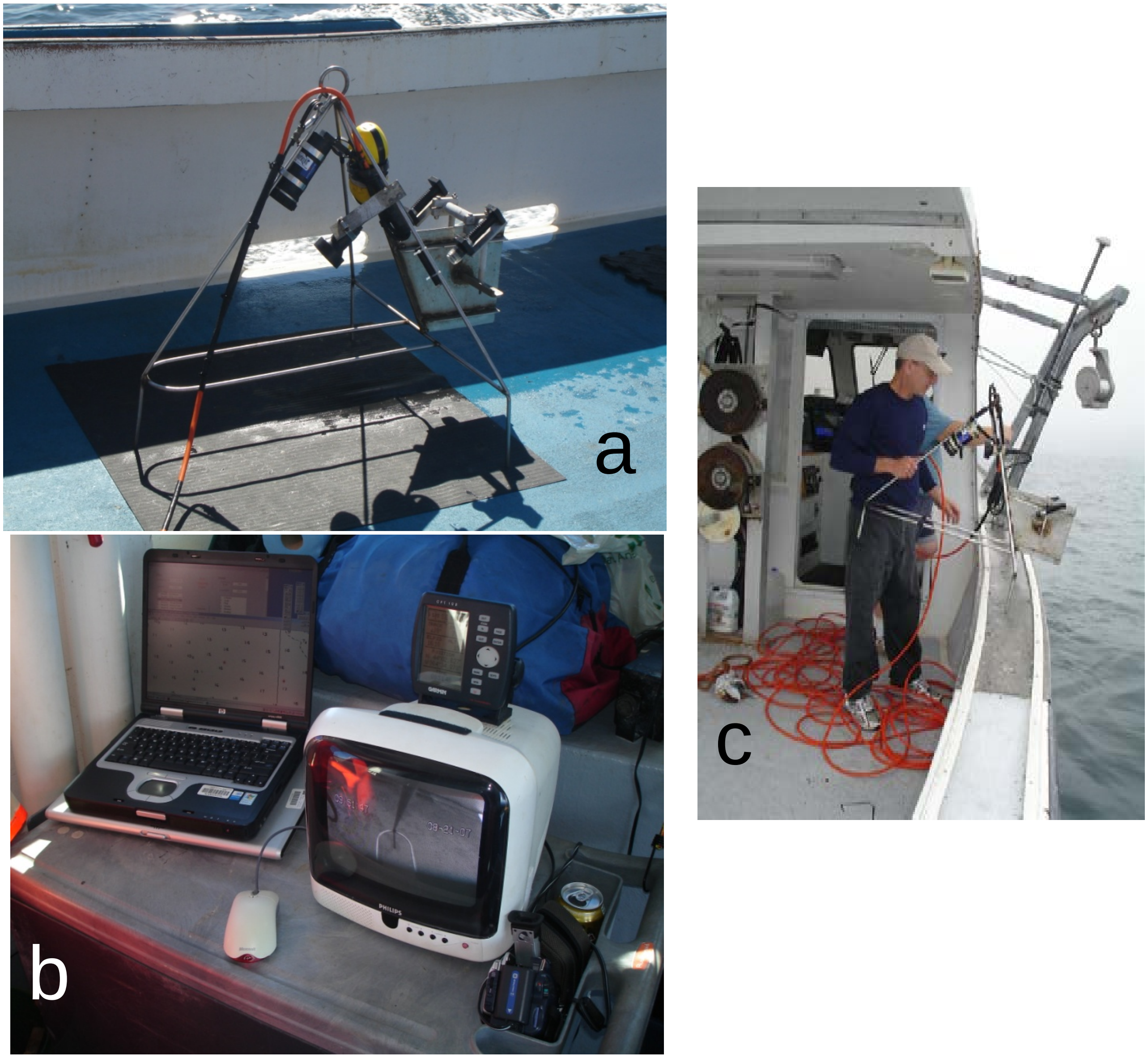

Figure 2. URCHIN camera system. (a) in between transects on deck. Low light black and white camera is at apex of tripod, looking forward; dual lasers are mounted at rear. Light (seldom used) is on left rear leg. Temperature recorder is strapped to same leg. (b) On-deck survey monitoring and data recording systems. Shown is laptop running geographical information system software, and a custom software program for time- and geo-referenced logging of discrete “events” (e.g. lobster encounter) and “classes” of habitat types (start and end points on the survey for each habitat class). GPS shown above TV monitor, with video camera for recording underwater video shown alongside. (c) Deploying URCHIN over the side of a lobster fishing boat

