# Revision of Data Layers (Strata, Sampling Units, Centroids) Critical to the Design and Operation of the Fisheries and Oceans Canada – Newfoundland and Labrador Scientific Research Vessel Bottom Trawl Surveys

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## ABSTRACT

Gullage, L., Rideout, R.M., Ryan, K., Brockway, B., Healey, B. and Ollerhead, N. 2026. Revision of Data Layers (Strata, Sampling Units, Centroids) Critical to the Design and Operation of the Fisheries and Oceans Canada – Newfoundland and Labrador Scientific Research Vessel Bottom Trawl Surveys. Can. Tech. Rep. Fish. Aquat. Sci. 3764: ix + 38 p. https://doi.org/10.60825/175j-hn02

Scientific research vessel (RV) bottom trawl surveys provide critical fishery-independent data used in stock assessments and ecosystem monitoring programs. Since 1971, RV bottom trawl surveys in the Newfoundland and Labrador (NL) region have been based on a random stratified survey design. The components that make up the survey design (e.g., strata, sampling units, and centroids) were originally documented on paper maps. Approximately 20 years ago, efforts were made to digitize key components (e.g., strata and centroids) to support improved mapping capabilities and incorporate automation into the set allocation process. Since the digitization of these files, numerous discrepancies have been identified raising concerns about implications to the survey design and underlying data. To address these concerns and to develop a full suite of accurate digital survey-related products, work was conducted to update the digitized strata and centroid files as well as create a digital copy of the associated sampling units. This report outlines the steps taken to complete this work and describes the data products generated as a result.

# RÉSUMÉ

Gullage, L., Rideout, R.M., Ryan, K., Brockway, B., Healey, B. and Ollerhead, N. 2026. Revision of Data Layers (Strata, Sampling Units, Centroids) Critical to the Design and Operation of the Fisheries and Oceans Canada – Newfoundland and Labrador Scientific Research Vessel Bottom Trawl Surveys. Can. Tech. Rep. Fish. Aquat. Sci. 3764: ix + 38 p. https://doi.org/10.60825/175j-hn02

Les relevés au chalut de fond effectués par les navires de recherche scientifique (NRS) fournissent des données essentielles indépendantes de la pêche qui sont utilisées dans les programmes d'évaluation des stocks et de surveillance des écosystèmes. Depuis 1971, les relevés au chalut de fond effectués par les RV dans la région de Terre-Neuve-et-Labrador (T.-N.-L.) sont basés sur un plan d'échantillonnage stratifié aléatoire. Les éléments qui composent le plan d'étude (par exemple, les strates, les unités d'échantillonnage et les centroïdes) étaient à l'origine documentés sur des cartes papier. Il y a environ 20 ans, des efforts ont été faits pour numériser les éléments clés (par exemple, les strates et les centroïdes) afin d'améliorer les capacités de cartographie et d'automatiser le processus d'attribution des ensembles. Depuis la numérisation de ces fichiers, de nombreuses divergences ont été identifiées, soulevant des inquiétudes quant aux implications pour le plan d'échantillonnage et les données sous-jacentes. Afin de répondre à ces préoccupations et de développer une gamme complète de produits numériques précis liés à l'échantillonnage, des travaux ont été menés pour mettre à jour les fichiers numérisés des strates et des centroïdes, ainsi que pour créer une copie numérique des unités d'échantillonnage associées. Le présent rapport décrit les mesures prises pour mener à bien ces travaux et présente les produits de données générés à la suite de ceux-ci.

# INTRODUCTION

Scientific research vessel (RV) bottom trawl surveys provide critical fishery-independent data used in stock assessments and ecosystem monitoring programs. The Newfoundland and Labrador (NL) region of Fisheries and Oceans Canada (DFO) has been conducting these surveys in various forms for approximately 80 years. In the 1940s-early 1950s, surveys were exploratory in nature, with fishing stations established in an *ad hoc* fashion along the slopes of the Grand Bank and St. Pierre Bank (Doubleday 1981, Pitt et al. 1981). In the 1950s, these surveys were organized into a series of transects to objectively estimate fish abundance, with a particular emphasis on haddock. In 1971, DFO-NL bottom trawl surveys switched to a random stratified design.

As part of the modifications made in 1971, the survey area was divided into irregular polygons made up of areas of similar depth, referred to as strata, and further subdivided into smaller polygons, referred to as sampling units (Doubleday 1981) (Figure 1). Single point features, referred to as centroids, were created within each sampling unit to represent potential survey set locations (Figure 1). For each survey, a predetermined number of centroids within each stratum were randomly selected and the average catches of any taxa from those survey sets was used to estimate the abundance/biomass of that taxa in the entire stratum.

Modifications to the underlying components of the survey design (e.g., strata, sampling units, and centroids) have been made over the years as new areas have been added to the survey domain, and as improved bathymetric data suggested that revisions were needed (Bishop 1994). The early strata formulations were detailed by the International Commission for the Northwest Atlantic Fisheries (ICNAF) (1979) and were based partially on work by Grosslein and Pinhorn (1971) as well as Pinhorn (1972). In 1987, stratification schemes were added for Northwest Atlantic Fisheries Organization (NAFO) divisions 2GH (Bowering 1987). Bishop (1994) made subsequent revisions to the strata in all NAFO divisions in order to better match strata boundaries with new bathymetric data, to extend survey coverage from the original 400 fathoms down to 800 fathoms, and to create inshore strata in some areas. Murphy (1996) subsequently made corrections to the NAFO subdivision 3Ps stratification scheme in order to account for a transcription error that incorrectly positioned the 3P – 4V division boundary.

Presently, the RV bottom trawl surveys in the NL region are conducted in the spring and fall each year following the random stratified design. Spatial coverage of the surveys varies by season, with the current spring survey covering NAFO divisions 3LNOPs and the fall survey covering NAFO divisions 2HJ3KLNO (Figure 2). Specific details regarding the previous coverage of other divisions (e.g., 2G, 3M, 3Pn) and the inclusion/exclusion of deep strata and inshore strata in the survey design are available in previous reports (e.g., Rideout et al. 2021 and references within).

Historically, records detailing the survey design were stored within the Northwest Atlantic Fisheries Centre (NAFC) in hard copy format (e.g., paper maps). In the early-2000s, as the

planning and operation of RV bottom trawl surveys (and the nautical industry in general) migrated towards the use of digital mapping products, efforts were made to develop digital copies of the strata and centroid layers. Initially, the digital files were used for illustrative purposes, but as advances were made to geographic information system (GIS) programs it became possible to automate the set allocation process, conduct spatial analyses, and perform quality control of survey set locations and data pre- and post-survey using these files.

As the use of the digital files expanded, concerns were raised about survey set locations not aligning properly with the digitized strata, as well as gaps or overlaps along the boundaries of adjacent strata, which occasionally resulted in survey data being labeled 'invalid.' However, a comprehensive assessment had not been conducted to determine the cause of these problems or to formally address them.

Considering the fundamental role that the RV bottom trawl survey plays in providing science advice, the exploration and correction of discrepancies within the digital survey files was prioritized by DFO Science in 2019. As the hard copy maps depicting strata, sampling units, and centroids stored within the NAFC were the best representation of the RV bottom trawl survey design, it was also deemed critical that a digital archive of these records be generated. The overall objectives of this project were to:

1. **Ensure Data Stewardship**: official survey design existed only as paper maps.
2. **Recognize and Correct Errors in Digitized Strata**: inconsistencies in strata boundaries complicated spatial analyses.
3. **Recognize and Correct Errors in Digitized Centroids**: irregularities in centroid positions caused problems in the positioning of allocated survey sets.
4. **Provide Accurate and Detailed Documentation**: limited information is available detailing the original survey design, subsequent strata modifications, or the development of digital centroids and strata.

This report details the objectives, methods, and data products generated from this work and points to downstream survey-related implications. Throughout this project, priority was placed on digitizing and modifying data layers for areas that are covered by the RV bottom trawl survey (NAFO Divisions 2GHJ3KLNOP).

# METHODOLOGY

## Data Stewardship

The paper strata and centroid charts that were digitized in the early 2000s represent the official RV bottom trawl survey design. Issues with centroid positions and adjacent strata boundaries in the digitized layers suggest the details of those paper charts may not have been fully or accurately captured in the original digitization process. To safeguard against accidental misplacement or disposal of the intended survey design details (i.e., strata, sampling units, and centroids), the first phase of the project focused on locating and scanning the paper maps for digital archival.

In total, 258 maps were located in an unmarked map cabinet at the NAFC. In the absence of any information on organizational structure or version control, all maps were retained for archival. Maps were organized by NAFO division and further subdivided into groups based on whether they illustrated strata, sampling units, depth contours, or negatives. All maps were then scanned using a large-format scanner. Scanned maps were saved in a structured directory and assigned filenames identifying the NAFO division(s) covered, what the map depicted, as well as what number the scan represented within that group (Figure 3). Once complete, digital copies of all the maps were archived on hard drives and shared with data stewards in the NL Science Branch.

## Georeferencing

After the maps were scanned and archived, a subset were selected to support the digitization of strata, sampling units, and centroids. In cases where duplicate maps existed, the highest quality map (e.g., good contrast, limited annotations, clear strata/sampling unit boundaries) was selected for further processing (Figure 4). Photo editing software was used to adjust the orientation, remove excess borders, and add grids of latitude and longitude to each of the selected maps (Figure 5). Maps were then imported into ArcGIS Pro version 3.3.0 (Esri Inc. 2024), georeferenced using the Esri World Latitude and Longitude Grid (Esri 2019), and saved as raster files.

Georeferenced maps were validated against the existing strata and centroid shapefiles as well as other distinguishable features (e.g., coastlines, NAFO boundaries) to identify potential misalignments. Georeferencing errors typically occurred for maps with incorrectly labelled latitude and longitude. Misaligned maps were replaced with duplicate maps where available. In instances where no alternate maps could be identified, georeferencing was completed using the existing centroid shapefile and other identifiable features (e.g., coastlines, NAFO boundaries) in lieu of the latitude and longitude grid.

In some cases, sampling unit maps for the same area illustrated different sampling unit boundaries. Without any clear indication of which map best represented current RV bottom trawl survey design, both versions were georeferenced and evaluated against the existing centroid file. The map whose sampling units best agreed with the existing centroid positions was retained for further use (Figure 6).

## Strata

Various steps were taken to assess the quality of the existing strata shapefile and determine what modifications would be required to update it. To begin, the '*Topology'* toolset in ArcGIS (Esri Inc. 2024) was configured to evaluate the existing strata shapefile boundaries and highlight areas where adjacent strata had gaps or overlaps (Figure 7). The boundaries of the existing strata layers were also validated against the georeferenced strata and sampling unit maps to determine which maps were originally used to digitize the existing strata layer (Figure 8). In the absence of sufficient documentation to resolve discrepancies between the strata boundaries illustrated by the strata and sampling unit maps, the existing centroid layer and historical RV

trawl positions (1971 – 2021) were also overlaid to determine which boundaries best represented the current RV bottom trawl survey design (Figure 9).

A digitizing tablet was used to manually digitize strata boundaries depicted on each of the georeferenced maps determined to be most representative of the existing strata layer. Areas where adjacent maps had gaps and/or overlaps between strata boundaries were identified for correction. As it formed the basis of survey set allocation in the current survey, the existing centroid shapefile was used to guide modifications of strata boundaries wherever possible (Figure 10). In cases where gaps and/or overlaps were associated with maps that met along NAFO division boundaries, strata were modified to meet at the NAFO division boundary (Figure 11), unless the existing centroids indicated that strata followed a depth contour which naturally extended into the neighbouring NAFO division (Figure 12). For areas where gaps and/or overlaps in the strata could not be corrected based on the existing centroids (e.g., the centroids also had gaps and/or overlaps), historical RV trawl positions (Figure 13) and/or GEBCO bathymetry (GEBCO Compilation Group 2021) (Figure 14) guided modifications.

Once all revisions were complete, the modified strata boundary polylines were merged and validated using the ArcGIS (Esri Inc. 2024) '*Topology'* toolset to ensure lines did not extend beyond one another or fail to join. They were subsequently converted to polygon features and validated using the '*Topology*' toolset to ensure no gaps or overlaps were introduced during the manual digitization process.

## Sampling Units

Sampling unit boundaries had not been previously digitized, which made it challenging to address and correct discrepancies in the existing centroid shapefile. Considering this, and to generate a full suite of digital files to support ongoing survey work and foster data stewardship, a sampling unit shapefile was also developed. Individual sampling units were manually digitized for each of the georeferenced sampling unit maps. In areas where strata boundaries had been modified during digitization, adjustments were made to the associated sampling units to account for this. Typically, the adjustments were minor (e.g., expansion or reduction in coverage of individual sampling units); however, in a small number of cases they resulted in the removal or addition of sampling units (Figure 15).

Areas within strata that had no sampling units were cross-referenced with the existing centroids, historical RV trawl locations, and bathymetry to determine if the sampling unit omission was intentional and justified (e.g., untrawlable bottom) or represented an oversight that should be corrected. If omissions were associated with shallow coastal areas (Figure 16A), isolated deep canyons along the shelf edge (Figure 16B), or in areas noted as untrawlable on the georeferenced maps (Figure 16C), no modifications were made. However, in cases where no obvious reasons for the omissions could be identified (e.g., area represented a gap between adjacent hand drawn historical maps) (Figure 16D), sampling units were added based on expert

opinion. For consistency, any holes in the sampling units (e.g., shallow coastal areas, isolated deep canyons, or untrawlable areas) were also excluded from the digitized strata layer.

As sampling units were designed to be relatively uniform in size within each stratum, an effort was made to ensure that boundary modifications did not result in the creation of excessively large or small sampling units. Doubleday (1981) reported that sampling units were derived by first dividing strata into areas equivalent to 5' latitude and 10' longitude and then dividing each of these areas into ten equally-sized sampling units. For most of NAFO Subarea 3, this resulted in sampling units covering approximately 12 $km^2$ (3.5 $nmi^2$). While some sampling units are known to be smaller or larger by design to account for irregularly shaped strata following bathymetric contours, we examined the size frequency distribution of the digitized sampling units based on this general 12 $km^2$ guideline.

Throughout the survey area, sampling units ranged from 1 – 36 $km^2$ (Figure 17). To reduce size variation, modifications were made to combine smaller sampling units (<6 $km^2$) and subdivide larger sampling units (>24 $km^2$) where appropriate. When sampling units were modified, efforts were made to maintain consistent sampling unit coverage within individual strata whenever possible (e.g., a 6 $km^2$ sampling unit was not added into a stratum that otherwise consisted of 20 $km^2$ sampling units). This ensured that the probability of set selection would be distributed as equally as possible across sampling units within a single stratum.

## Centroids

A preliminary assessment was conducted to categorize the discrepancies within the existing centroid shapefile. Based on the results, duplicate centroids were removed, new centroids were created for sampling units where they had previously been omitted (Figure 18A), and misplaced centroids were manually relocated to the appropriate sampling unit (Figure 18B). Any centroids associated with sampling units that had been removed because of boundary modifications (Figure 15), those falling outside the current survey area, or those unrelated to RV bottom trawl surveys, were deleted. In the event that the attribute IDs of associated sampling units and centroids did not match, centroid IDs were retained and applied to the sampling units in order to maintain as much consistency between the existing and modified centroid files (Figure 18C).

The initial quality control of the centroid data layer focused on ensuring that each sampling unit contained a single centroid. However, in many cases the centroids did not fall in the physical center of their corresponding sampling units (Figure 19A). To maximize the trawlable area surrounding each centroid, modified centroids were generated with the *'Feature to Point'* tool (Esri Inc. 2024) for the newly digitized sampling unit shapefile (Figure 19B). Although rare, for some irregularly shaped and asymmetrical sampling units the modified centroids were generated outside the sampling unit boundary. When this occurred, the modified centroids were manually relocated to the position of the existing centroid or another suitable location within the boundaries of the sampling unit.

