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Historical distribution of kelp forests on the coast of British Columbia: 1858–1956

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ABSTRACT

The quantification of kelp forest distribution across space and time is critical to support decision-makers responsible for habitat management and conservation. Spatial data such as aerial photos and satellite imagery are key for deriving kelp distribution; however, they have only become available at an adequate quality within the 20th and 21st centuries. In this study, British Admiralty (BA) charts created between 1858 and 1956 covering the British Columbia coast and portions of the adjacent Washington and Alaska coast were used to create a digital historical baseline map of kelp presence. A total of 137 BA charts were scanned at 200 DPI, georeferenced, and kelp features were manually digitized following a rigorous method considering the scale and quality of the data. An accuracy assessment of the digitized kelp features concluded that 99% of the kelp features occurred in expected areas within a depth of less than 40 m, and only about 1% of the features occurred entirely outside of this depth. Recently mapped kelp forests in similar areas reaffirmed the results of the produced baseline map. Potential sources of uncertainty should be considered when working with the historic BA charts such as the surveyor's method for defining floating kelp features, the artistic ability of the cartographer when transcribing the information from the surveys to the BA charts, and the regional seasonality of kelp cover. The outcome of this research shows that the historical BA charts are an unconventional but extremely rich source of baseline coastal habitat data from the 19th century. The methods conducted are simple and robust and could be applied to other regions where historical charts with sufficient quality exist.

1. Introduction

Aggregations of canopy-forming kelps, often referred to as kelp forests, are important biologically as shelter and food sources for a variety of marine species (Bennett & Wernberg, 2014; Christie, Norderhaug, & Fredriksen, 2009), physically as protection of shorelines (Teagle, Hawkins, Moore, & Smale, 2017), and biogeochemically as a contributor to carbon and nitrogen cycling (Pfister, Altabet, & Weigel, 2019). Specifically in British Columbia (BC), Canada, kelp forests provide important habitat for invertebrate and vertebrate species, including commercially valuable ones such as herring (*Clupea* sp.), salmon (*Oncorhynchus* sp.), and rockfish (*Sebastes* sp) (e.g., Beamish, Neville, Sweeting, & Lange, 2011; Daly, Brodeur, & Weitkamp, 2009; Haegele & Schweigert, 1985; Markel & Shurin, 2015; Paddack & Estes, 2000), and kelp forest cover is an attribute of the critical habitat for endangered northern abalone (*Haliotis kamtschatkana*) (DFO, 2012, p. 65). Kelp fronds are also harvested both commercially and by coastal First Nations because the roe on kelp fishery is of commercial and cultural importance (Schweigert, Cleary, & Midgley, 2018). As such, canopy-forming kelp have been identified by the Canadian government as ecologically significant species, and a priority for marine conservation planning and oil spill response (Gale et al., 2019; Thornborough, Hannah, St. Germain, & Miriam, 2017).

Given their significant ecological and economic importance, it is important to understand how kelp forests have changed over time. Kelp forests in the Northeast Pacific have changed over time due to a variety of processes and threats that operate at different scales (e.g., Schroeder, Boyer, Juanes, & Costa, 2019a; Cavanaugh, Reed, Bell, Castorani, & Beas-Luna, 2019; Pfister, Berry, & Mumford, 2018; Burt et al., 2018; Bell, Cavanaugh, Reed, & Siegel, 2015; Edwards, 2004). At local and

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regional scales, processes including overgrazing by sea urchins (Watson & Estes, 2011; Burt et al., 2018), severe storms (Byrnes et al., 2011), oil spills (Peterson et al., 2003; Thornborough et al., 2017), and local increases in water turbidity and nutrients (Pfister et al., 2018) have contributed to the decline of kelp forests. On a global scale, these habitats are threatened by warming ocean waters (Cavanaugh et al., 2019; Krumhansl et al., 2016; Schiel, Steinbeck, & Foster, 2004). In the context of BC, the quantification of the spatial-temporal loss of kelp forests and the associated drivers is relevant to several regional science programs, including science being used to inform marine spatial planning (e.g., Marine Plan Partnership for the North Pacific Coast - http://mappocean.org/), the Coastal Environmental Baseline Program (https://www.dfo-mpo.gc.ca/science/environmental-environnement/cebp-pdecr/index-eng.html), and the development of a marine protected area network (e.g., Marine Protected Area Network process in Northern Shelf Bioregion - http://mpanetwork.ca/bcnorthernshelf/). As part of these programs, historical kelp distribution data provides a benchmark for analysis against current status and associated drivers of change, defines expectations on distribution over time, and may also play a role on stakeholder's perception of change over time, which is collectively beneficial for prioritizing and guiding conservation plans (Thurstan et al., 2015).

The quantification of kelp changes over long-time frames and across large spatial scales requires spatial data from the past (baseline) and present. Data derived from historical aerial photos, satellite imagery, and uncrewed aerial vehicles (UAV) may be appropriate for mapping kelp forests, depending on the timing of acquisition and quality of the imagery (Mora-Soto et al., 2020; Burt et al., 2018; Nijland, Reshitnyk, & Rubidge, 2019; Schroeder et al., 2019a; Schroeder, Dupont, Boyer, Juanes, & Costa, 2019b; Cavanaugh, Siegel, Kinlan, & Reed, 2010). In BC, kelp mapping has been conducted in smaller areas using field surveys in the early 20th century (Cameron, 1916), and infrared aerial photos since the 1970s (Field & Clark, 1978; Sutherland, Karpouzi, Mamoser, & Carswell, 2008). Air photo data for the entire coast is available from the early 1930s with black and white film and, more recently, with true colour and false-colour infrared films (small areas). Still, the time of photo acquisition, quality, and film type were chosen mostly for land cover mapping purposes (Nahirnick, Costa, Schroeder, & Sharma, 2019), making it unsuitable for broad-scale kelp mapping.