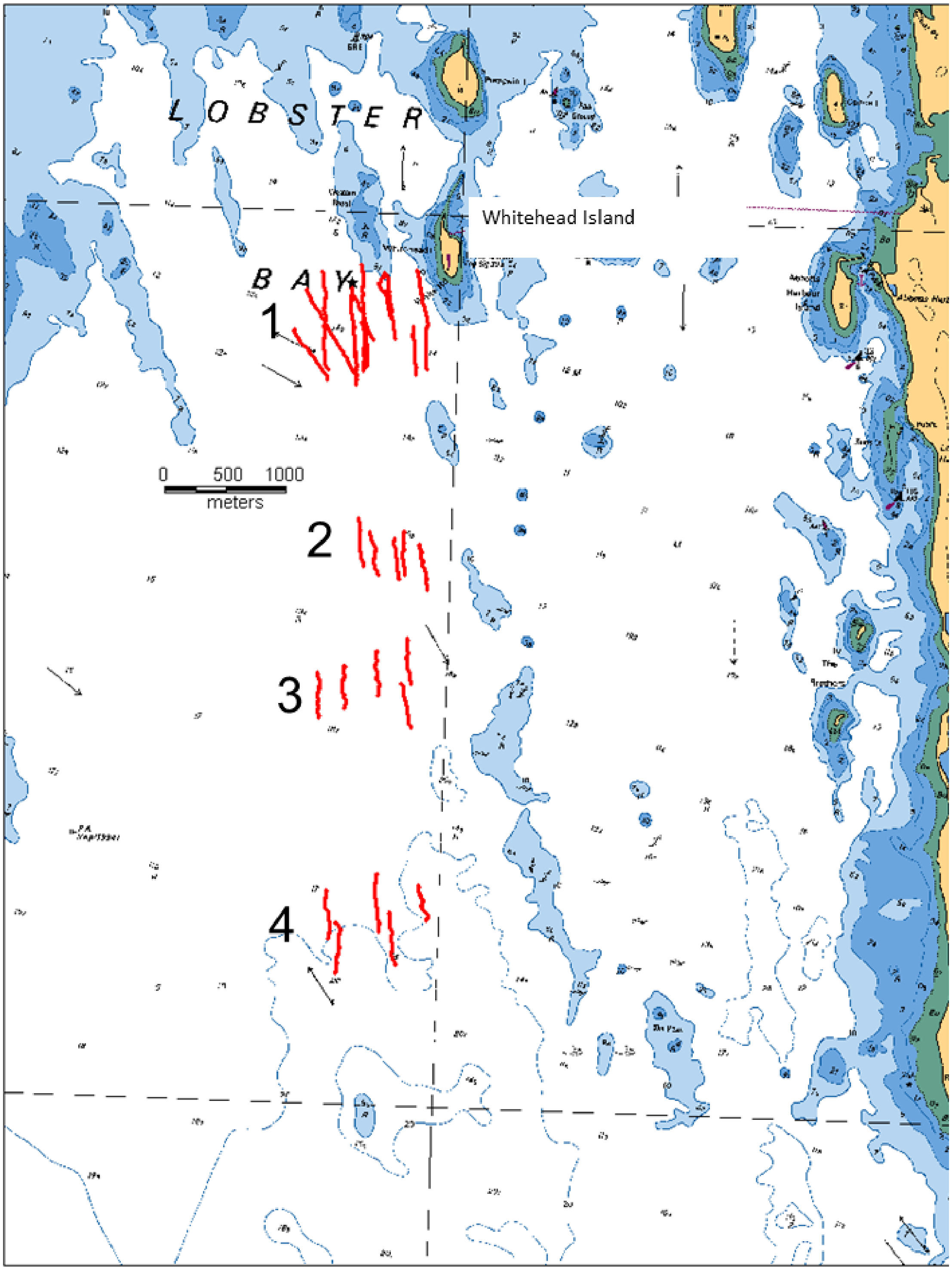

Figure 3. Lobster Bay transects sampled Aug. 30 to Aug. 31, 2005. Numbers refer to transect block.

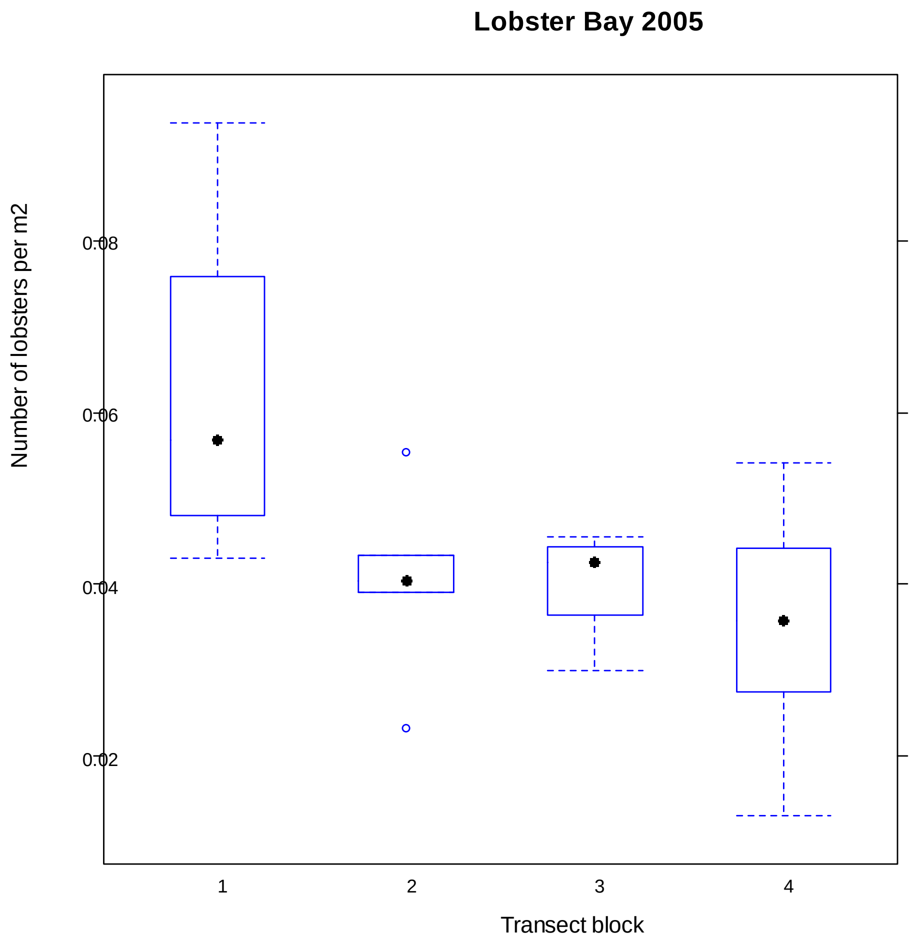

Figure 4. Box and whisker (BW) plot of estimated number of lobsters m^{-2} in Lobster Bay in 2005 by transect block (see Fig. 3). Box and whisker plot has the following features: the median is represented by the solid circle and the interquartile range (IQR) is represented by the rectangle with lower boundary at the first quartile (25^{th} percentile) and upper boundary at the third quartile (75^{th} percentile). The horizontal dashed lines ("whiskers") show the minimum and maximum values unless there are values beyond 1.5 times the IQR. If this is the case, the whiskers are at 1.5 times the IQR, and values outside of this ("outliers") are depicted with open circles.