## Attributes

The existing centroid file contained attribute information relevant to the modified strata, sampling unit, and centroid files. Spatial joins were used to capture this information and incorporate it into the attribute tables of the modified layers. However, due to the errors in the existing centroid file (e.g., missing centroids, misplaced centroids), some of the modified sampling units were not assigned attributes or were assigned incorrect attributes during this process. In these instances, attribute details were manually modified using information from the georeferenced maps and the adjacent sampling units. Some additional changes were also made to the final attributes to improve clarity and incorporate additional fields relevant to survey design and analyses (Table 1).

# RESULTS

## Georeferencing

Of the 258 archived maps, 52 were identified as being potentially suitable for digitization (16 maps of survey strata and 36 maps of sampling units). As a result of validation against existing centroids, 28 of the 36 georeferenced sampling unit maps were ultimately retained for digitization.

## Strata

Through validation, the ArcGIS *'Topology'* toolset (Esri Inc. 2024) identified 1,545 errors with the existing strata layer (Figure 7). Of these, 779 represented areas where the boundaries of adjacent strata overlapped and 766 represented areas where the boundaries of adjacent strata did not meet (e.g., gaps).

Evaluation of the existing strata against the georeferenced maps found that strata boundaries depicted on the georeferenced strata and sampling unit maps often varied, with the strata boundaries of the existing strata shapefile typically aligning best with those on the sampling unit maps (Figure 8). Furthermore, the strata boundaries from the sampling unit maps typically aligned best with the locations of existing centroids and historical RV trawl positions (Figure 9). To ensure that the updated strata layer would capture the most accurate boundaries and align with the digitized sampling units as the project progressed, the sampling unit maps were used to digitize all subsequent boundaries.

The modified strata shapefile, illustrated in Figure 20, consists of 344 strata covering 699,165 $km^2$ across NAFO divisions 2GHJ3KLNOP. The size frequency distribution was comparable for the existing and modified strata (Figure 21). However, due to the omission of strata within NAFO division 3M, which is no longer surveyed by DFO, there is a noticeable reduction in the total area covered by the strata compared to the existing strata shapefile (Figure 21 and Table 2). While other areas (i.e., division 2G, subdivision 3Pn, inshore strata, and deepwater strata in division 3NOP) are also excluded from the current survey design, the associated strata were still digitized to ensure the modified shapefile provided complete coverage for the entire NL region.

## Sampling Units

The modified sampling unit shapefile, illustrated in Figure 22, consists of 60,955 sampling units covering 699,165 $km^2$ (Table 3). Across the entire survey area, the modified sampling units ranged in size from 6 – 24 $km^2$, and averaged 11.5 $km^2$, with 95% of sampling units covering between 8 – 16 $km^2$ (Figure 23). The majority of larger sampling units (>16 $km^2$) are concentrated in nearshore areas and areas along the shelf edge (Figure 24), where irregularly shaped bathymetric contours and strata make the delineation of consistently sized sampling units difficult.

## Centroids

A preliminary assessment between the sampling unit shapefile and the existing centroids found errors associated with: (1) duplicate centroids; (2) missing centroids (Figure 18A); (3) misplaced centroids (Figure 18B); (4) centroids that were no longer needed as their associated sampling units had been removed as a result of boundary modifications (Figure 15); (5) centroids that fell outside the survey area (e.g., NAFO divisions 3M and 4V); (6) centroids unrelated to the current RV bottom trawl survey (e.g., juvenile survey - JUV); and (7) mislabeled centroids (Figure 18C). While many of these discrepancies were attributed to transcription errors when the existing centroids were initially digitized or changes to survey coverage over time, a small number resulted from modifications made to the strata and sampling unit boundaries.

Many of the centroids did not fall in the physical center of their corresponding sampling units and required repositioning (Figure 19). When repositioned to the center of their corresponding sampling unit, 91% of centroids moved <1 km, 7% moved 1 – 2 km, and only 2% moved >2 km. In all cases where centroids moved >2 km, the existing centroids had been located outside the associated sampling unit or strata, suggesting they would have been excluded in previous RV bottom trawl surveys.

The modified centroid file, illustrated in Figure 25, consists of 60,955 centroids positioned in the center of their associated sampling unit. While the modified and existing centroid shapefiles contain the same attribute details, the modified centroid shapefile covers fewer NAFO divisions and consists of 14,585 fewer centroids (Table 4). Specific details outlining the reduction in centroids are provided in Table 5.

## Outstanding Issues

Considering that real-time adjustments to account for discrepancies in the existing data layers were common during RV bottom trawl surveys, it is expected that the formal modifications outlined in this report will improve survey efficiency without impacting the survey time-series or related analyses. Additional improvements outside of the scope of this report are also recommended to further streamline survey efficiency.

While bathymetry was used to guide modifications to strata boundaries in areas of concern (e.g., areas with gaps and overlaps), large scale efforts to align all survey strata with updated bathymetry (GEBCO Compilation Group 2021) was not conducted. Although there is generally agreement between defined strata depth classes (

Table 6) and updated bathymetry, there are still instances where strata overlap areas where bathymetry falls outside the defined depth class (Figure 26). It is recommended that work be done to better align the strata, sampling units, and centroids with updated bathymetric data.

In addition, subsea structures (e.g., cables, shipwrecks, rocky outcrops) which impede trawling activities are also known to delay RV bottom trawl survey operations. However, the locations of known subsea structures are not presently considered during the set selection process. To correct for this, it is recommended that the positions of subsea structures be identified and used to flag centroids in areas where trawling is not possible (e.g. too close to a known shipwreck) before set selection occurs.

## ACKNOWLEDGEMENTS

This project was made possible through opportunistic staffing and funding arrangements by the DFO-NL Science Branch's Aquatic Resources and Environmental Sciences divisions as well as the Technical Expertise in Stock Assessment program. Additional support was provided by the Canadian Hydrographic Service who provided access to a large format scanner to allow for the initial digitization of paper maps.

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## FIGURES

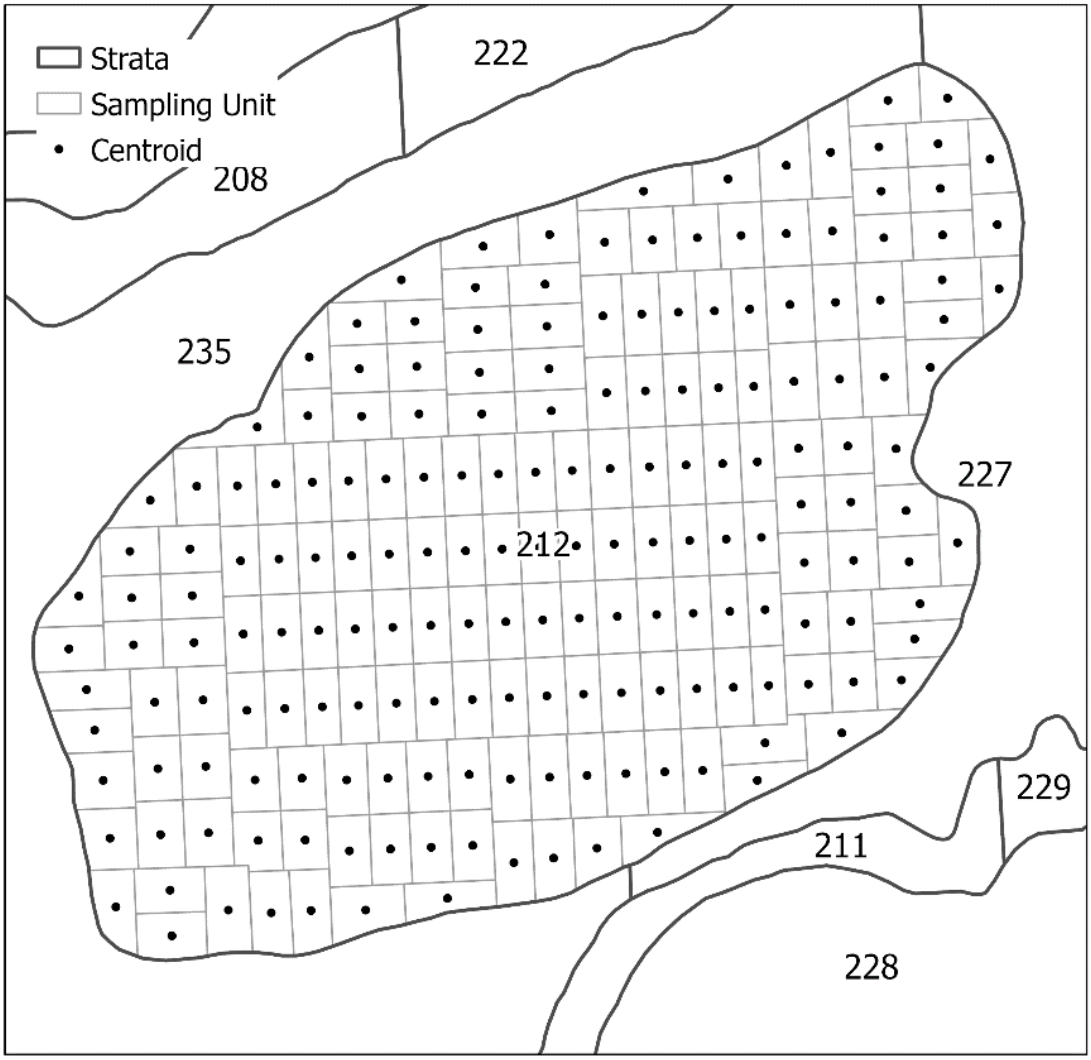



*Figure 1: Illustration of the components (i.e., strata, sampling units, and centroids) which make up the RV bottom trawl survey.*

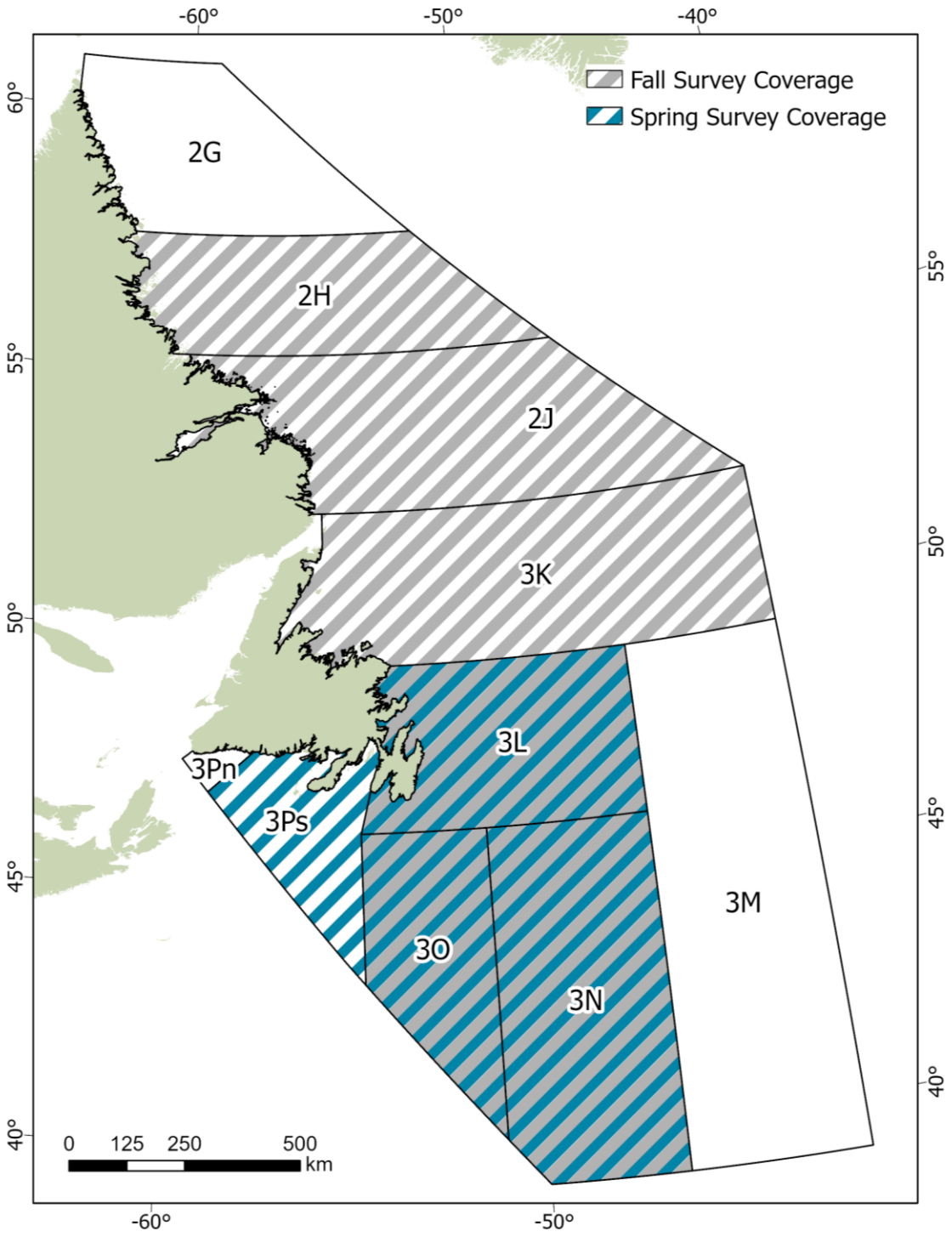



*Figure 2: Spatial coverage for spring and fall RV bottom trawl surveys in the NL region.*

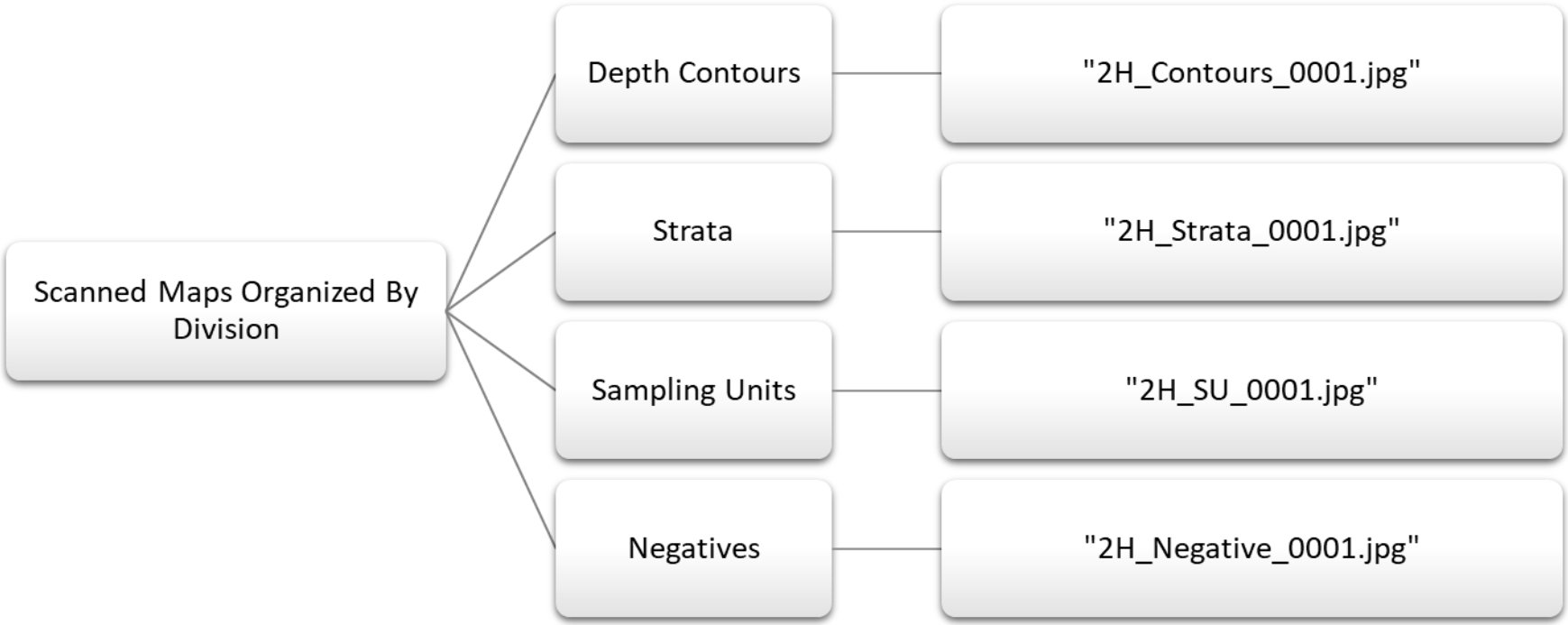



*Figure 3: The file naming structure used to archive scanned copies of maps documenting RV bottom trawl survey design with sample file names.*