With the advent of Earth Observation satellites, specifically, the Landsat series with visible and infrared spectral bands at coarse spatial resolution (80-30 m) (Schroeder et al., 2019b), satellite imagery has been used for creating time series of kelp distribution for BC (Nijland et al., 2019) and other regions (Stekoll, Deysher, & Hess, 2006; Cavanaugh et al., 2010; Uhl, Bartsch, & Oppelt, 2016). High spatial resolution satellite imagery (~2 m), such as the WorldView series (Schroeder et al., 2019b), is being used for mapping current kelp distribution for specific regions of BC (Schroeder et al., 2019a, 2019b). Additionally, local organizations and citizen science groups have conducted sea kayak-based kelp inventory (e.g., Help the Kelp, 2015; MICS, 2010), helicopter surveys (Harper, Morris, & Daleym, 2013), and compiled existing historical datasets into more complete sets through the Pacific North Coast Integrated Management (PNCIMA) and the British Columbia Marine Conservation Analysis (BCMCA) initiatives.

These data sources are extremely valuable, but they are recent and do not provide a historical context of century-scale change. Infrared aerial photos from the 1970s are limited to very few areas in BC, Landsat 5 (30 m resolution) satellite imagery has only been available since 1984, and higher resolution satellite imagery (~2 – 4 m resolution) have been available since 2000, which together provide a record for the end of the 20th century and early 21st century.

An unconventional but extremely rich source of information on kelp presence is a series of British Admiralty charts of the BC coast, dating back to the mid-19th century. These correspond to the time of colonial BC when mining, fishing, and logging activities brought a large increase in permanent settlements (Robinson, 2019). Similar data has been previously used for, for example, historical mapping of corals (McCleachan et al., 2017) and kelp presence (Pfister et al., 2019), both for smaller areas. Here, we compiled British Admiralty (BA) charts between the years 1858–1956 to derive a digital map of kelp presence on the BC coast and portions of the adjacent Washington and Alaska coast – a historical map. Comparing the digital historical map of BA charted kelp to on-going mapping kelp using remote sensing technology may improve our understanding of spatiotemporal kelp dynamics and, in doing so, support several governmental and First Nation conservation, including marine planning initiatives and harvesting management in BC. For instance, the regional planning initiatives, such as the Marine Protect Area Network and the Marine Plan Partnership, will make use of the historical kelp data to define spatiotemporal changes in kelp distribution overtime to evaluate management efforts.

2. Methods

2.1. Study area

The study area includes the BC coast and extends to portions of the Washington and Alaska coasts, approximately 47° 1' N to 56° 17' N and 122° 5' W to 136° W (Fig. 1). In this region, the dominant canopy-forming kelp species are bull kelp (*Nereocystis leutkeana*), which is an annual species (although some specimens may persist into the second year), and perennial giant kelp (*Macrocystis sp.*) (Druehl & Clarkson, 2016). Bull kelp is a brown macroalga that forms narrow beds on subtidal rocky substrates, typically from a depth of 3 to about 20 m, in protected and high energy coastal areas from California to Alaska (Springer, Hays, Carr, & Mackey, 2007). Its form consists of a holdfast, a narrow hollow stipe that can reach 30 m in height, and a gas-filled floating bulb with tens of blades attached, which are visible from the surface. Similarly, giant kelp occurs along the entire coast of BC, except in the Strait of Georgia, in the lower intertidal and shallow subtidal, typically to a depth of about 10 m in this area (Graham, Vasquez, & Buschmann, 2007); however, it's occurrence is documented to 40 m in depth in California (Ladah & Zertuche-González, 2005). This species also has gas-filled pneumatocysts and tens of fronds and blades forming a large canopy that is easily visible from the surface.

2.2. Dataset description

This study used 137 British Admiralty (BA) charts, including insets, with scales ranging from 1:6080 to 1:500,000, created between 1858 and 1956 (Fig. 1); this comprises the available inventory of historical BA charts from the Canadian Hydrography Service (CHS). The charts are cartographic interpretations of the original BA surveys, that is, cartographers converted the survey data to charts depending on the scale and purpose of the chart (Field & Wharton, 1920). As a result, the representation of kelp features may vary between charts depending on how the cartographer chose to represent these features from the surveys. Generally, however, the presence of kelp was drawn as dendritic features representing the blades and stipe (Fig. 2). Additionally, the charts provide notations of depth, substrate, and rock formations that were used to aid in the interpretation of the kelp data.