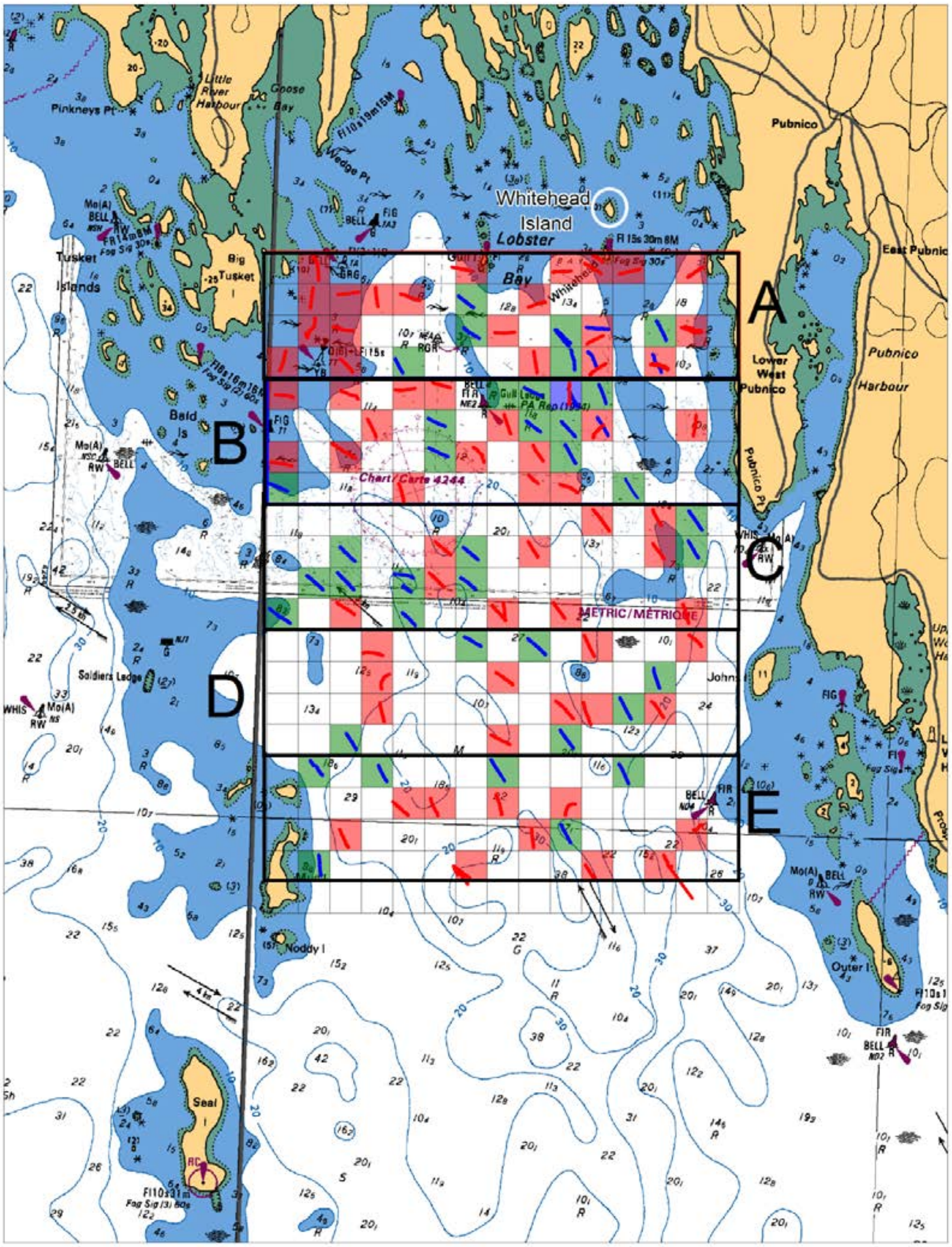

Figure 5. Lobster Bay video transect lines. Shown are transects completed within 1 km^2 grid cells in 2006 (red) and 2007 (blue transect in green grid cell). Cells were selected from within five strata (A, B, C, D, E) comprised of 54 cells each. 2005 sampling was all within strata A and B, in a 2 km wide by 7 km long block south of Whitehead Island. Sampling in Lobster Bay was on 10 days from Aug. 29 to Sept. 15 2006 and on 5 days from Aug. 27 to Aug. 31 2007.