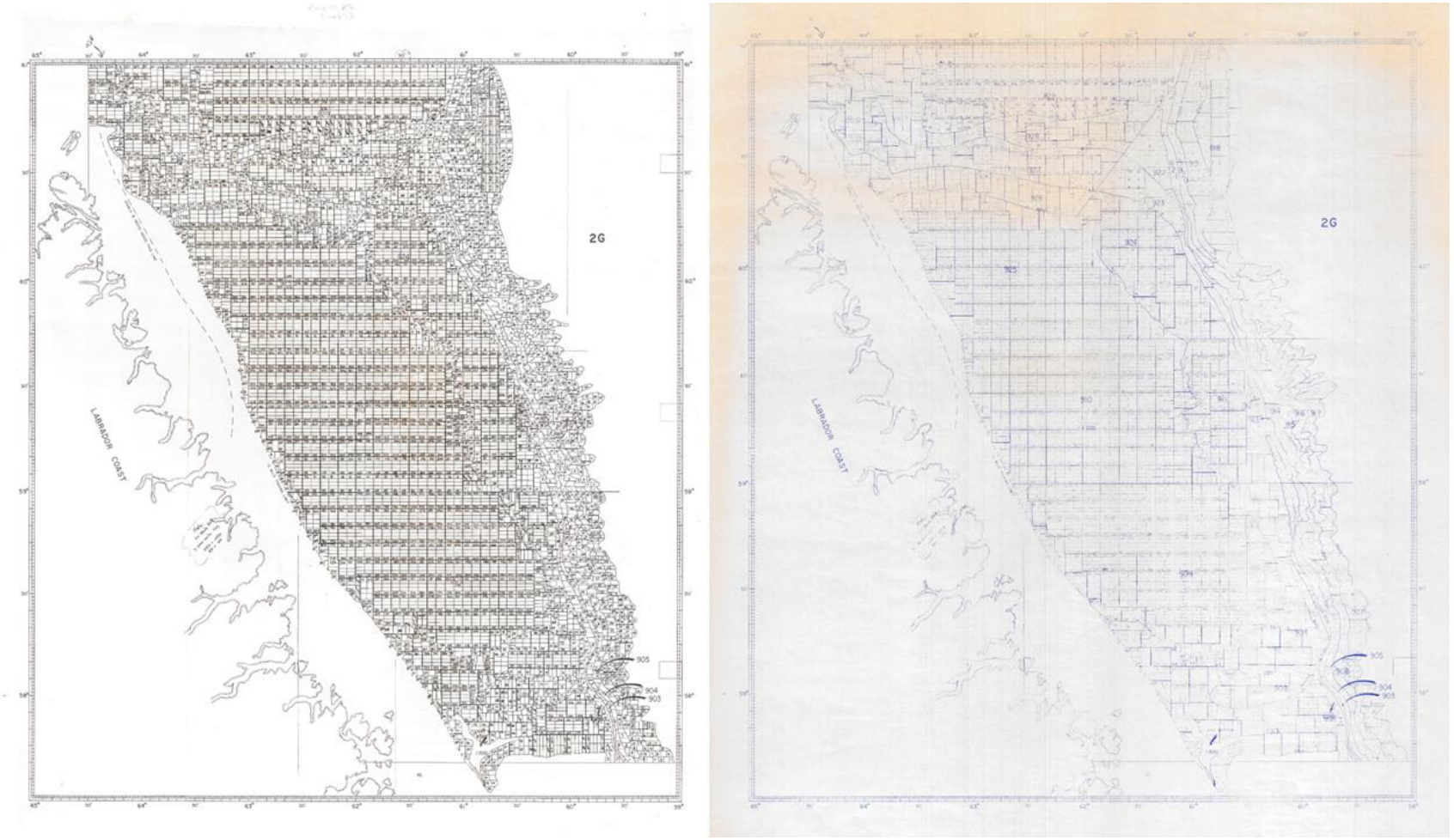



*Figure 4: An example of varying image quality for scanned maps depicting strata and sampling units within NAFO division 2G.*

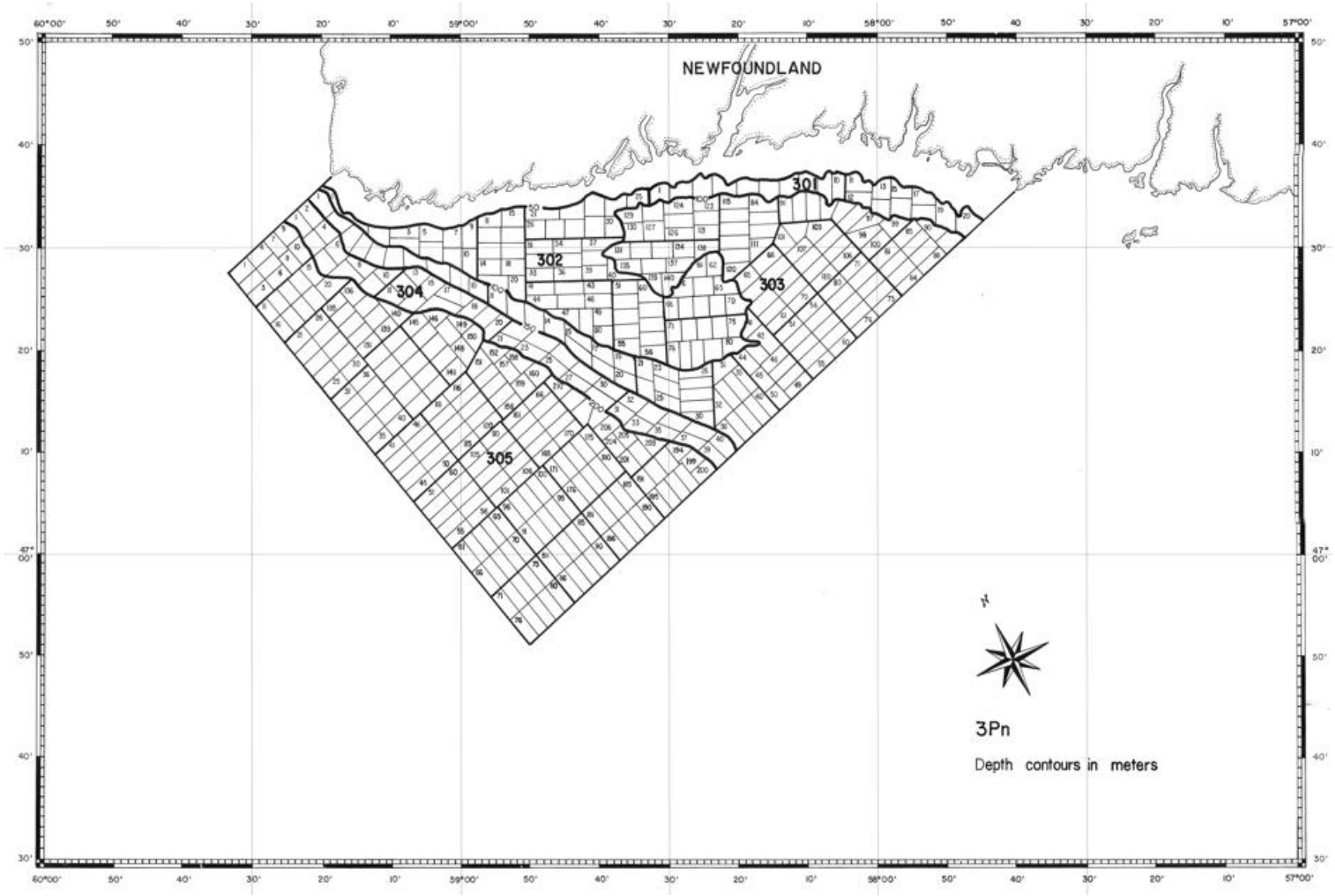



*Figure 5: An illustration of the grid of latitude and longitude (light grey lines) which were added to scanned maps in preparation for georeferencing in ArcGIS.*

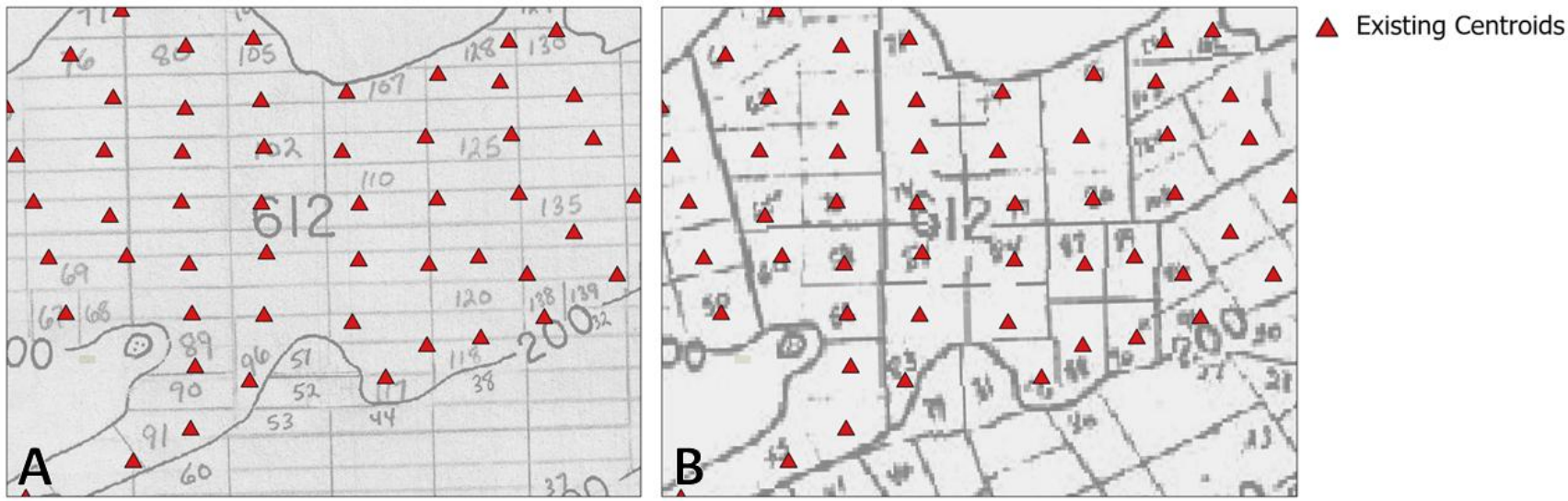



*Figure 6: An example of existing centroids overlaid on two georeferenced maps depicting different sampling unit boundaries within stratum 612. The map on the right (B) was chosen for digitization as it aligned best with the existing centroid file.*

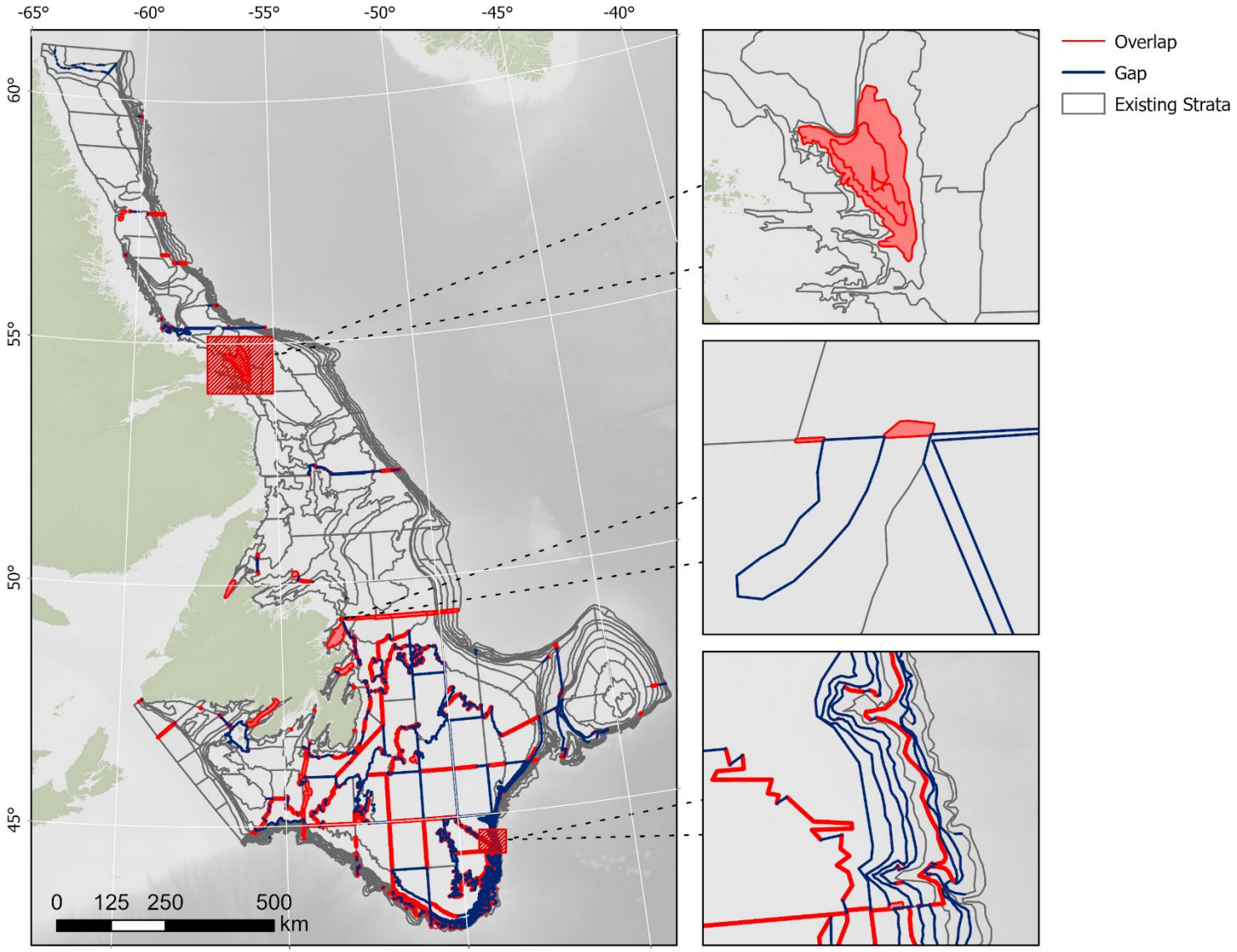



*Figure 7: An illustration of boundary misalignments in the existing strata shapefile. Overlapping strata boundaries are symbolized with red, while gaps are symbolized with blue. Inset maps provide examples of the different boundary misalignments that were identified in the existing strata.*