According to historical documentation, three slightly different survey methods were used to create the charts, and the defined methodology was dependent on the area to be surveyed, required scale, coastline characteristics, weather conditions, time and resources, number of assistants, and experience of the surveyor (Field & Wharton, 1920). The following methods were used: (1) preliminary or sketch surveys – these were not the most accurate, but were based on a triangulated base and were useful for depicting unmapped coastlines; (2) surveys for the ordinary purposes of navigation – these were the most common type of survey in which everything denoted was accurate, but due to constraints, not all of the land or sea was surveyed; and (3) detailed surveys – these were considered the most accurate, typically

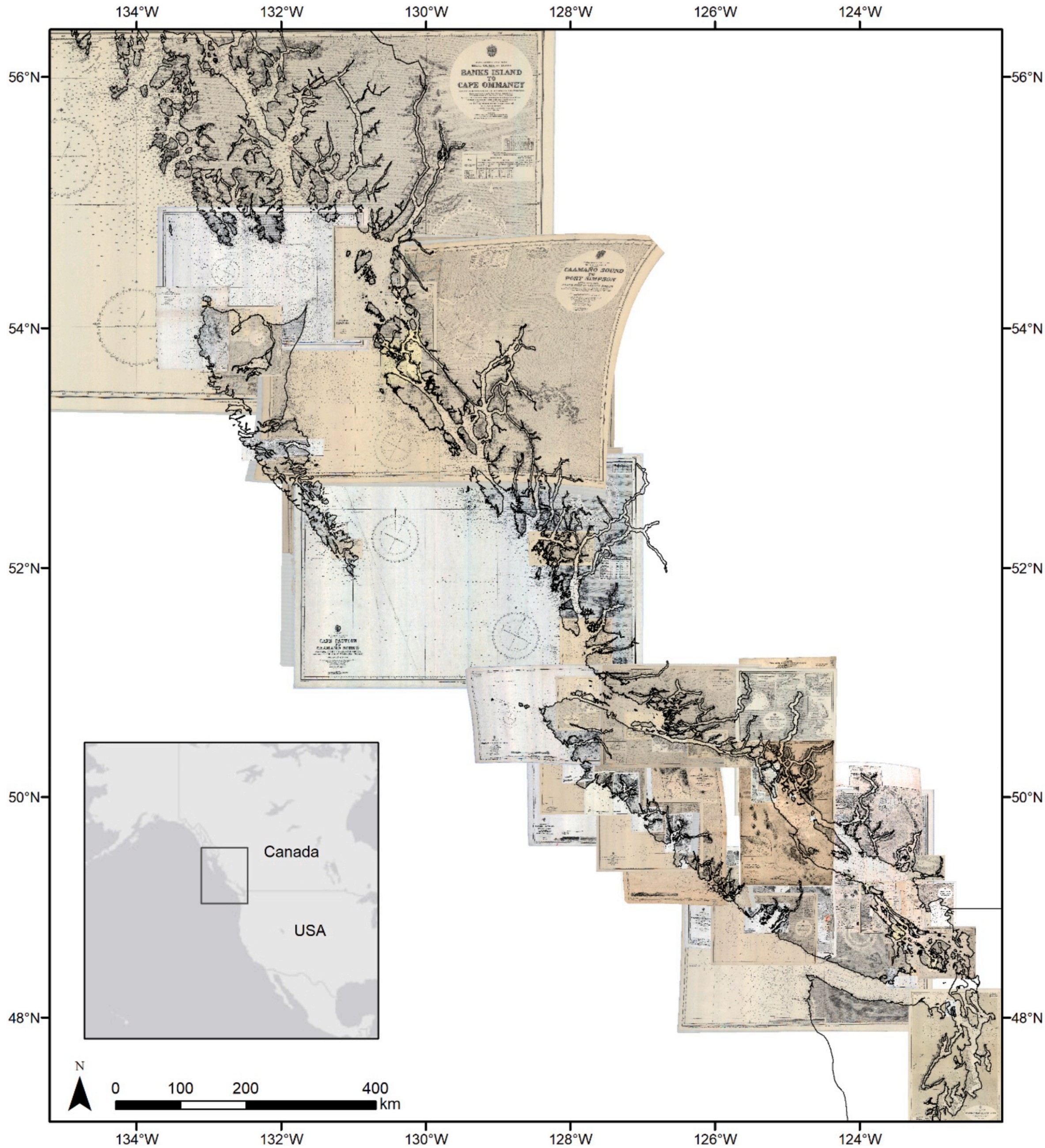

Fig. 1. Study area: geometrically corrected British Admiralty charts for the BC coast and portions of the WA and AK coast.

reserved for well-populated areas where there was intense trading (Field & Wharton, 1920). All surveys were based on triangulation, in which a sextant or theodolite was used to determine latitude and angles, while a chronometer was used to help determine longitude. Typically, a sheltered harbour was used for the first two points or base of the main triangulation measurement (ideally between 1000 and 3000 m). The third corner of the main stations was taken from a "considerable distance apart," then a "sufficient number of secondary stations" were taken from the main stations so that the chart could "be filled in between them" (Field & Wharton, 1920, p. 63). The points "are then transferred to the field books, either by pricking through the plotting sheet with a fine needle, or, what is a better way when carefully done, by making a tracing of them on tracing-cloth, and pricking through that on to the boards" (Field & Wharton, 1920, p. 63).