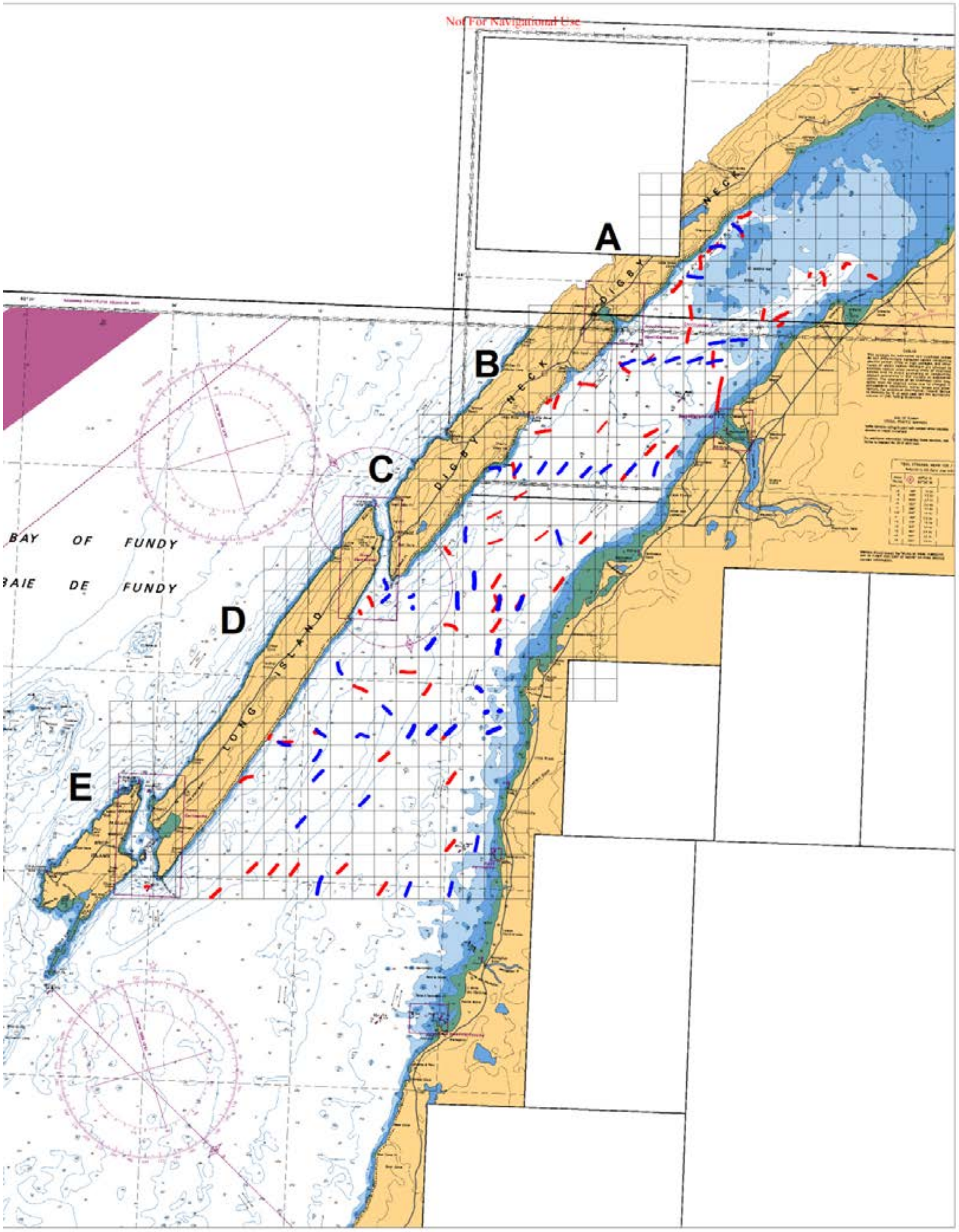

Figure 6. St. Mary's Bay video transect lines. Shown are transects completed within 1 km^2 grid cells in 2006 (red) and 2007 (blue). Cells were selected from within five strata (A, B, C, D, E). Sampling in St. Mary's Bay was on 6 days from Sept. 21 to Oct. 4 2006 and 5 days from Sept. 10 to Sept. 16 in 2007.

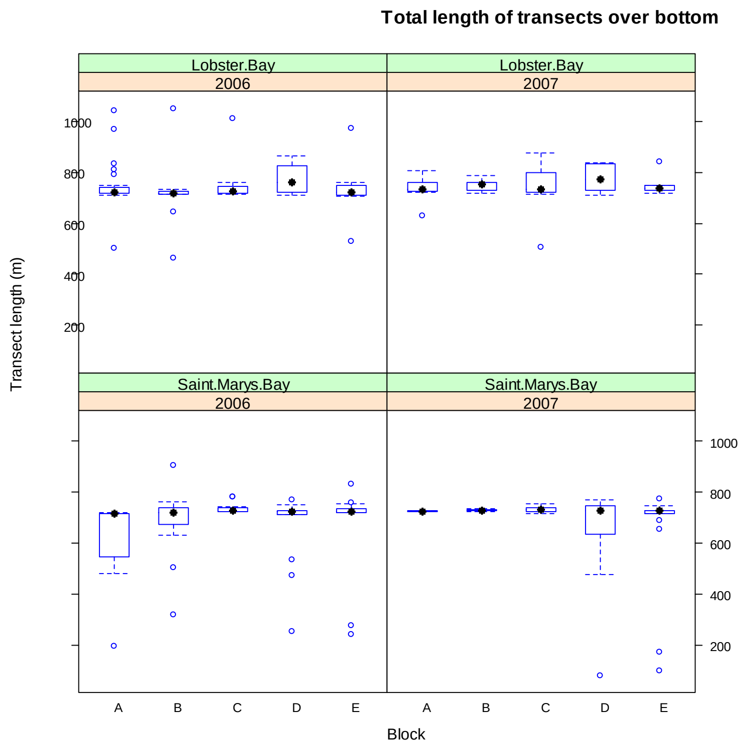

Figure 7. BW plot of total length of transects by area, year and stratum. See Fig. 4 caption for description of the BW plot.

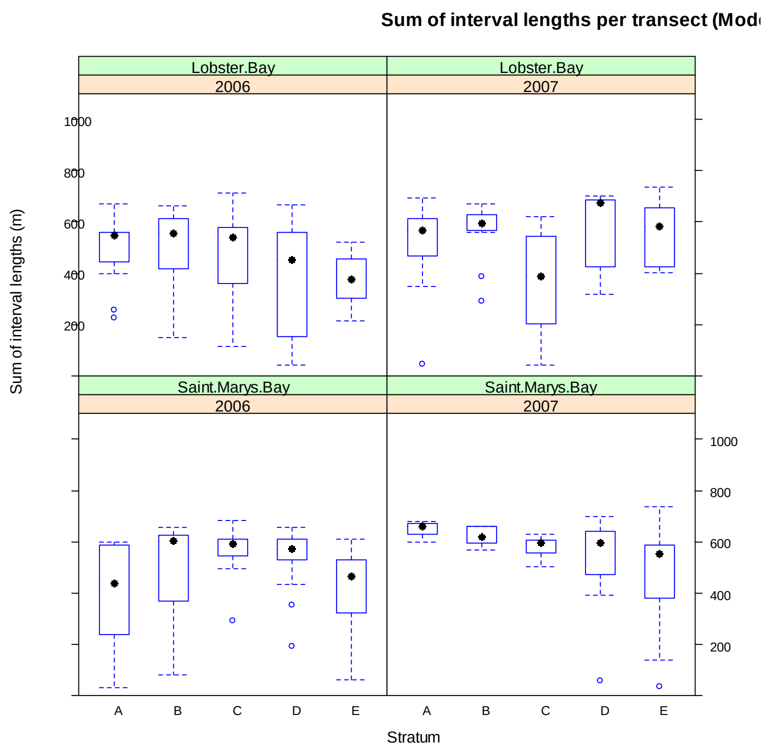

Figure 8. BW plot of sum of lengths of countable intervals (Class A) per transect by area, year and stratum. See Fig. 4 caption for description of the BW plot.