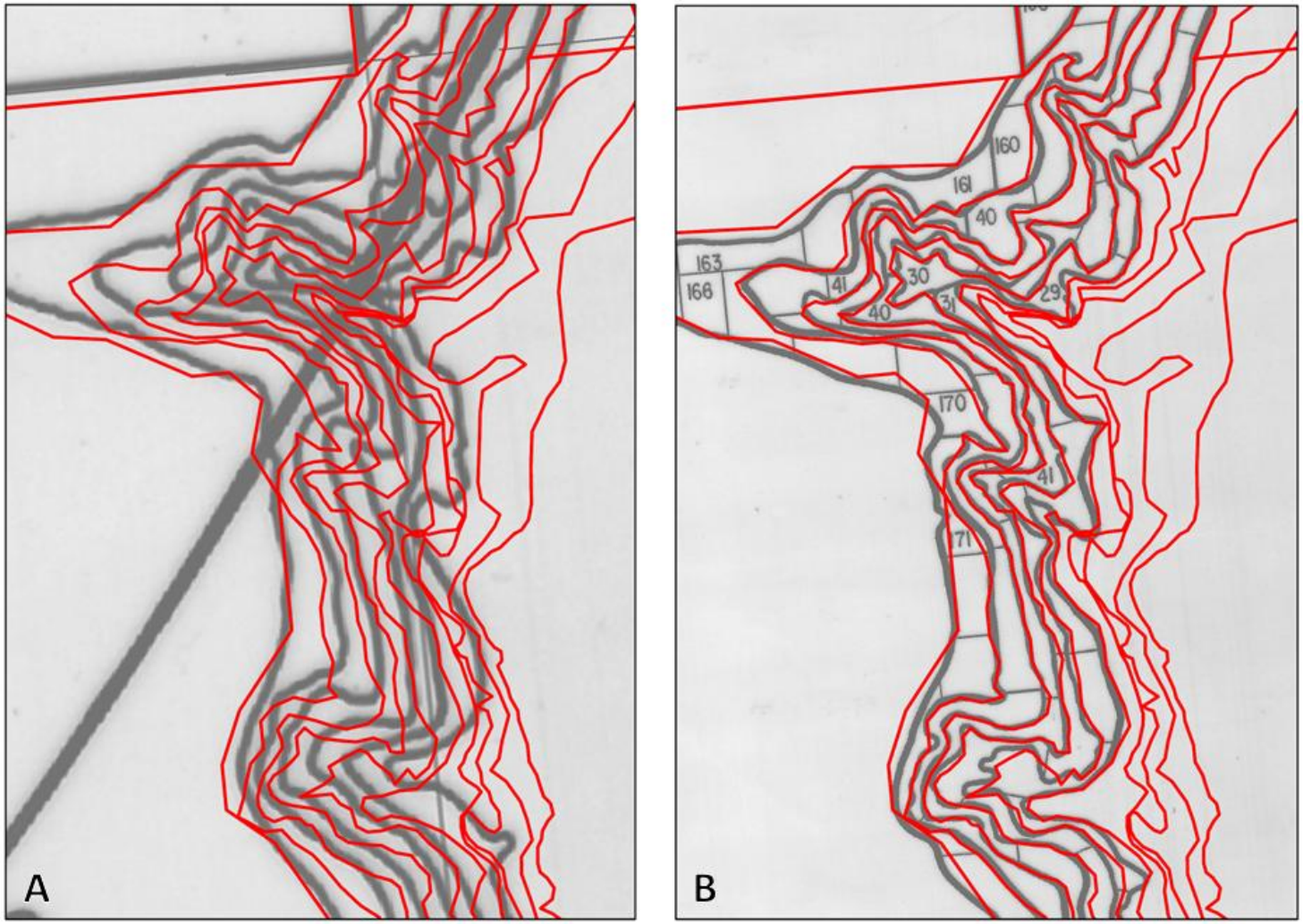



*Figure 8: An example of the existing strata shapefile (red lines) overlaid on georeferenced strata (A) and sampling unit (B) maps. Overall, strata boundaries of the existing strata shapefile aligned more consistently with those delineated on the georeferenced sampling unit maps.*

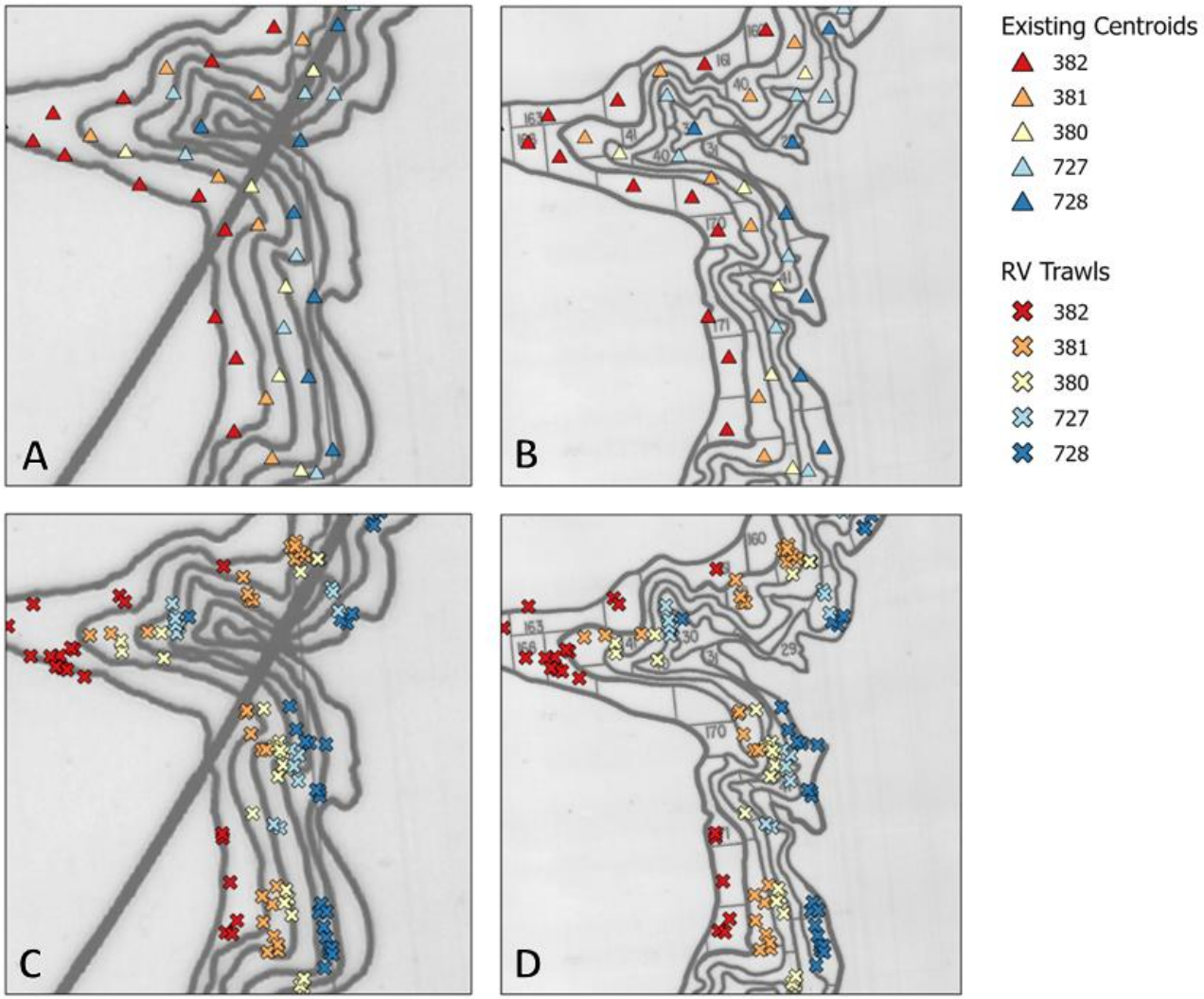



*Figure 9: An example of existing centroids (top) and RV trawl locations (bottom) (coloured by strata number) overlaid on georeferenced strata (A & C) and sampling unit (B & D) maps. Overall, the existing centroids and RV trawls aligned more consistently with strata boundaries delineated on the georeferenced sampling unit maps (B & D).*

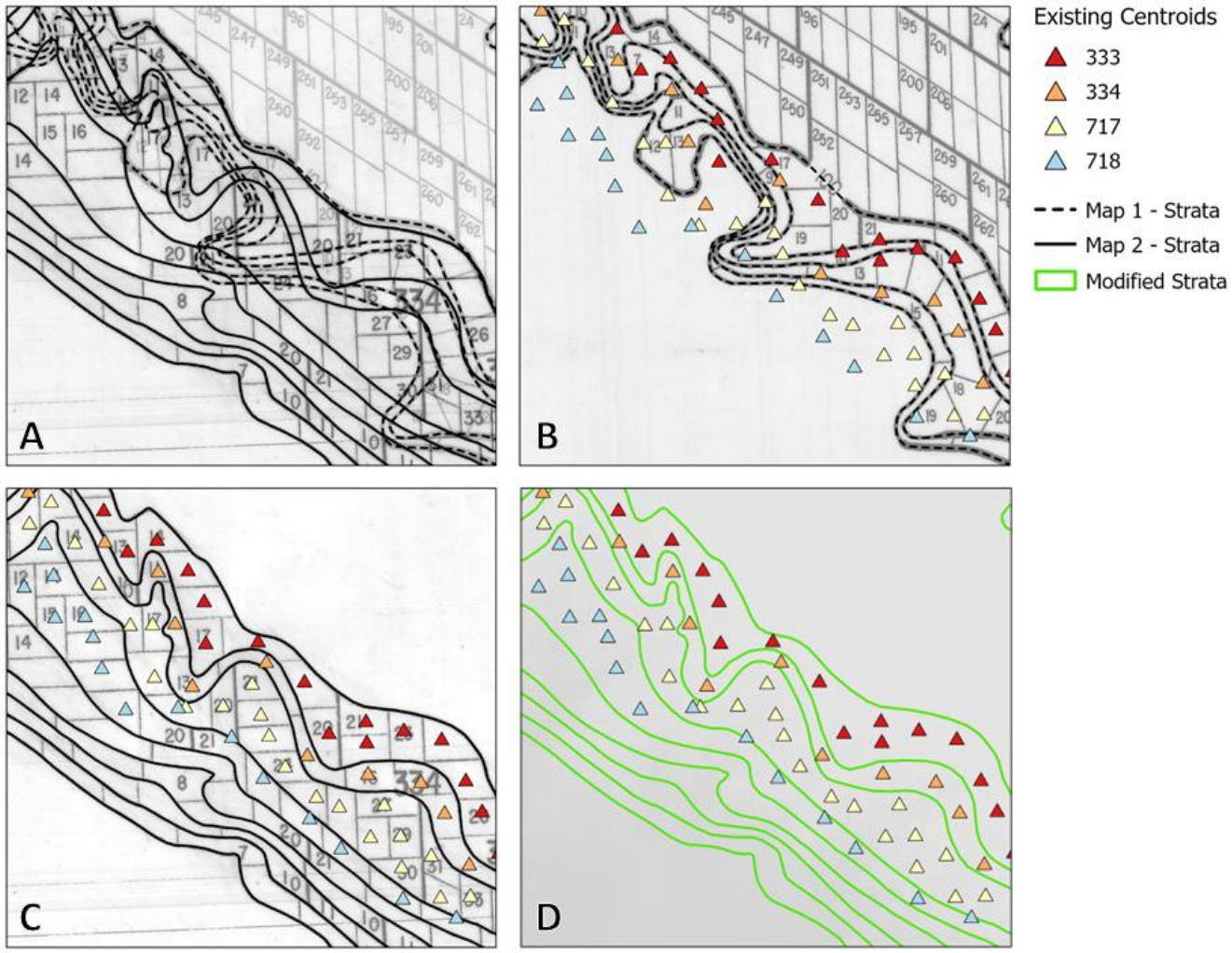



*Figure 10: An example of discrepancies in four strata boundaries digitized for adjacent maps (A). The existing centroids were poorly aligned with strata boundaries depicted on Map 1 (B) but aligned well with those depicted on Map 2 (C). Modifications to strata boundaries were made to reflect this in the updated strata boundary shapefile illustrated (D).*

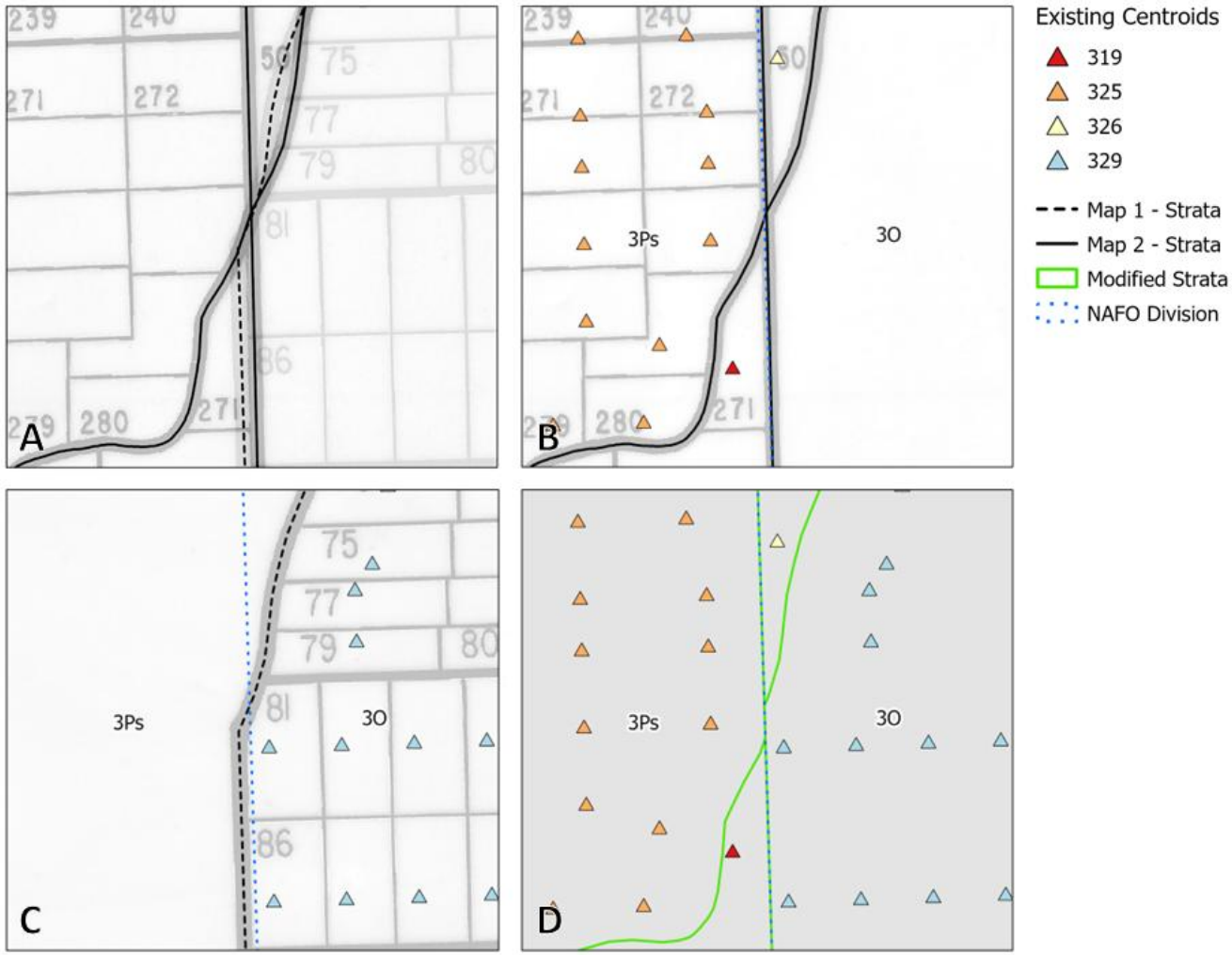



*Figure 11: An example of discrepancies in strata boundaries digitized for two adjacent maps (A). Here the existing centroids are aligned well with both georeferenced maps (B & C). As a result, the strata boundaries were modified to align with the NAFO division boundary between 3O and 3Ps (D).*