2.3. *Charts preparation: digital format and geometry*

The extraction of kelp features from the BA charts followed standard procedures of using historical maps for data extraction (Peller, 2018; Bromberg & Bertness, 2005). First, each BA chart was scanned by the Canadian Hydrographic Service using the CHS Colortrac large format scanner and saved as a Tagged Image Format at 200 DPI, which was deemed sufficient resolution to visualize all the features of interest properly. Subsequently, the scanned charts were imported into ESRI ArcMap and georeferenced directly to WGS84 using CHS georeferencing standards and principles (CHS, 2019). In order to minimize error, a hierarchy of control points was used, ranging from high survey order control points to comparing conspicuous stable rock features apparent in satellite imagery. Where possible and when needed to attain consistent control distribution to minimize and distribute error, graticule positions were used by applying Natural Resources Canada's Clarke 1866/North

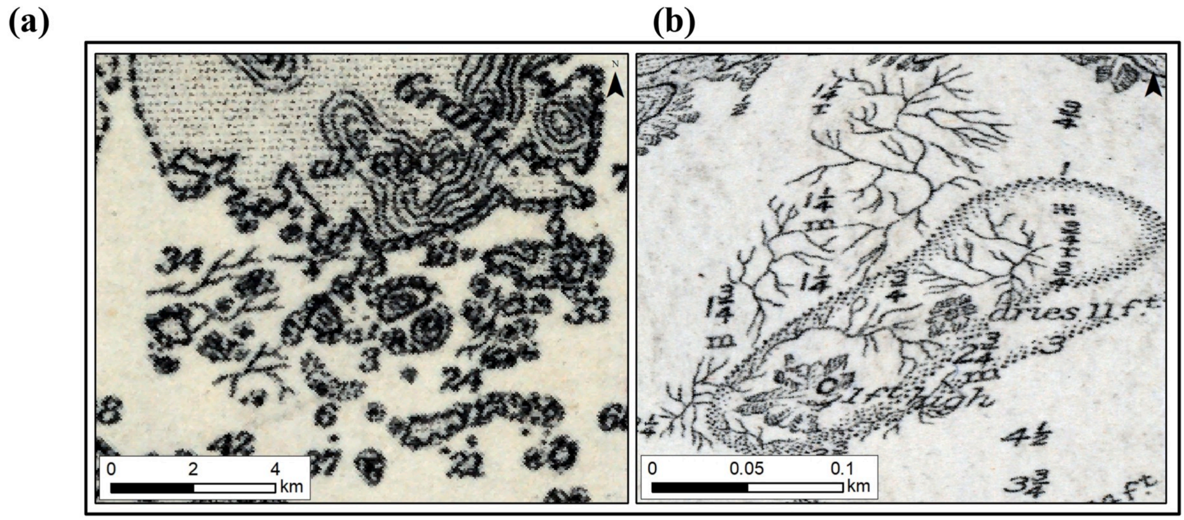

Fig. 2. Example of how a cartographer's style, as well as chart scale, can affect how kelp features are represented. (a) Kelp features on the left (scale 1:500,000) are simplified and concise. (b) Features on the right (scale 1:6080) are more branched and spread out.

American Datum 1927 to Nad83/WGS84 shift values. The combination of the best selection of control points and transformation algorithms (1st order polynomial and spline) was used to achieve the least Root-Mean-Square (RMS) error residual values. Absolute allowable tolerances were relative to the chart scale and typically better than 0.5 mm at the chart scale. The georeferencing result was further validated against satellite imagery, CHS charts and fieldsheets, the CHS-Pacific High Water Line (http://www.charts.gc.ca/documents/data-gestion/CHS_Pacific_High_Water_Coastline_2014.zip), and adjacent and overlapping BA charts.