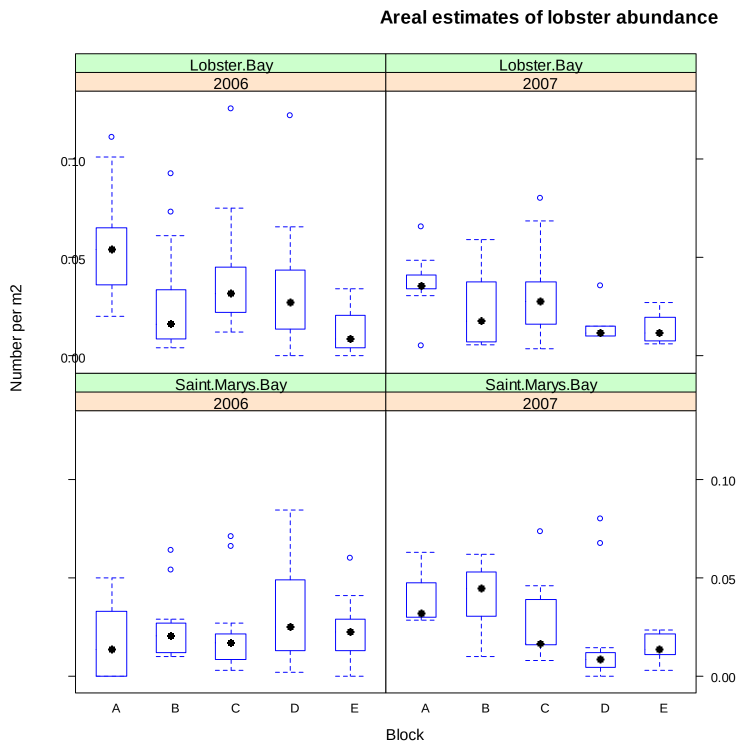

Figure 9. BW plot of lobster abundance by area, year and stratum. See Fig. 4 caption for description of the BW plot.

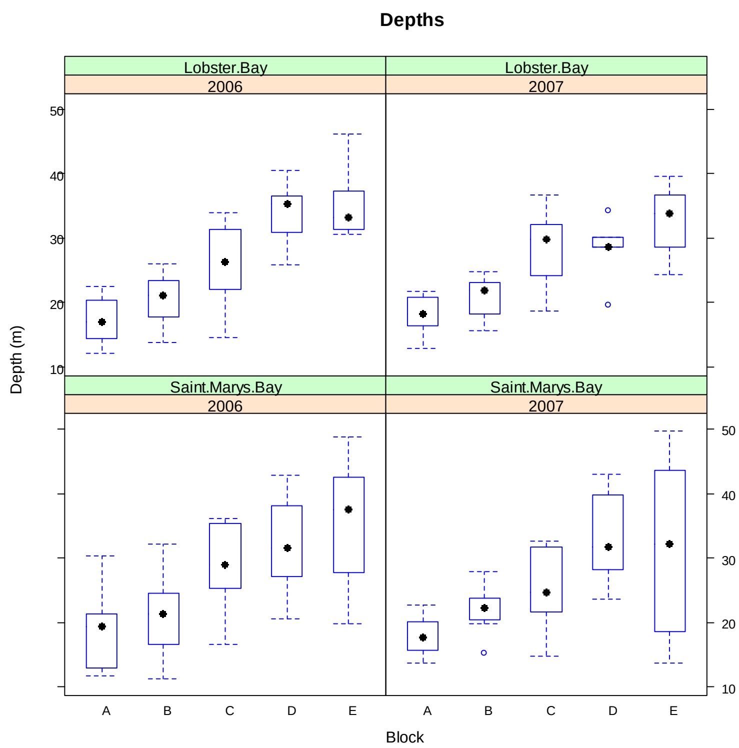

Figure 10. BW plot of depths for transects by area, year and stratum. See Fig. 4 caption for description of the BW plot.

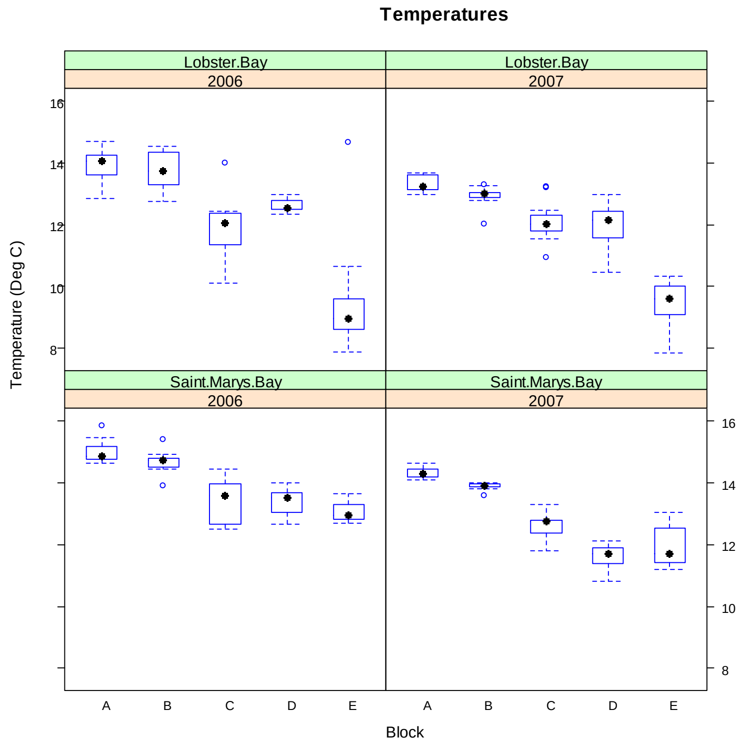

Figure 11. BW plot of temperatures for transects by area, year and stratum. See Fig. 4 caption for description of the BW plot.