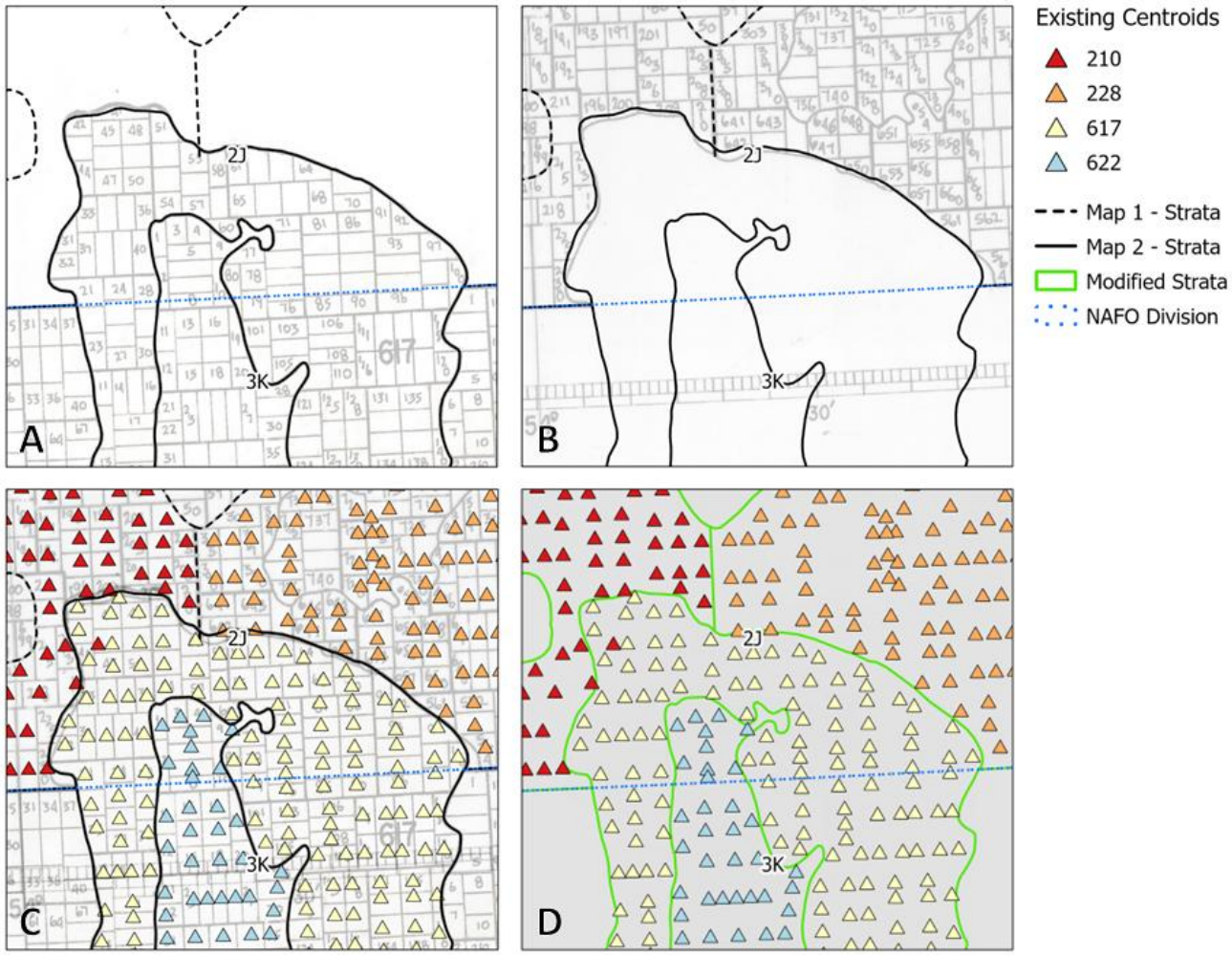



*Figure 12: An example of discrepancies in strata boundaries digitized for adjacent maps where strata extend across the NAFO division boundary between 2J and 3K (A & B). Here, the existing centroids align well with the digitized strata boundaries extending across the NAFO division boundary suggesting that the northward extension of strata 617 and 622 follows a natural depth contour (C). Modifications maintained the northward extension of the boundaries for strata 617 and 622 and were otherwise made to align with the NAFO division boundary between 2J and 3K (D).*

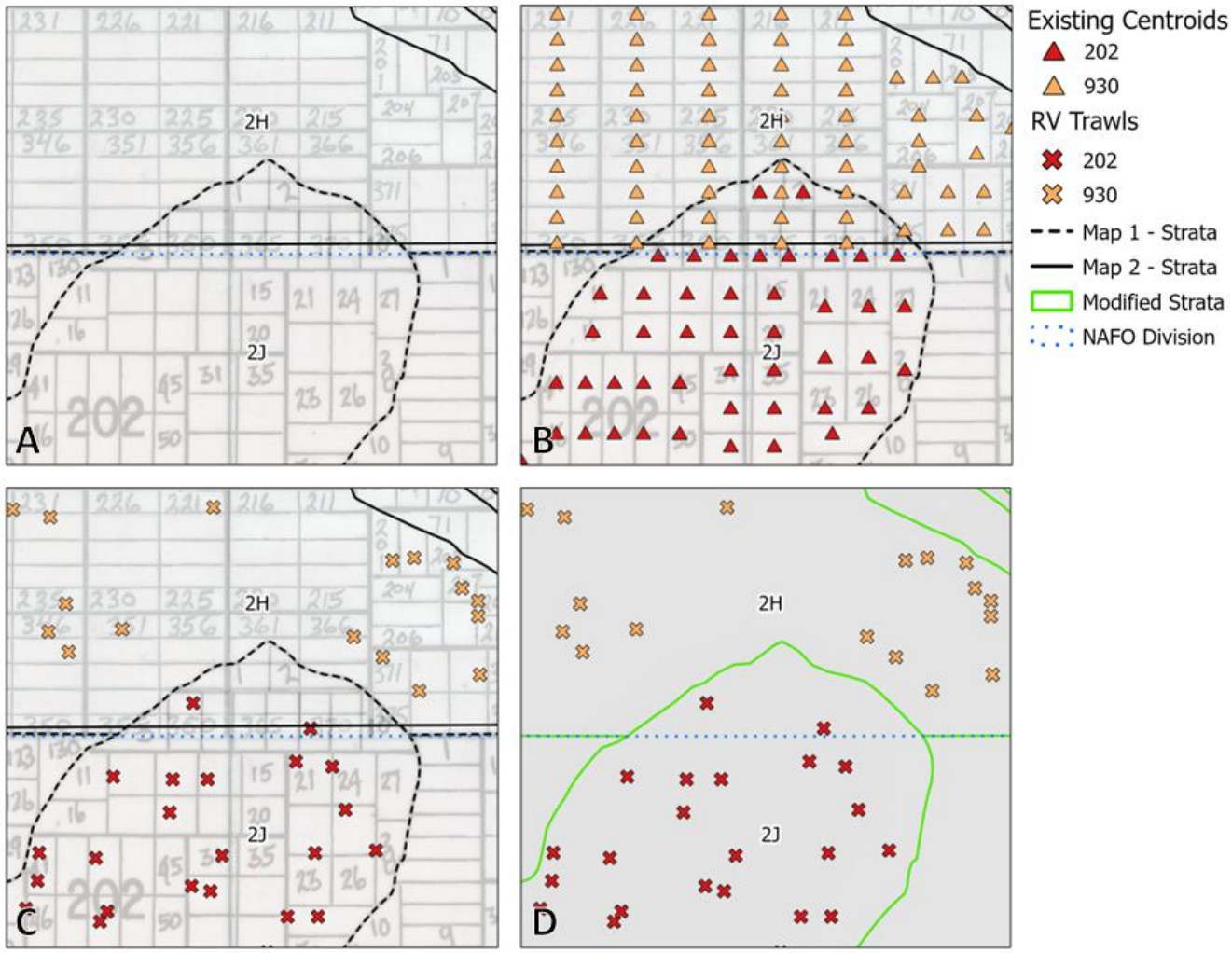



*Figure 13: An example of discrepancies between strata boundaries digitized for adjacent maps extending across the NAFO division boundary between 2H and 2J (A). The existing centroids associated with these strata 202 and 930 also overlapped (B). RV trawl locations indicated that trawls within the area of overlap were historically associated with strata 202 (C). Based on this, strata modifications maintained the northward extension of strata 202 and strata boundaries were otherwise aligned with the NAFO division boundary (D).*

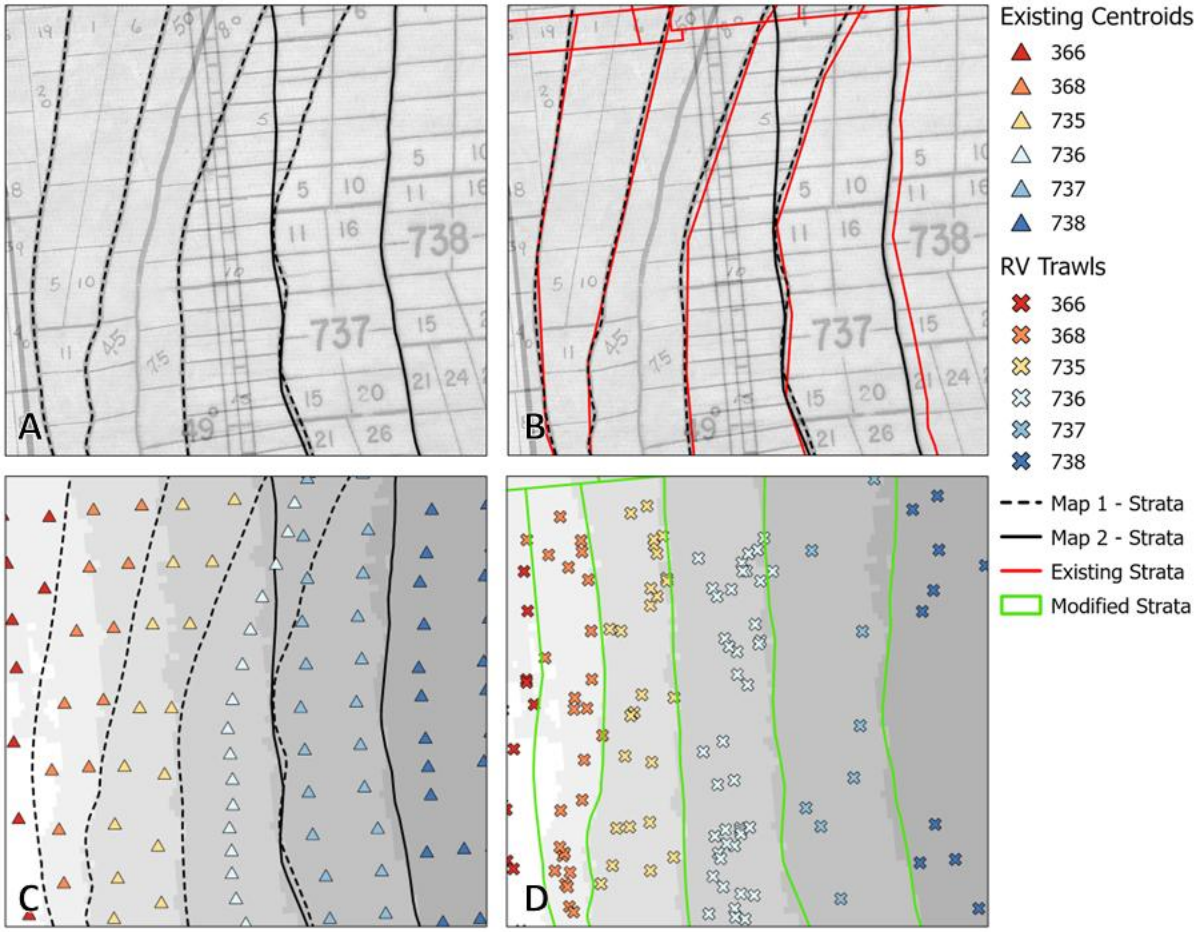



*Figure 14: An example of overlapping strata where shallower (sometimes referred to as 'core') strata from Map 1 meet up with deeper strata from Map 2 (A). The shallower strata, in general, have a different orientation than the neighbouring deep strata, resulting in the overlap. The existing strata shapefile appeared to have truncated this area of overlap by following the strata boundaries delineated on Map 1 (B). The existing centroids also overlapped, aligning well with the digitized strata for both maps, and provided no guidance for modifications (C). The RV trawl locations did not align well with the strata boundaries but were in agreement with the depth classes associated with the strata (D). In this case, modifications to the strata boundaries were made to align with the classified bathymetry layer, while capturing historical RV trawls into the appropriate strata as well as possible (D).*

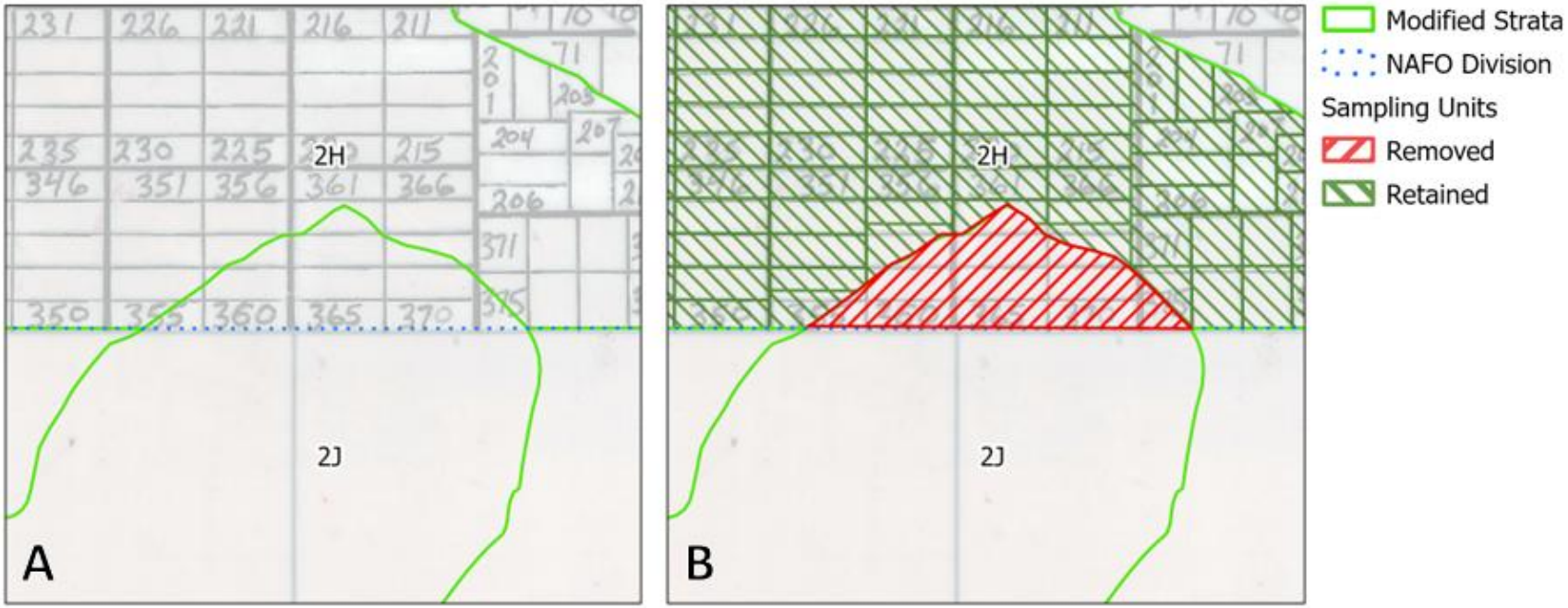



*Figure 15: An example of an area where modified strata boundaries (A) resulted in the removal of previously overlapping sampling units during digitization (B). In the red hatched area, the sampling units for existing strata within NAFO Divisions 2H and 2J overlapped. However, based on strata modifications described in Figure 13, sampling units in the 2H strata (i.e., strata 930) were retained for digitization, while sampling units in the 2J strata (i.e., strata 202) were removed.*