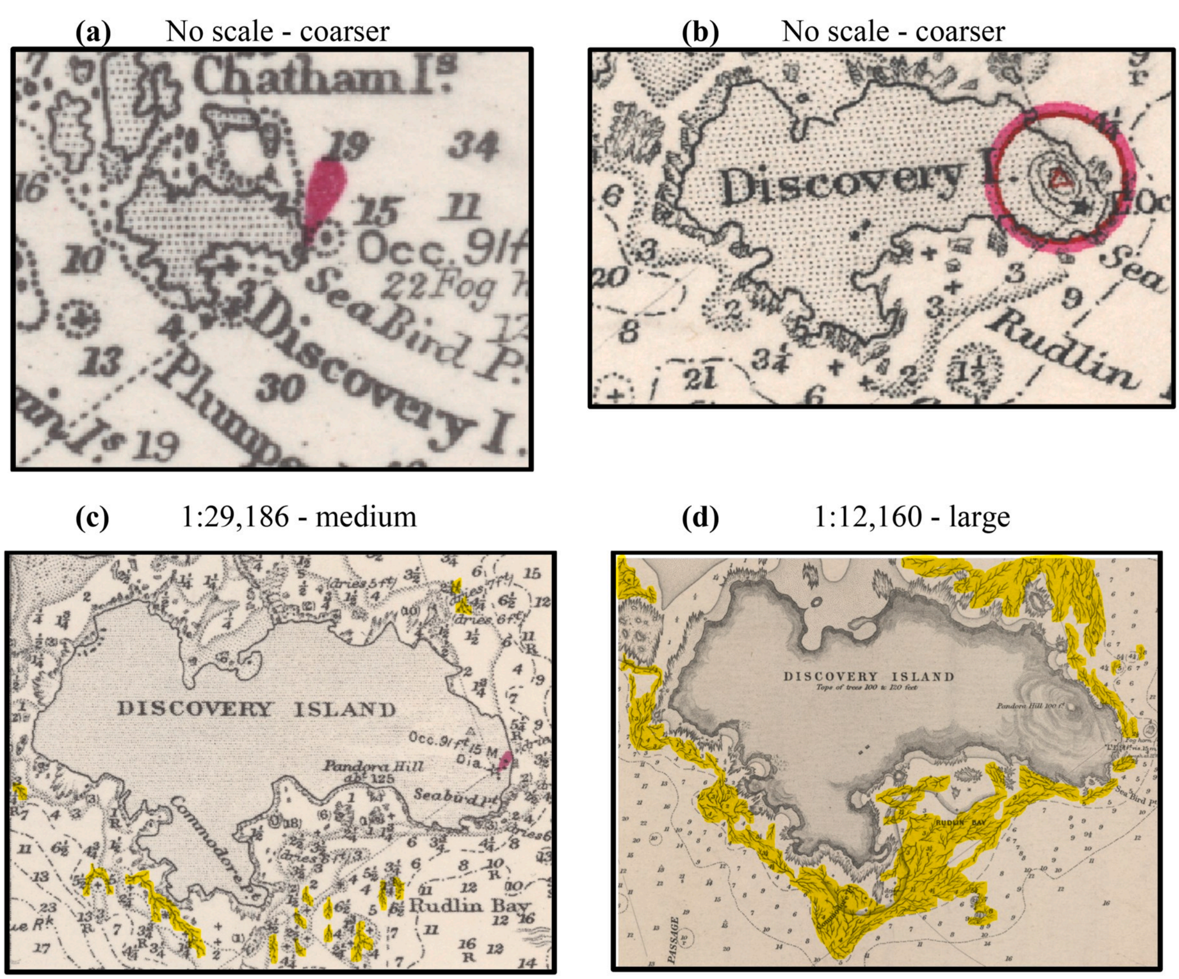

Fig. 3. Discovery Island at four different scales with kelp features highlighted in yellow.

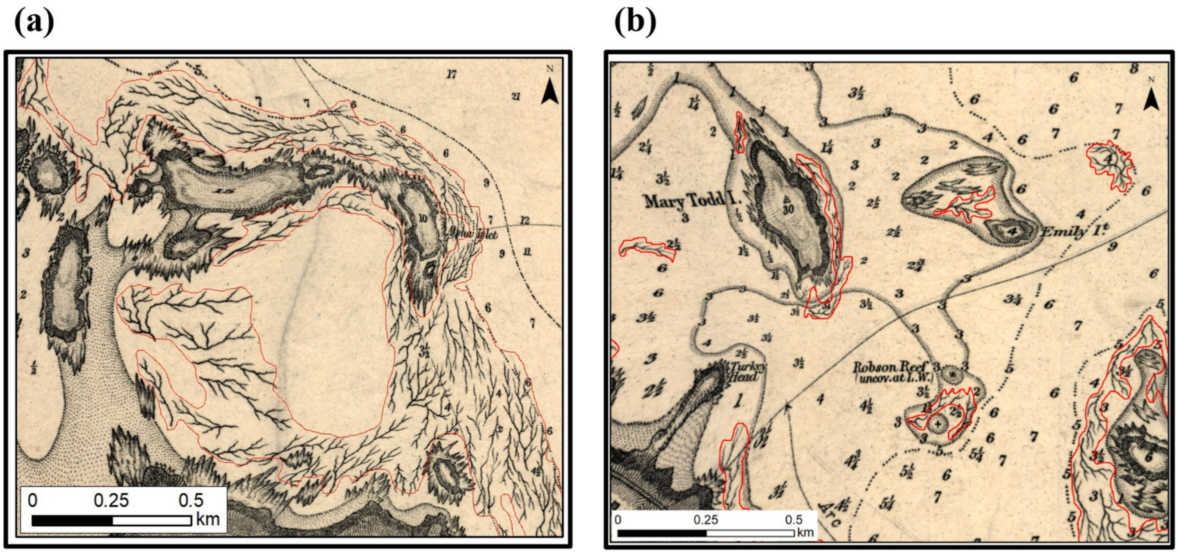

Fig. 4. Examples of digitized kelp features on a 1:12,160 scale. (a) The red line shows the grouping of several kelp features as one polygon; (b) the red line shows kelp features as several individual polygons.

2.4. Digitizing and defining the accuracy of kelp features

A strategic methodology was followed, so that kelp features from 137 charts and chart insets were digitized in a continuous, non-overlapping manner. First, the study area was divided into several subjective zones into which the charts were organized. Next, the charts in each zone were further organized in the order in which they would be digitized to ensure that the kelp features were digitized in a continuous mosaic, and finer resolution charts were prioritized instead of coarser-resolution charts. When an area was covered by multiple charts, only the finer resolution charts were digitized because the coarser-resolution charts generally didn't contain kelp features. Coarse features that were present appeared very large and had less positional accuracy, compared to the smaller, more precise locations of the kelp from finer resolution charts. Finally, the kelp features were digitized, and corresponding chart information (scale, chart number, title, survey start year, survey end year, and comments) was added as attributes to each feature.