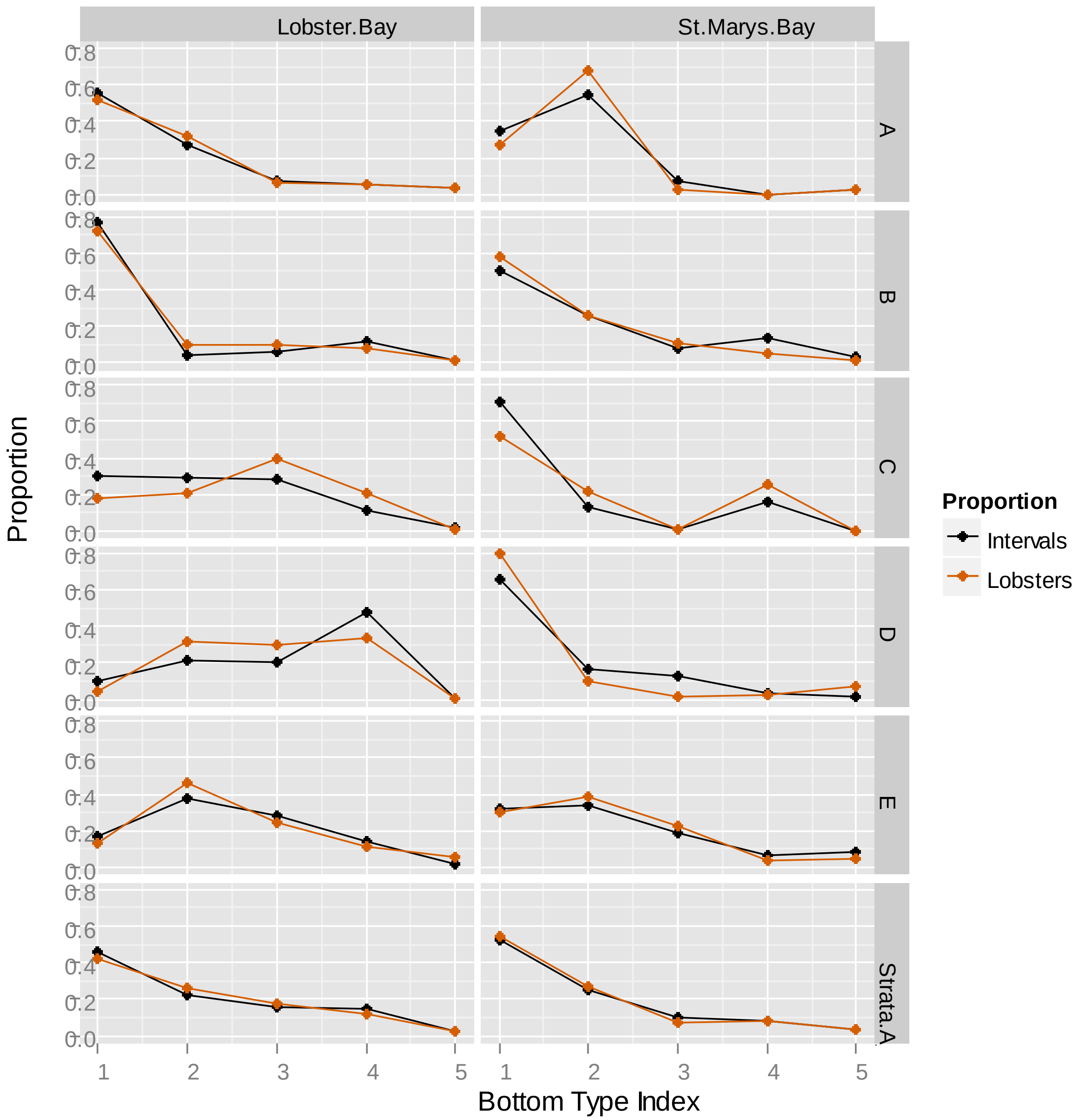

Figure 12. Lobsters and availability of seabed type by area and stratum (A to E), 2006 and 2007 combined. Class A and Class B data included. Shown is proportion of lobsters counted within each seabed type (in red) by area and stratum, together with length of intervals of each seabed type as a proportion of total interval lengths within each area and stratum (in black). Seabed types were as follows: 1) Mud or sand only; 2) Gravel with or without sand or mud; 3) Cobble with or without sand or mud; 4) Boulder with or without cobble or gravel; 5) Boulder with kelp.