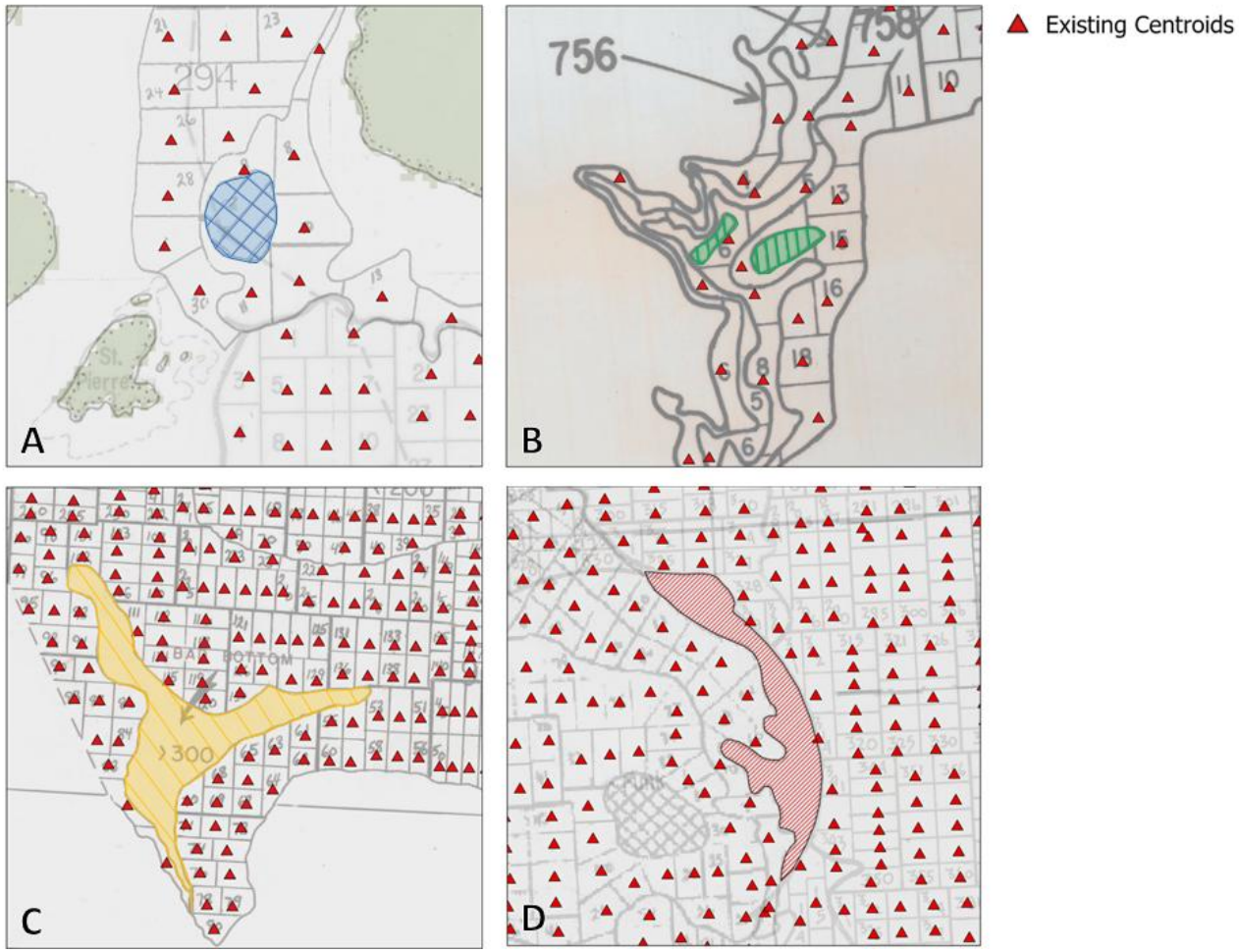



*Figure 16: Examples of areas within the survey where sampling units (grey polygons) did not exist. The existing centroids (red triangles) were used to verify that the omissions were not the result of an outdated map. They represent areas where depths are too shallow (A – blue hatching) or deep (B – green hatching) for trawling, areas that maps annotations indicated were untrawlable due to "bad bottom" (C – yellow hatching), and areas where no clear justification for omission could be identified (D – red hatching).*

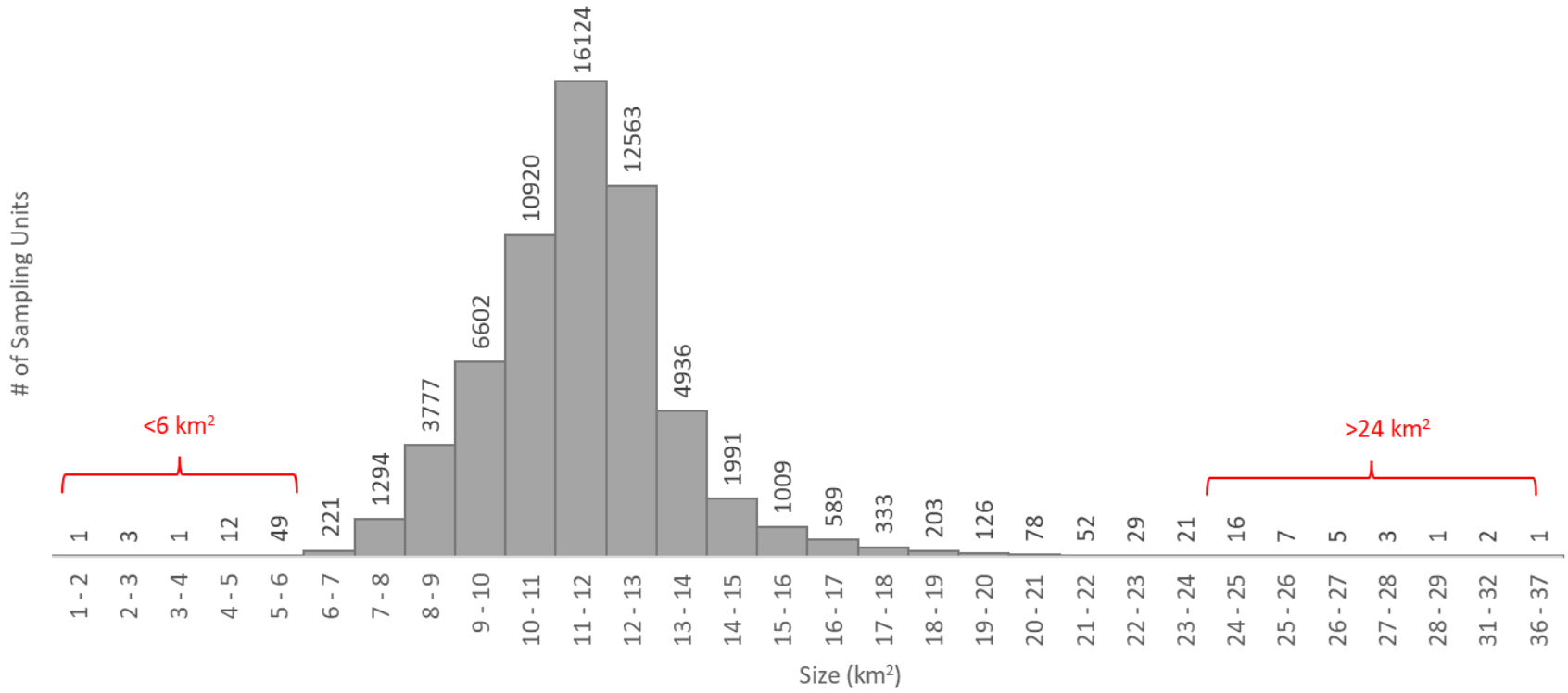



*Figure 17: The size frequency distribution (km²) of individual sampling units in the preliminary phase of digitization. Sampling units falling with the highlighted bins were the focus for modification.*

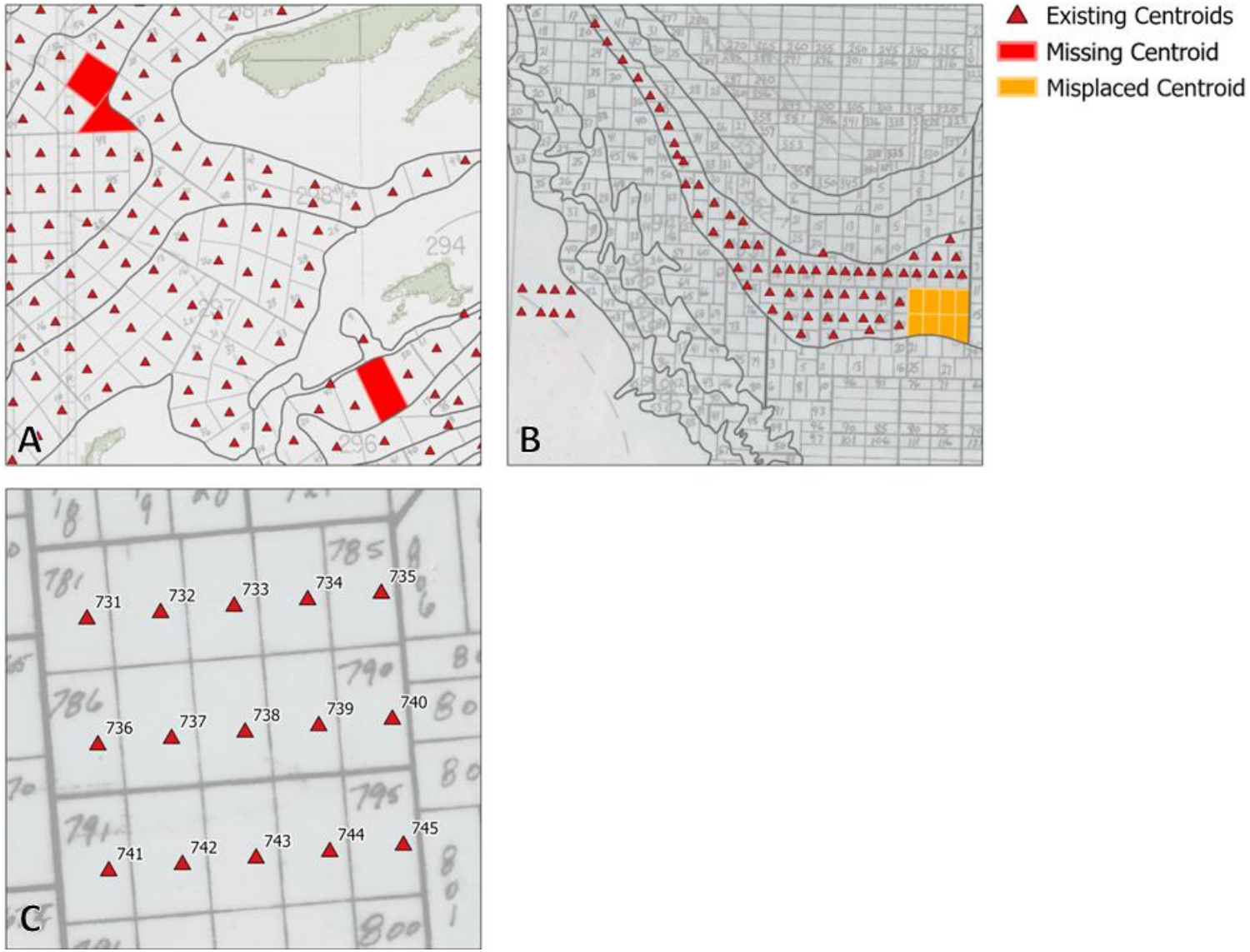



*Figure 18: Examples of sampling units with missing (A), misplaced (B), or mislabeled (C) centroids in the existing centroid shapefile.*

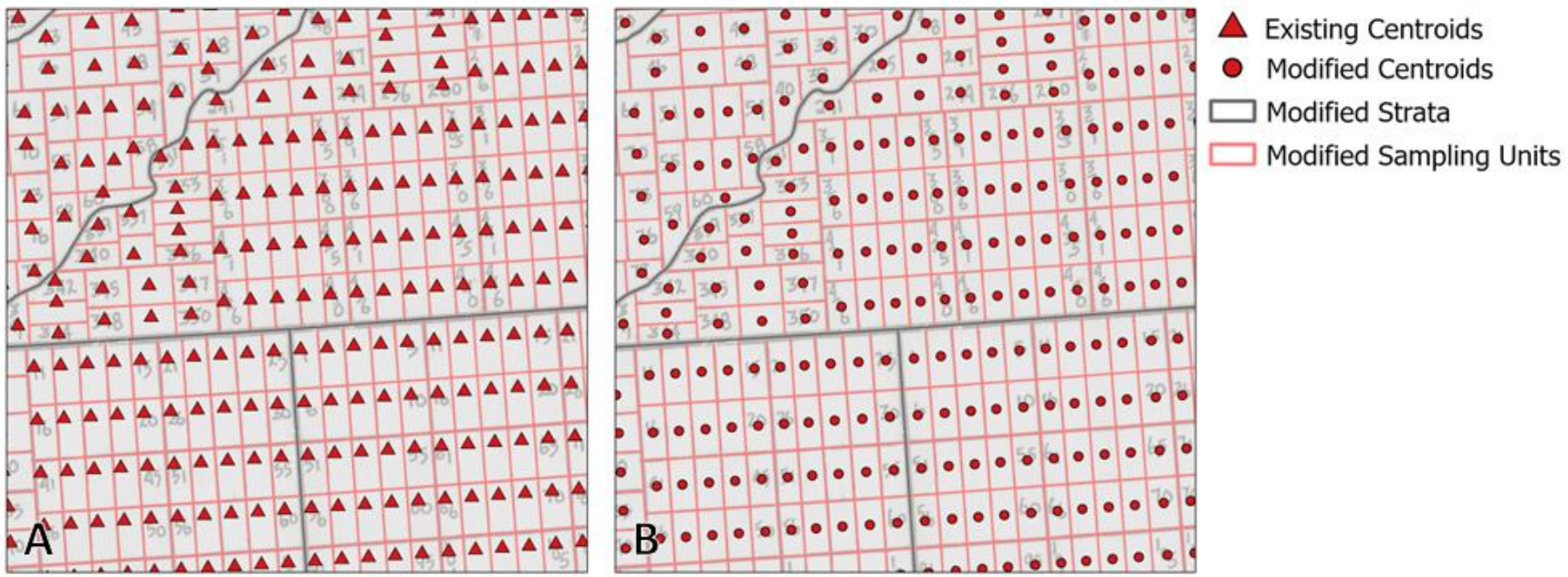



*Figure 19: An example of misalignment between existing centroids and associated sampling units (A) compared to the modified centroids which were generated at the center of each sampling unit (B).*