Features from large scale charts with a relatively fine resolution were prioritized because the intention of those charts at the time was to show more detailed features for navigation (McClenachan, O'Connor, Neal, Pandolfi, & Jackson, 2017), and therefore are assumed to be more accurate. For example, Fig. 3 shows the same area (Discovery Island, BC) at four different scales to illustrate the role of scale in the display of kelp features. Note in Fig. 3a and b, showing inserts of charts at the smallest scales (scales not available), kelp features are not present, while Fig. 3c and d at medium and large scales show kelp features. Further, for the medium (1:29,186) and large (1:12,160) scale charts, note that the medium-scale chart (Fig. 3c) shows simple, concise symbology of kelp features, compared to kelp features from the large-scaled chart (Fig. 3d), which shows more linear features, branched, or complex.

Given the observed differences in kelp feature representation at different scales, when digitizing kelp features, polygons were used to represent the discrete observations, and as such, they represent the presence of kelp and not kelp area. Polygons were created by tracing around the kelp feature, aiming to keep the outline close to the stipe and blades (Fig. 4). If several kelp features were within 100 m of each other for charts with scales less than 1:75,000 or 200 m for scales greater than 1: 75,000, these features were clustered together in one polygon (see example in Fig. 4a); otherwise each kelp feature was defined as one individual polygon (Fig. 4b). The 100 and 200 m distances were visually defined as an appropriate distance for the scale of the charts.

The locational accuracy of the digitized kelp features was defined using a reliability criterion, which considers the location of the digitized kelp feature (polygon) in relation to the local depth in which the feature occurs. For this, we defined a depth threshold of 40 m because kelp is unlikely to occur beyond this depth regionally (Graham et al., 2007; Ladah & Zertuche-González, 2005; Springer et al., 2007). Forty metres was chosen to account for (1) known depth occurrence, and average length of kelp in the region and Pacific Northwest, (2) movement of kelp canopy with tide and currents, (3) possible residual errors on feature location associated with geometry of the charts and the surveyor's drawing abilities (Field & Wharton, 1920), and (4) line thickness of kelp features throughout the entire dataset; line thickness on map features across different scales can vary considerably (Peller, 2018).

For defining accuracy, we overlaid the kelp polygons on a 20 m resolution raster bathymetric dataset created from interpolated CHS field sheet data (Davies, Gregr, Lessard, Bartier, & Wills, 2019). Kelp polygons outside of BC waters did not overlap with the bathymetry dataset used and, therefore, could not be evaluated, corresponding to 12% of the total kelp polygon features. For the BC dataset, kelp feature reliability was classified into four categories based on the proportion of each polygon that occurred shallower than the 40 m threshold (Table 1). The reliability category 'Very High' corresponds to kelp polygons that occur only over areas where the bathymetry is shallower than 40 m. Category 'High' corresponds to kelp polygons with more than 50% of the polygon area occurring over areas where the depth is shallower than 40 m. Category 'Medium' corresponds to kelp polygons with more than 50% of the polygon area occurring in areas where depth is greater than 40 m. It is important to note that because a polygon is labelled as medium reliability, it does not mean that the entire polygon is in an area where kelp is unlikely to grow. Rather, it means that at least 50% of that polygon is in an area where kelp is unlikely to grow. Lastly, the

Table 1
Reliability of the kelp feature polygons.

Reliability	Frequency	Description
Very High	4116 (88.0%)	Entire individual polygon occurs where the bathymetry is shallower than 40 m
High	349 (7.5%)	At least 50% of the individual polygon occurs where the bathymetry is shallower than 40 m
Medium	163 (3.5%)	More than 50% of the individual polygon occurs in an area were the bathymetry is greater than 40 m
Low	48 (1.0%)	Entire individual polygon occurs where the bathymetry is greater than 40 m