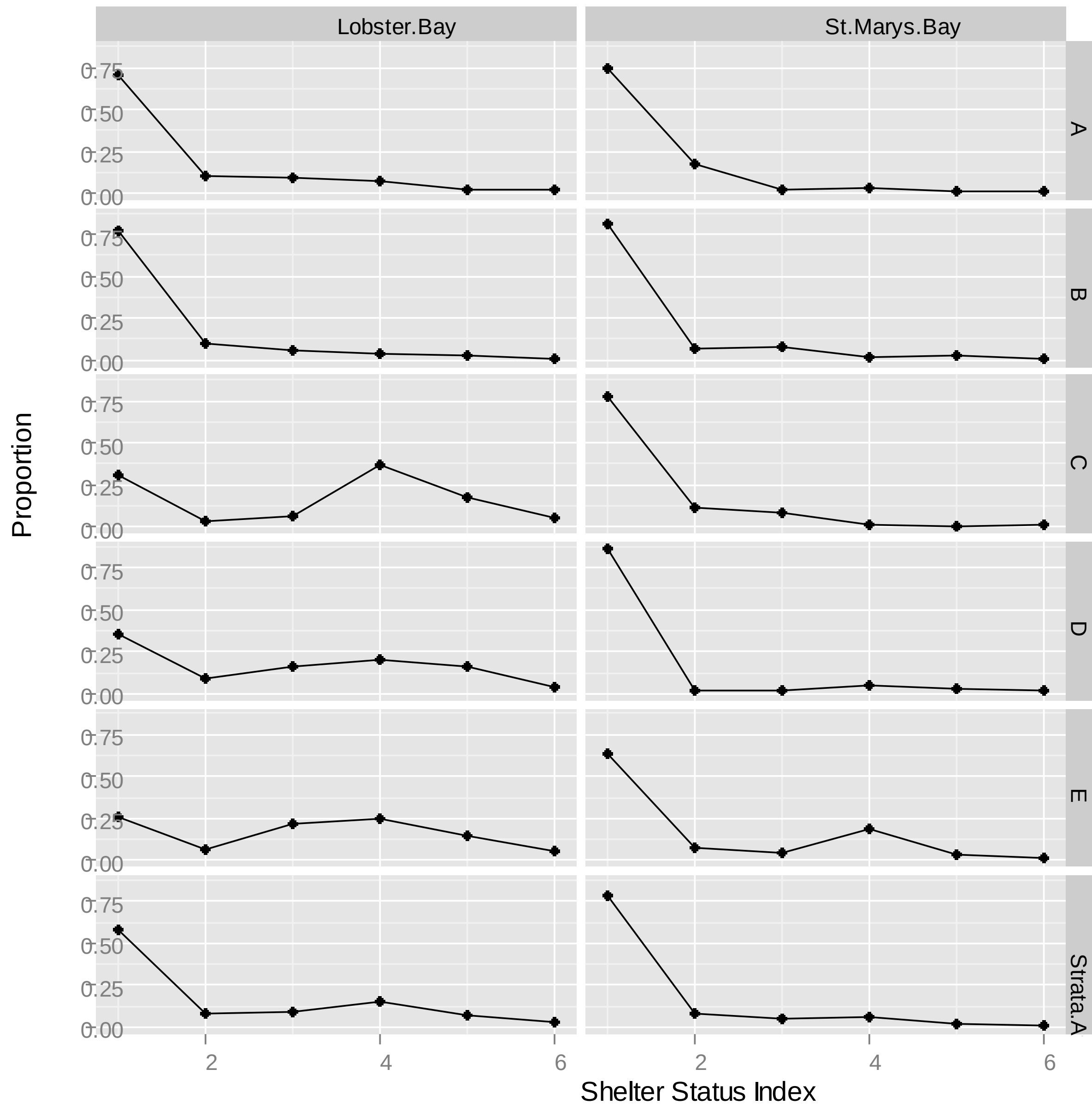

Figure 13. Shelter status of lobsters by area and stratum (A to E), 2006 and 2007 combined. Class A and Class B data included. Shelter status 1-6 defined below.

1. In open, not associated with burrow or shelter, on mud or sand;
2. Associated with pit or burrow, on sand or mud;
3. Partially sheltered against rock on sand or mud;
4. In open on hard seabed (gravel, cobble, boulder);
5. Partially sheltered in pit or against rock on hard seabed;
6. Primarily sheltered in pit, burrow or crevice on hard seabed.

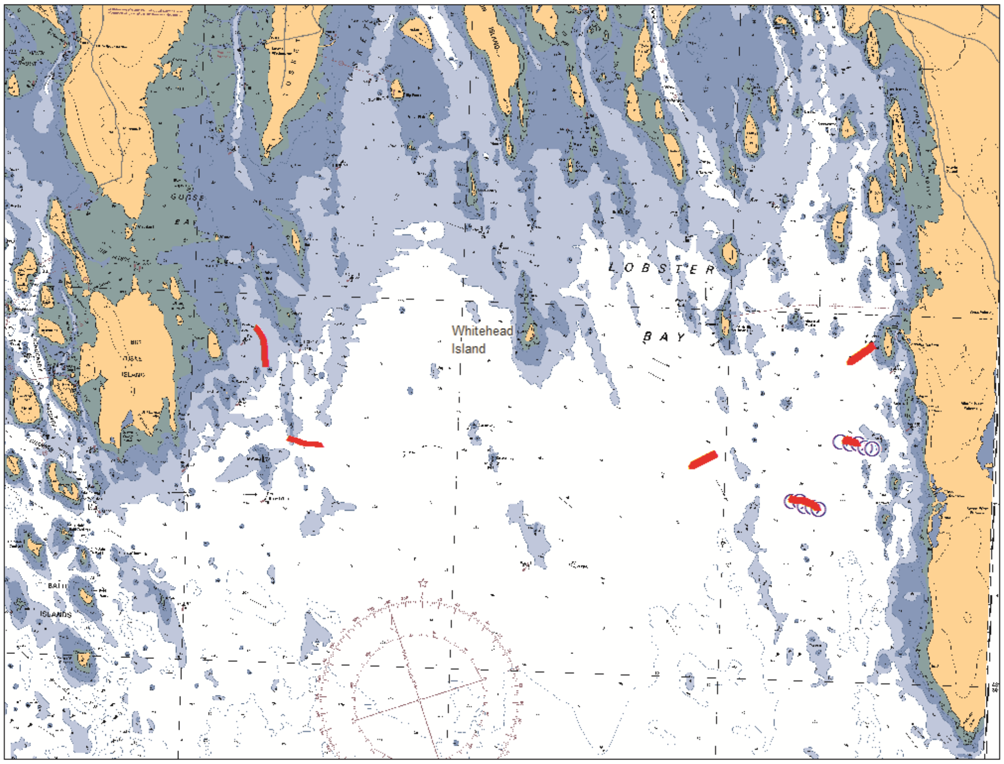

Figure 14. Locations of transects (red) and traps (circles) where lobsters were obtained for measurement of carapace length in Sept. 2006.

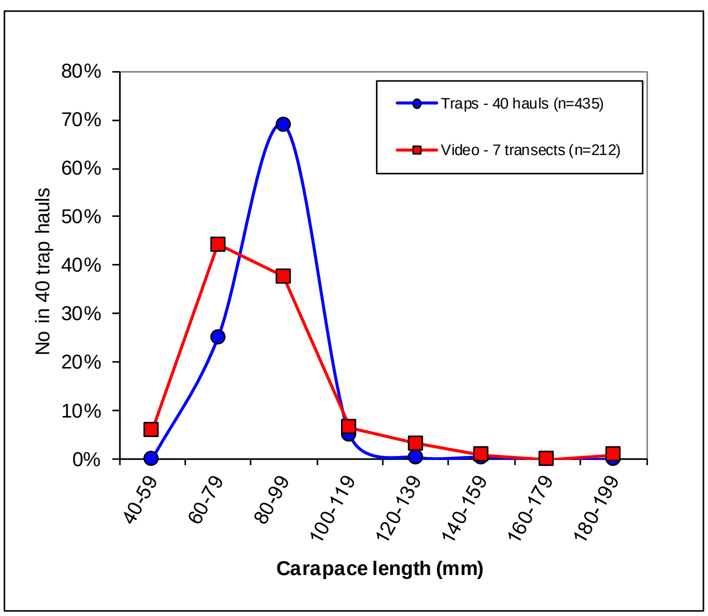

Figure 15. Lobster size frequency as measured in lobsters from traps and lobsters in video. Sizes binned by 20 mm increments because this was the best resolution achievable from video images.