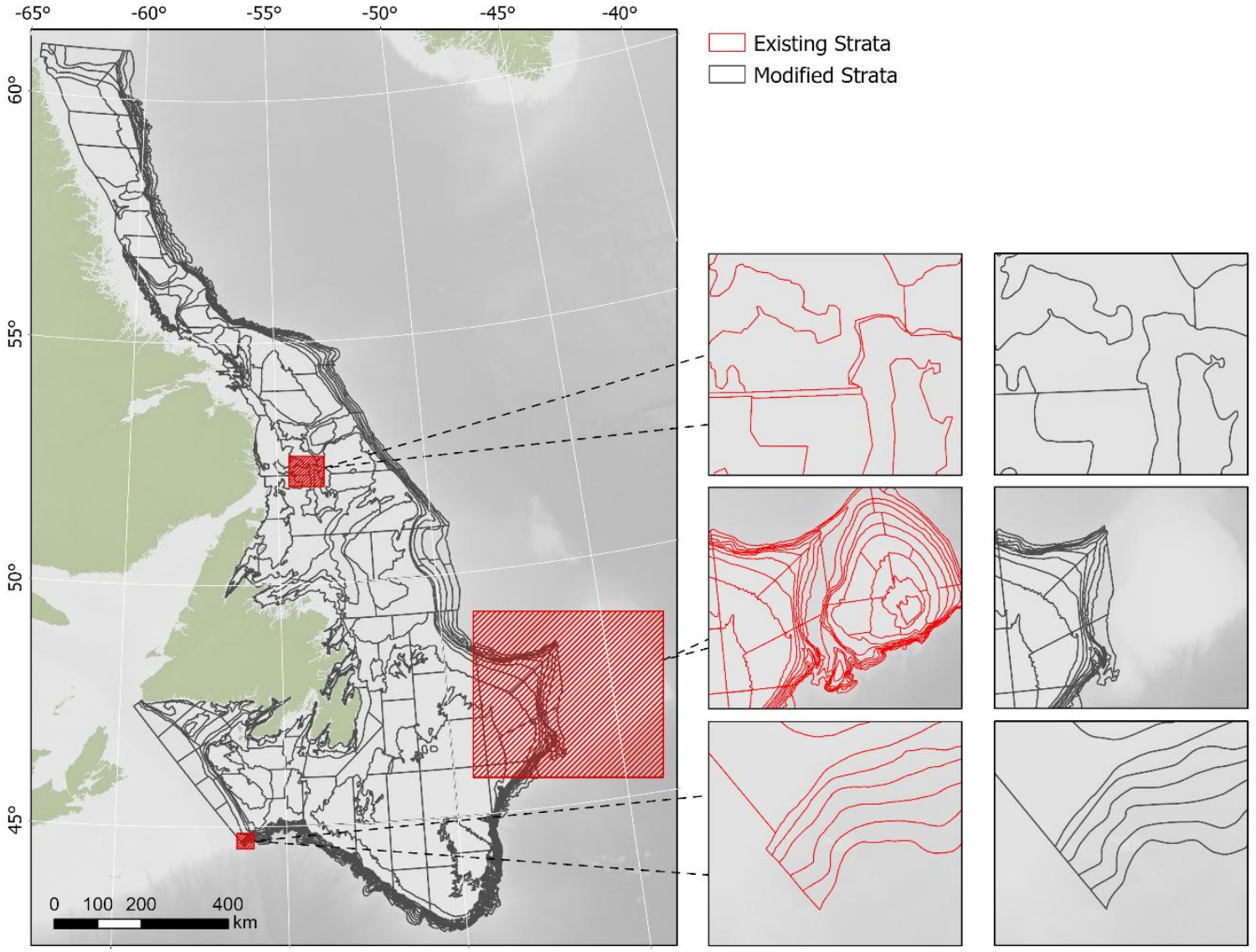



*Figure 20: Map of the modified strata shapefile with insets comparing some examples of differences in the existing (red lines) and modified (grey lines) strata boundaries for different areas.*

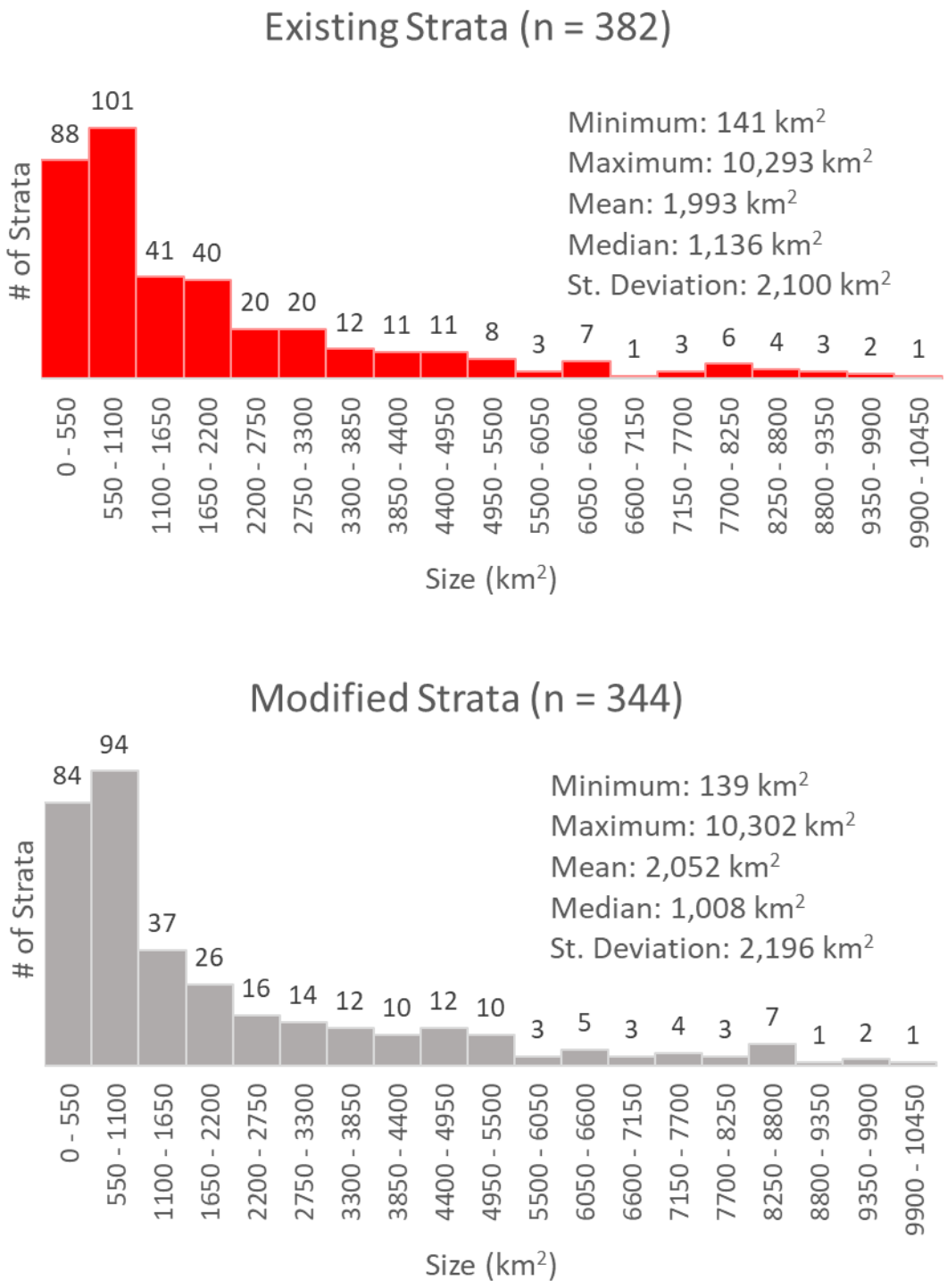



*Figure 21: The size frequency distribution (km²) of survey strata in the existing (top) and modified (bottom) strata shapefiles. The existing strata shapefile contained strata for NAFO Division 3M, which is not covered by the RV bottom trawl survey. These were excluded in the modified strata shapefile, which reduced in the total number of strata.*

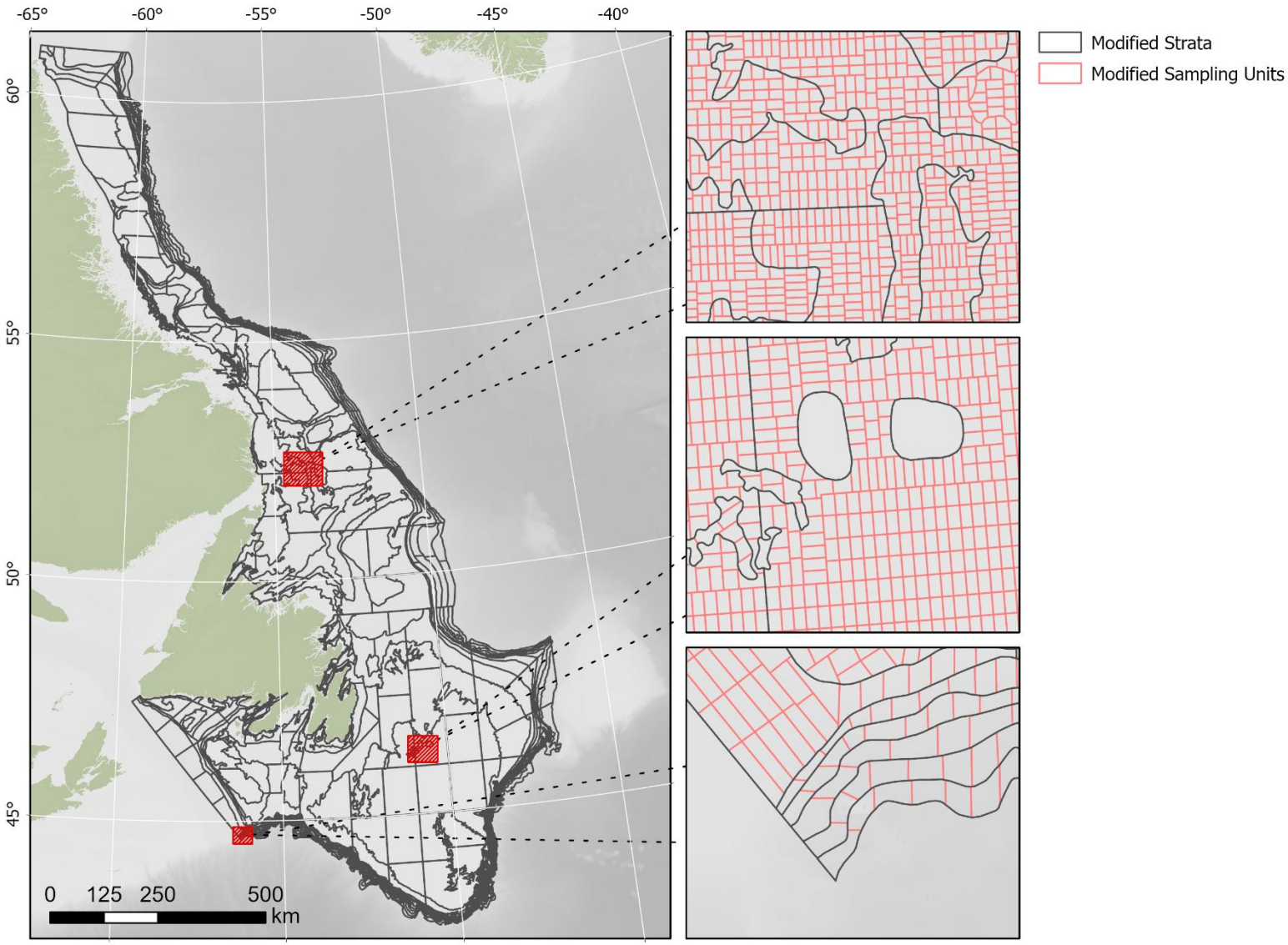



*Figure 22: Map of the modified strata shapefile with insets illustrating examples of modified sampling unit boundaries in select locations within the survey area.*

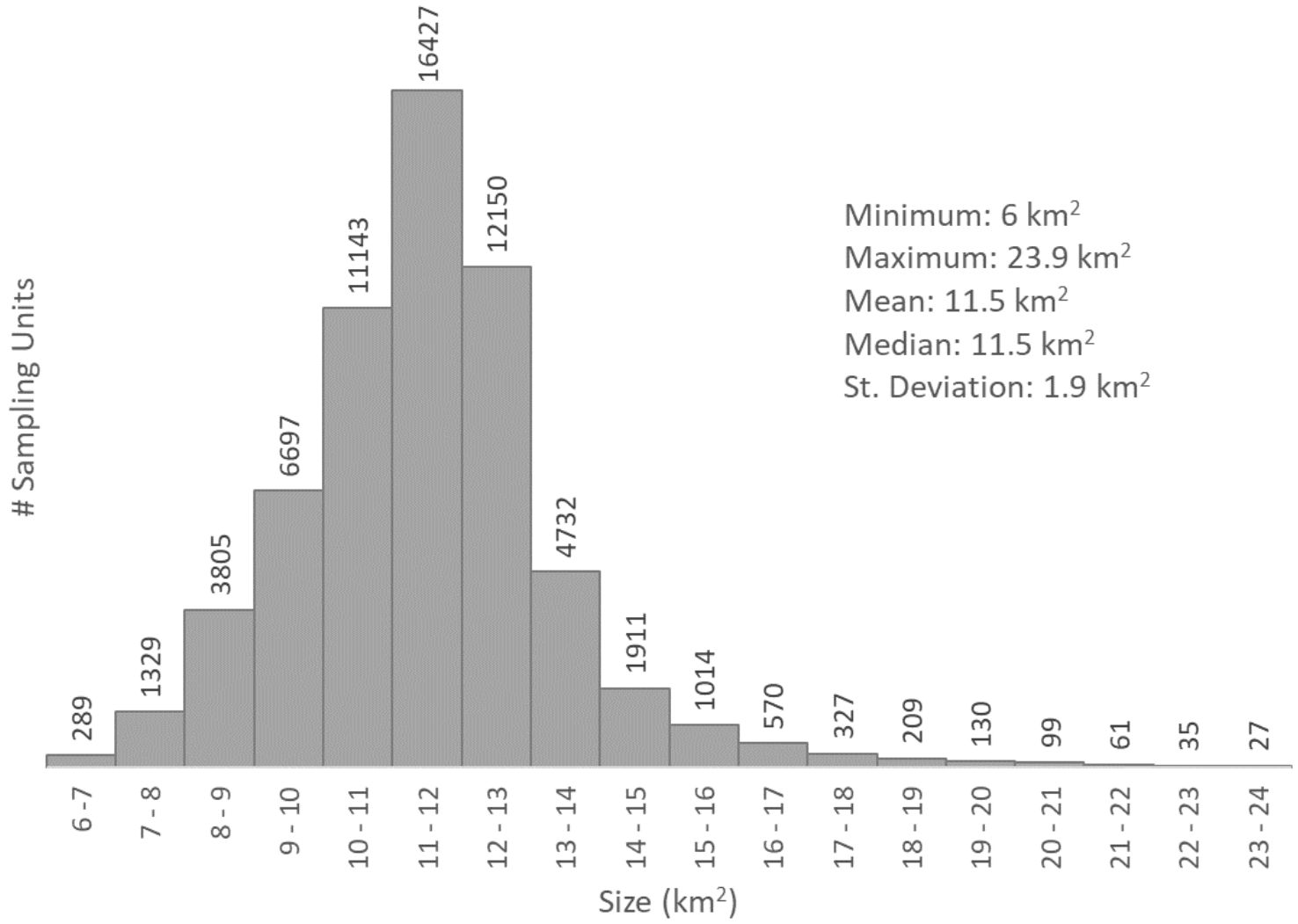



*Figure 23: The size frequency distribution (km²) of individual sampling units in the sampling unit shapefile.*