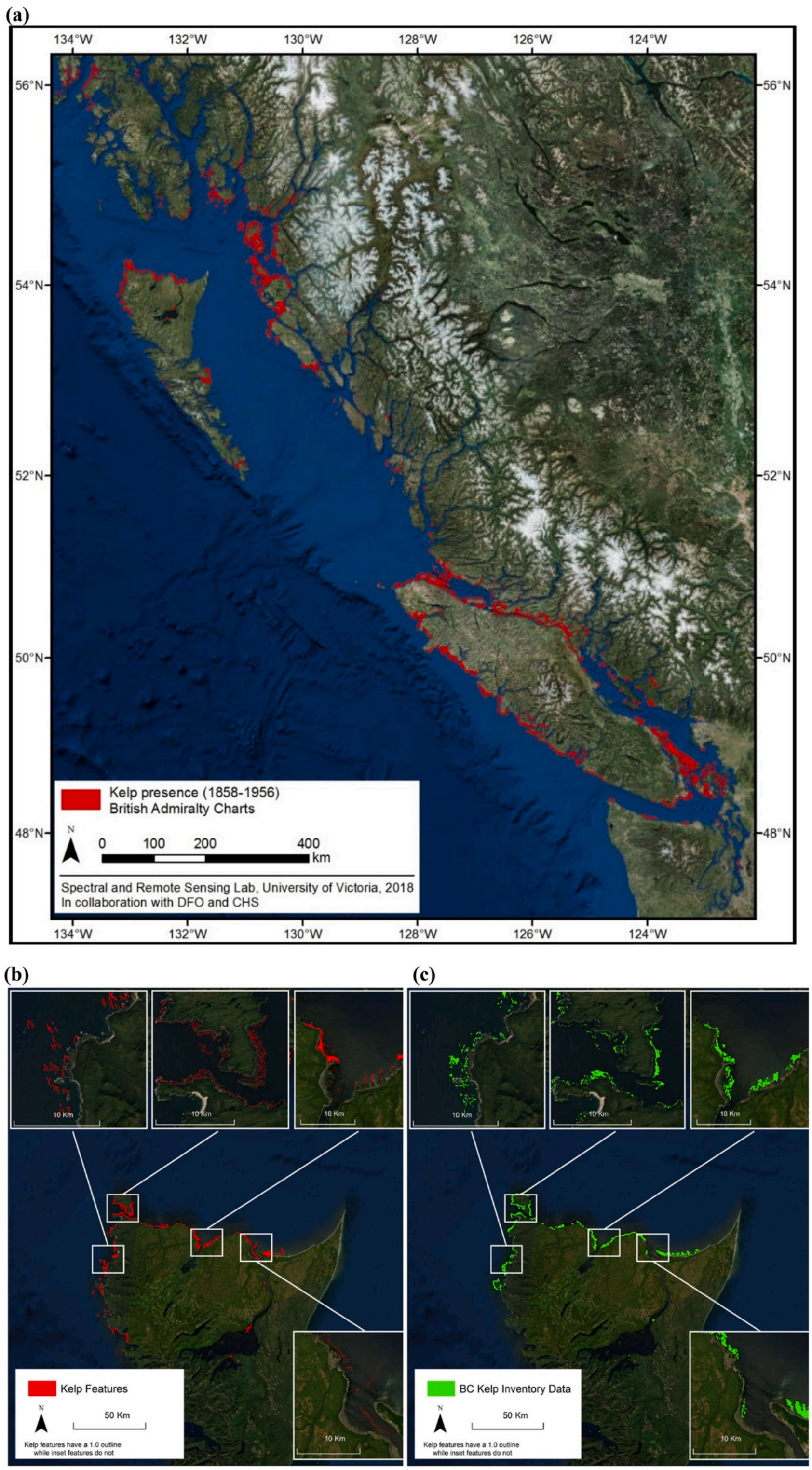

Fig. 5. (a) Digitized kelp features from historic British Admiralty charts for the period of 1858–1956. In order to facilitate visualizations of the kelp features, a 1 pt outline was applied to the kelp polygons. Enlargement of areas of Northern Haida Gwaii showing kelp presence as shown in the (b) BA historical map and (c) BCMCA map (BCMCA, 2011).