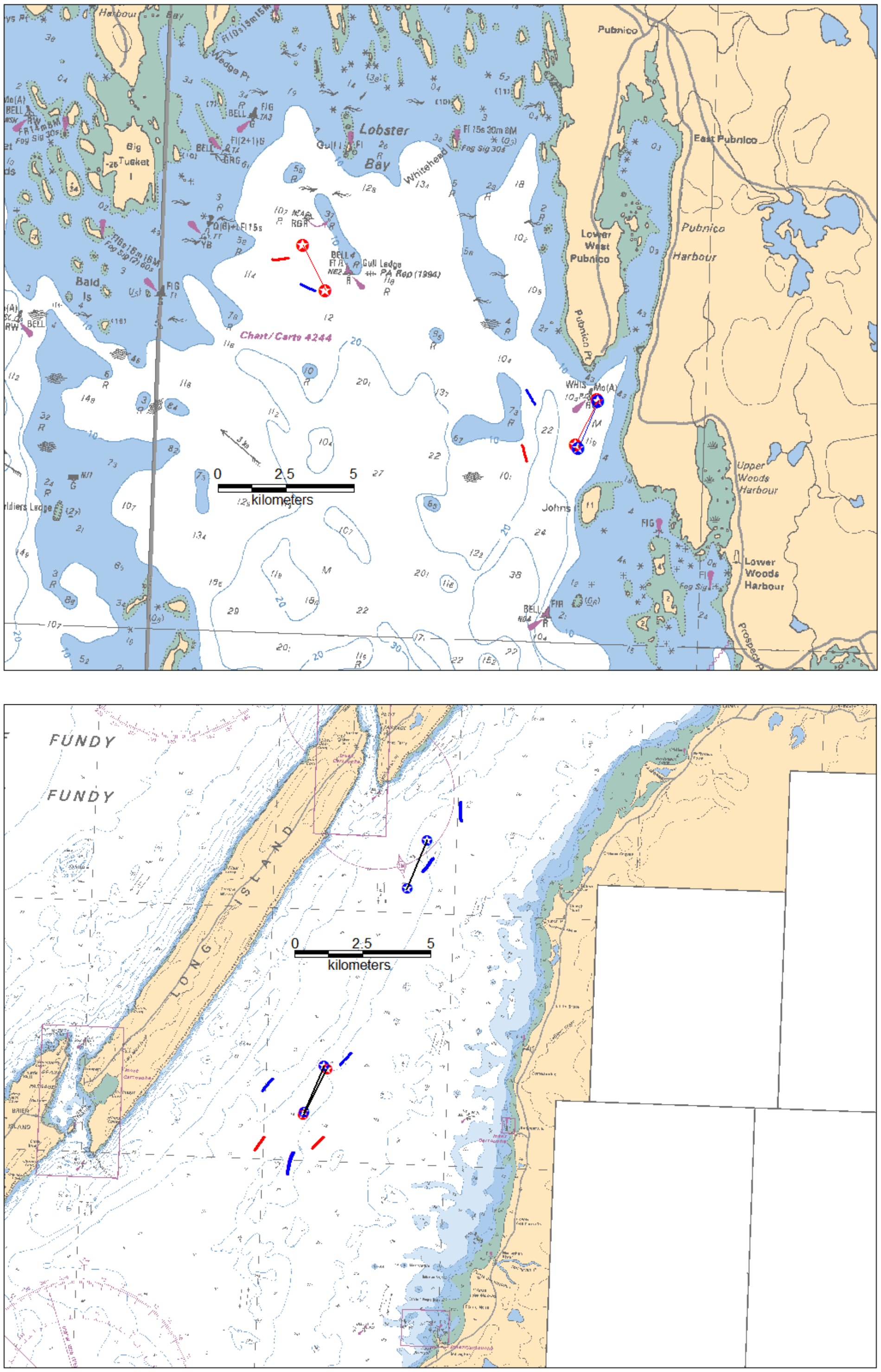

Figure 16. Locations of trawls and video transects used to compare abundance estimates using these two sampling methods. Upper panel is Lobster Bay, lower panel St. Mary’s Bay. Trawl locations have circles at endpoints. Red transects and circles indicate 2006; blue transects and circles indicate 2007. Trawls were conducted in July, video transects in late August-September.

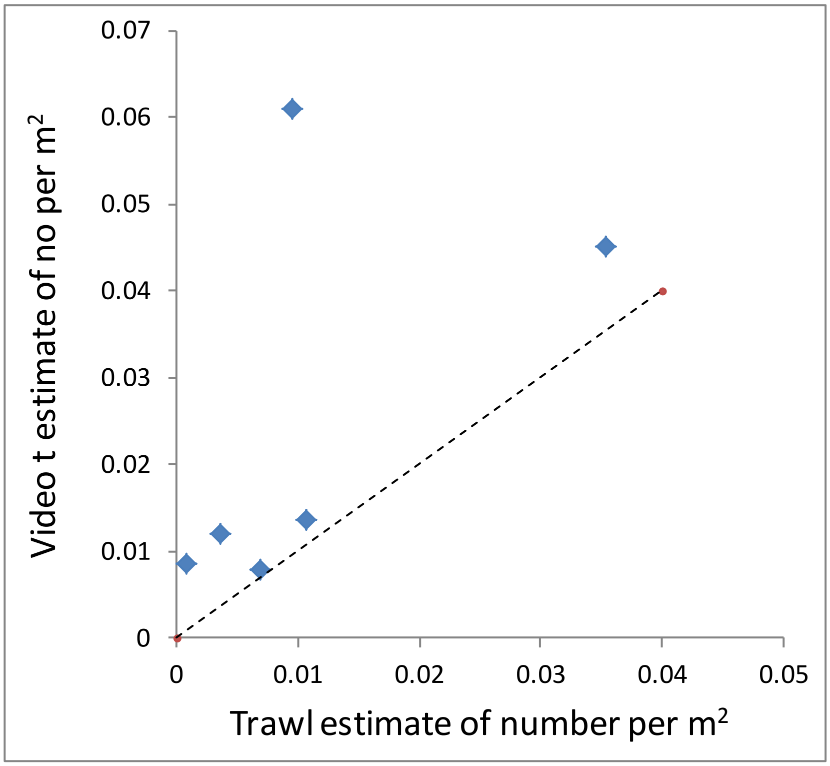

Figure 17. Estimates of lobster abundance from video transects versus those from trawls. Where there was more than one video transect in the vicinity of a trawl location, the abundance estimates from the two transects were averaged. Dashed line represents the line of 1:1 correspondence of abundance (where x=y). Locations of transects and tows are depicted in Fig. 16.