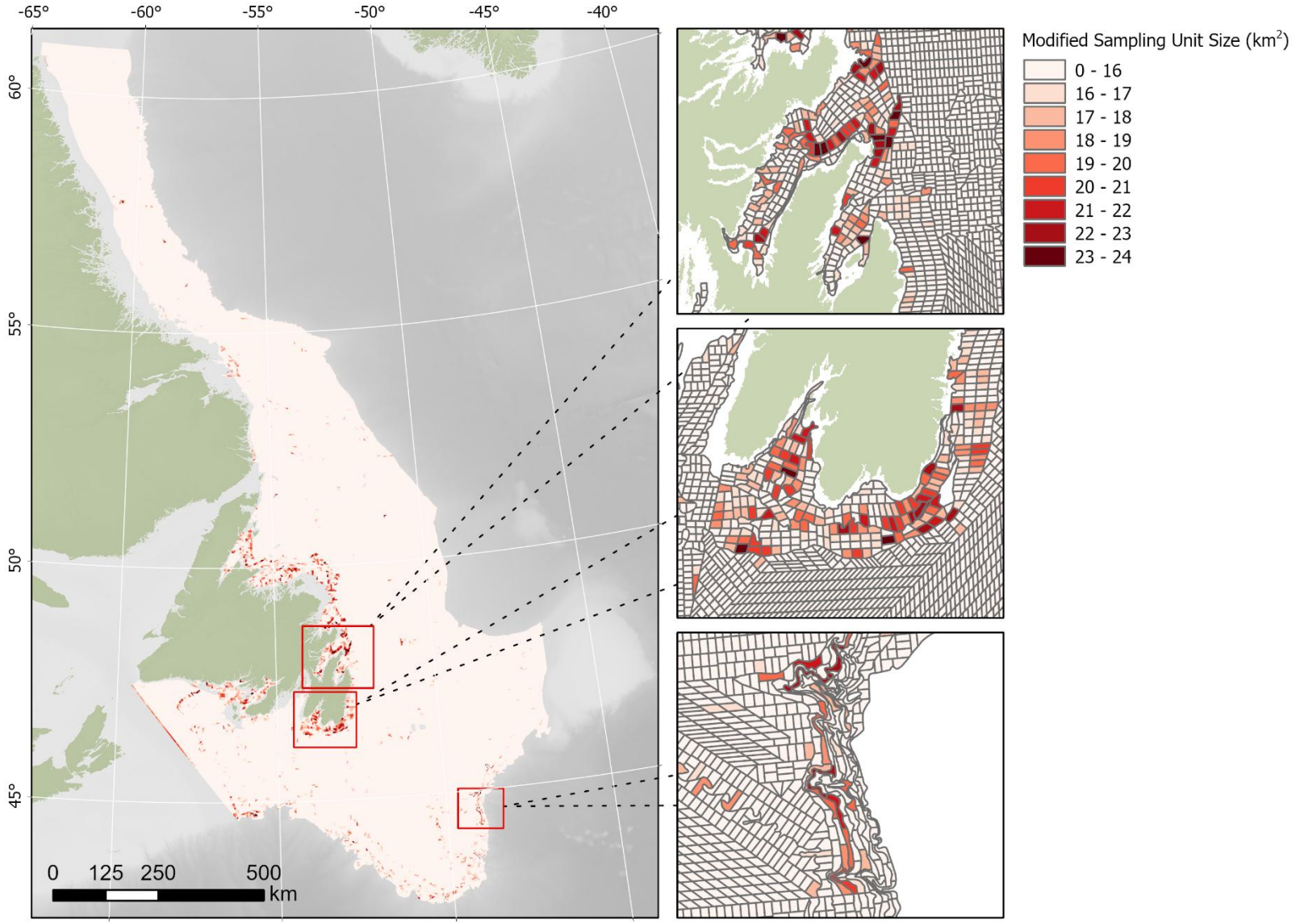



*Figure 24: Modified sampling units coloured by size to highlight locations of sampling units larger than 16 km². Insets provide some examples of areas where size variations were most prevalent.*

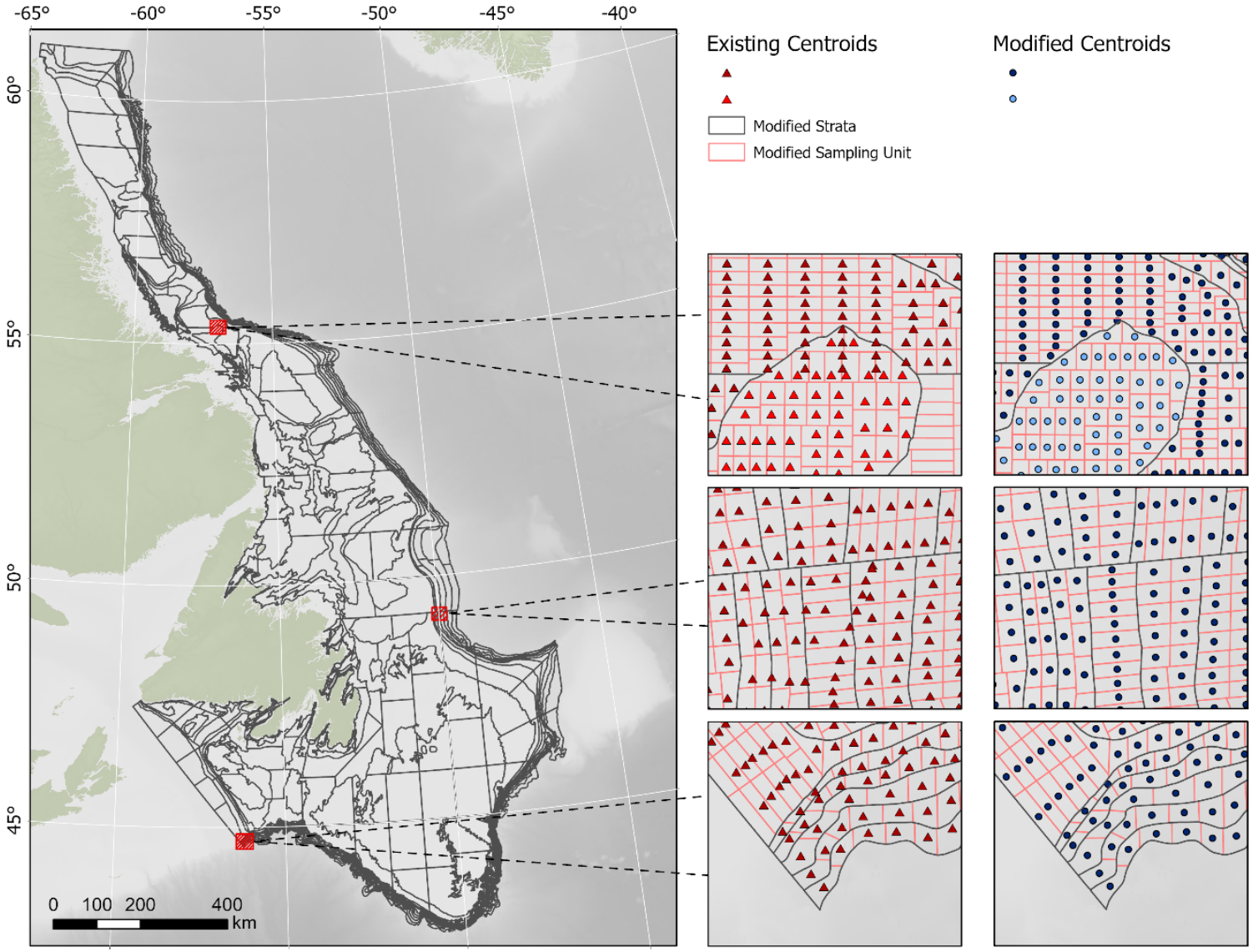



*Figure 25: Map of the modified strata shapefile with insets comparing the existing and modified centroid shapefile with digitized sampling units at select locations within the survey area. The different centroid colours are intended to highlight areas where strata overlap was corrected.*

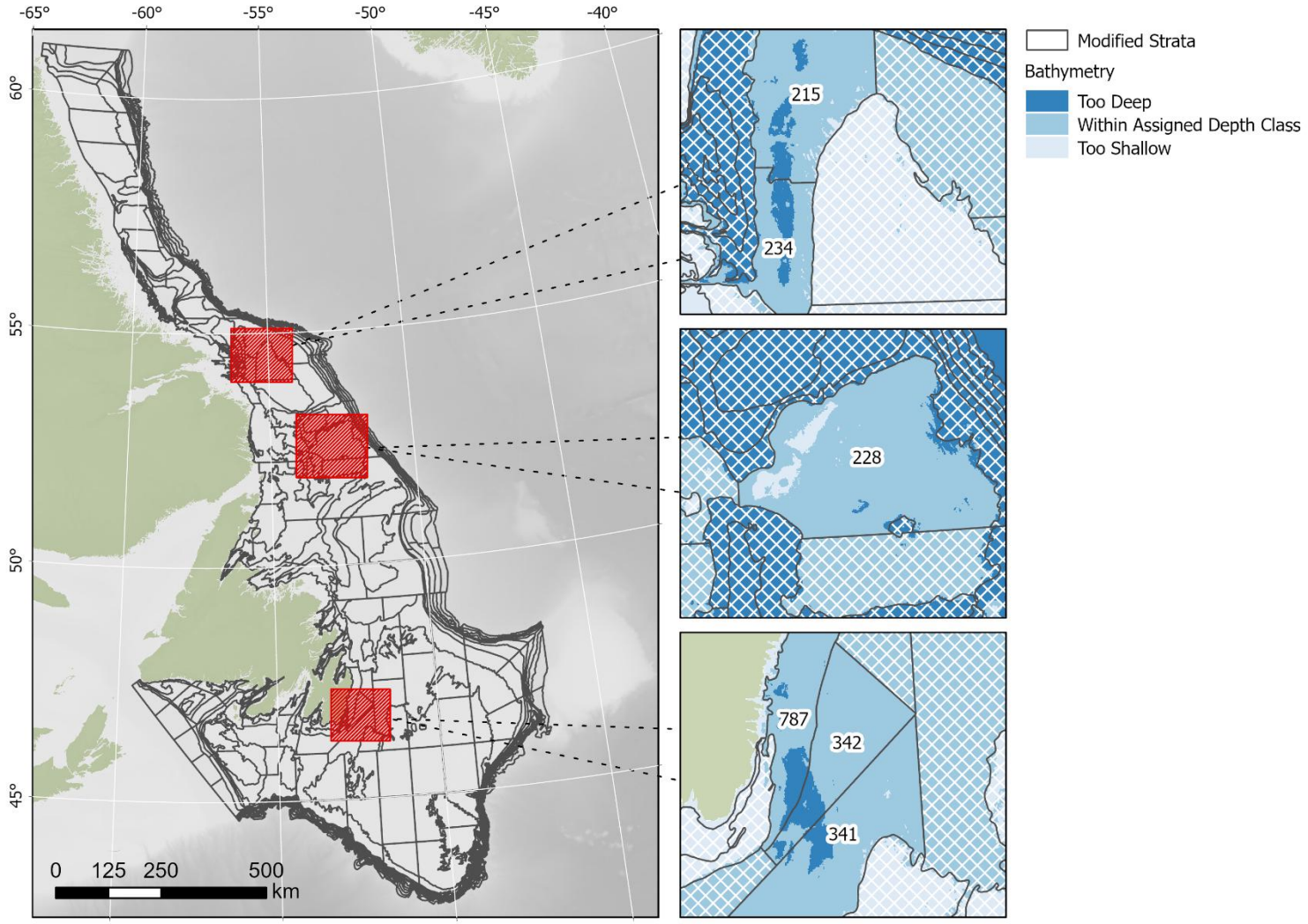



*Figure 26: Examples of strata covering areas where underlying bathymetry falls outside of the assigned depth classes. Strata 215, 234, and 228 are designed to cover depths of 201 – 300 m but are found to contain bathymetry in the depth classes above (301 – 400 m) and below (≤200 m) this range. Strata 341, 342, and 787 are designed to cover depths of 92 – 183 m but are found to contain bathymetry in depth classes above (184 – 274 m) and below (56 – 91 m) this range.*

# TABLES

*Table 1: Description of the attributes that were used in the modified strata, sampling unit, and centroid shapefiles.*

| Original Attribute Name | Updated Attribute Name | Description | Shapefile(s) containing the attribute |
|---|---|---|---|
| divn | NAFO_DIV | The NAFO division the feature falls within | Strata, Sampling Unit, Centroid |
| strat | STRATA | The number associated with the strata or the strata containing feature | Strata, Sampling Unit, Centroid |
| id | CNTROID_ID | The number assigned to the sampling unit and corresponding centroid (may be repeated for features in different strata) | Sampling Unit, Centroid |
| strat id | STRATA_ID | A unique identifier for sampling units and corresponding centroids that represents a combination of the strata ("STRATA") and centroid ("CNTROID_ID") | Sampling Unit, Centroid |
| - | DEPTHRANGE | Depth range associated with each stratum (**according to survey design; may differ from updated bathymetry data) | Strata |
| - | CENTROIDS | Number of centroids contained within each stratum | Strata |
| - | AREA_KM2 | Area covered by a single feature (calculated using Canada Albers Equal Area projection) | Strata, Sampling Unit |
| lat_dd | LAT_DD | Latitude in decimal degrees | Centroid |
| long_dd | LONG_DD | Longitude in decimal degrees | Centroid |

*Table 2: Comparing strata coverage, count, and attributes for the existing and modified strata shapefiles.*

| | Existing Strata | Modified Strata |
|---|---|---|
| **NAFO Divisions** | 2GHJ3KLMNOP | 2GHJ3KLNOP |
| **Area Covered ($km^2$)** | 764,496 | 699,165 |
| **# Strata** | 382 | 344 |
| **Attributes Included** | NAFO Division | NAFO Division |
| | Strata Number | Strata Number |
| | Area | Area |
| | | Depth Range |
| | | Number of Centroids |

*Table 3: Details of sampling unit coverage, count, and attributes. Sampling units had not been previously digitized, so no comparison is available.*

| | Existing Sampling Units | Modified Sampling Units |
|---|---|---|
| **NAFO Divisions** | - | 2GHJ3KLNOP |
| **Area Covered ($km^2$)** | - | 699,165 |
| **# Sampling Units** | - | 60,955 |
| **Attributes Included** | - | NAFO Division |
| | | Strata Number |
| | | Centroid ID |
| | | Strata ID |
| | | Area |

*Table 4: Comparing details of the existing and modified centroids coverage, count, and attributes. The (*) indicates that the existing centroid file also contained centroids designed for an unrelated juvenile survey (JUV) which were excluded from the modified centroid shapefile.*

| | Existing Centroids | Modified Centroids |
|---|---|---|
| **NAFO Divisions** | 2GHJ3KLMNOP4V* | 2GHJ3KLNOP |
| **# Centroids** | 75,540 | 60,955 |
| **Attributes Included** | NAFO Division | NAFO Division |
| | Strata Number | Strata Number |
| | Centroid ID | Centroid ID |
| | Strata ID | Strata ID |
| | Area | Area |
| | Latitude | Latitude |
| | Longitude | Longitude |

*Table 5: Description of the modifications made to the existing centroid file.*

| Problem Identified | Centroids Impacted (#) | Modification |
|---|---|---|
| **Outside survey area** | 7,453 | Removed |
| **Unrelated to survey** | 2,830 | Removed |
| **Duplicated** | 4,286 | Removed |
| **Sampling units eliminated** | 36 | Removed |
| **Sampling units missing centroid** | 11 | Added |
| **Sampling units added** | 9 | Added |

*Table 6: Depth classes used to delineate strata within the survey area.*

| Depth Classes (m) – NAFO Divisions 2GHJ3K | Depth Classes (m) - NAFO Divisions 3LNOP[1] |
|---|---|
| ≤200 | ≤55 |
| 201 – 300 | 56 – 91 |
| 301 – 400 | 92 – 183 |
| 401 – 500 | 184 – 274 |
| 501 – 750 | 275 – 366 |
| 751 – 1000 | 367 – 549 |
| 1001 – 1250 | 550 – 731 |
| 1251 – 1500 | 732 – 914 |
| - | 915 – 1097 |
| - | 1098 – 1280 |
| - | 1281 – 1463 |

[1] Depth classes for NAFO Divisions 3LNOP were originally defined in fathoms (Doubleday 1981) but are presented in meters for compatibility with depth classes defined in NAFO Divisions 2GHJ3K.