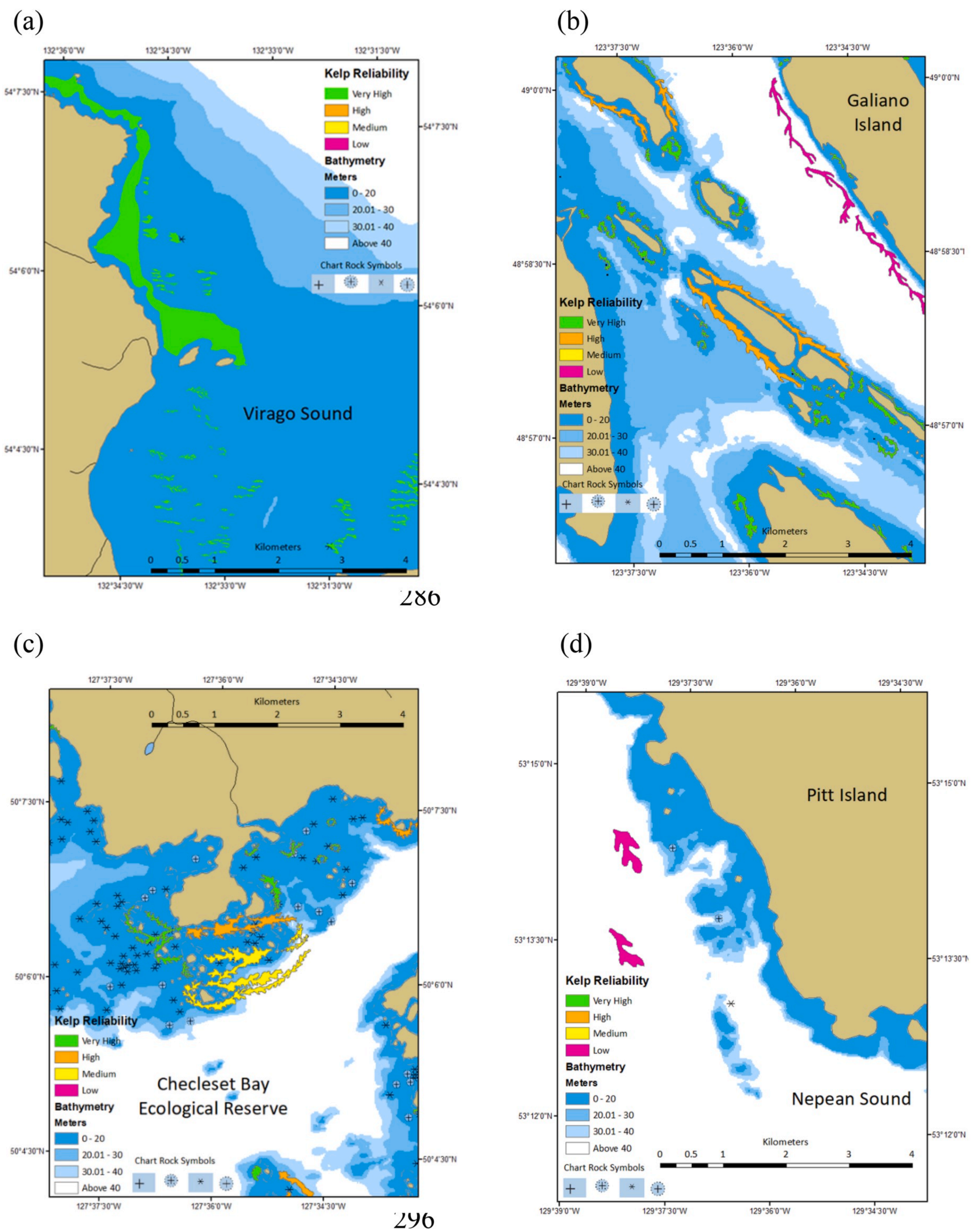

Fig. 6. Examples of different levels of reliability for the location of kelp features. (A) Very high (green polygon); (B) high (orange polygon); (C) medium (yellow); and (D) low (pink polygon) reliability.

reliability category 'Low' corresponds to kelp polygons that occur only in areas where depth is greater than 40 m.

3. Results and discussion

The digitized kelp features comprise 5287 polygons, which include individual and clustered kelp features on the BC coast and part of the Washington and Alaska coasts based on 137 charts (Fig. 5). The accuracy of the location where the digitized kelp features occurred was evaluated based on the reliability index. The index showed that the majority of charted kelp polygons where located in areas where kelp is likely to occur based on depth; i.e., 99% of the polygons occurred in areas where the depth is shallower than 40 m (very high to medium reliability) (Table 1). Specifically, the category 'Very High' comprised of about 88% of the kelp features; note in Fig. 6a the 'Very High' reliability kelp feature polygon (shown in green) is entirely in an area where the

Table 2
Comparison between chart scale and reliability index showing the percentage of kelp features across reliability index categories for each chart scale category.

	Very high	High	Medium	Low
Large scale (<1:10,000)	100	0	0	0
Medium scale (<1:25,000)	98	1	<1	<1
Small scale (<1:50,000)	89	7	3	1
Very small scale (<1:350,000)	78	15	6	<1

bathymetry is shallower than a depth of 40 m. The reliability category 'High' comprised of about 7.5% of the polygons. Fig. 6b illustrates that a small percentage of the kelp polygon (shown in orange) intersects with the 40 m isobath. The reliability category 'Medium' corresponds to 3.5% of the polygons. Fig. 6c shows that more than half of the area of the kelp polygon (yellow) is in areas deeper than the 40 m isobath. The reliability category 'Low' corresponds to 1% of the polygon occurring in depths greater than 40 m; Fig. 6d shows kelp feature polygons (pink) at a depth greater than 40 m.

To further evaluate the role that scale plays in the representation of kelp features (Fig. 3), we compared the chart scale and the reliability index. Four scale categories were used for the comparison: large, medium, small, and very small scale (see Table 2 for category definitions). We found that large scale charts only produced kelp features with very high reliability (100%), as expected. The reliability tended to decrease with the increasing coarseness of the charts, as very small scale charts contained a greater proportion of features with lower reliability index scores, 15% and 6% of the kelp features at high and medium reliability.

The BA charts showed that spatially, the most concentrated kelp features are around Vancouver Island, near the western and northern coast of the Island, Johnstone Strait, as well as in the northernmost BC waters and northwestern Haida Gwaii. Kelp features are sparse around Alaska, Washington, the area south of Banks Island, and the southern area of Vancouver Island along the Juan de Fuca Strait. This is generally similar to kelp presence reported for some limited areas of BC by Cameron (1916), based on field observations, and Sutherland et al. (2008) and Field and Clark (1978), where a compilation of spatial kelp presence derived from aerial photos from 1976 to 2007 for some regions of the BC coast was presented. Other regional programs such as PNCIMA and BCMCA also presented similar kelp distribution based on collated information from a variety of sources (BCMCA, 2011). Fig. 5b and c illustrate the agreement in kelp presence around northern Haida Gwaii as shown in the BA and the BCMCA maps, respectively.

While the spatial distribution of the derived kelp features aligns well with more recent available maps (Sutherland et al., 2008; BCMCA, 2011), areas with no kelp features do not necessarily indicate non-occurrence of kelp. There could be several explanations for non-occurrence of kelp features, such as: (1) the areas may not have been surveyed using the most accurate techniques because of their relatively lower importance for navigation; (2) during the cartographic interpretations of the original surveys, kelp features were more generalized or may not have been translated to small-scale charts depending on the purpose of the chart and whether that information was deemed relevant (Field & Wharton, 1920), that is, the surveyors' efforts and transcription of the surveys to charts were likely not consistent across the entire coast of BC; or (3) kelp did not actually occur in those areas. Another explanation is the generalization of the kelp features in small to very small scale charts, which is illustrated in Fig. 7. In the represented region, North of Vancouver Island, very small scale charts (<1:350,000) were used to extract kelp features on the west side of the Island while small-medium scale charts (<1:50,000) were used at the east side of the Island. Note that the BA map shows reduced kelp presence on the west side of the Island compared with the BCMCA maps (BCMCA, 2011).

Several potential sources of uncertainty should be considered when working with the historic BA charts, for instance, uncertainties regarding the surveyor's method for defining floating kelp features. This may not be an issue since a commonly applied method for the BA charts was the observation of features from the surface (McClenachan et al.,

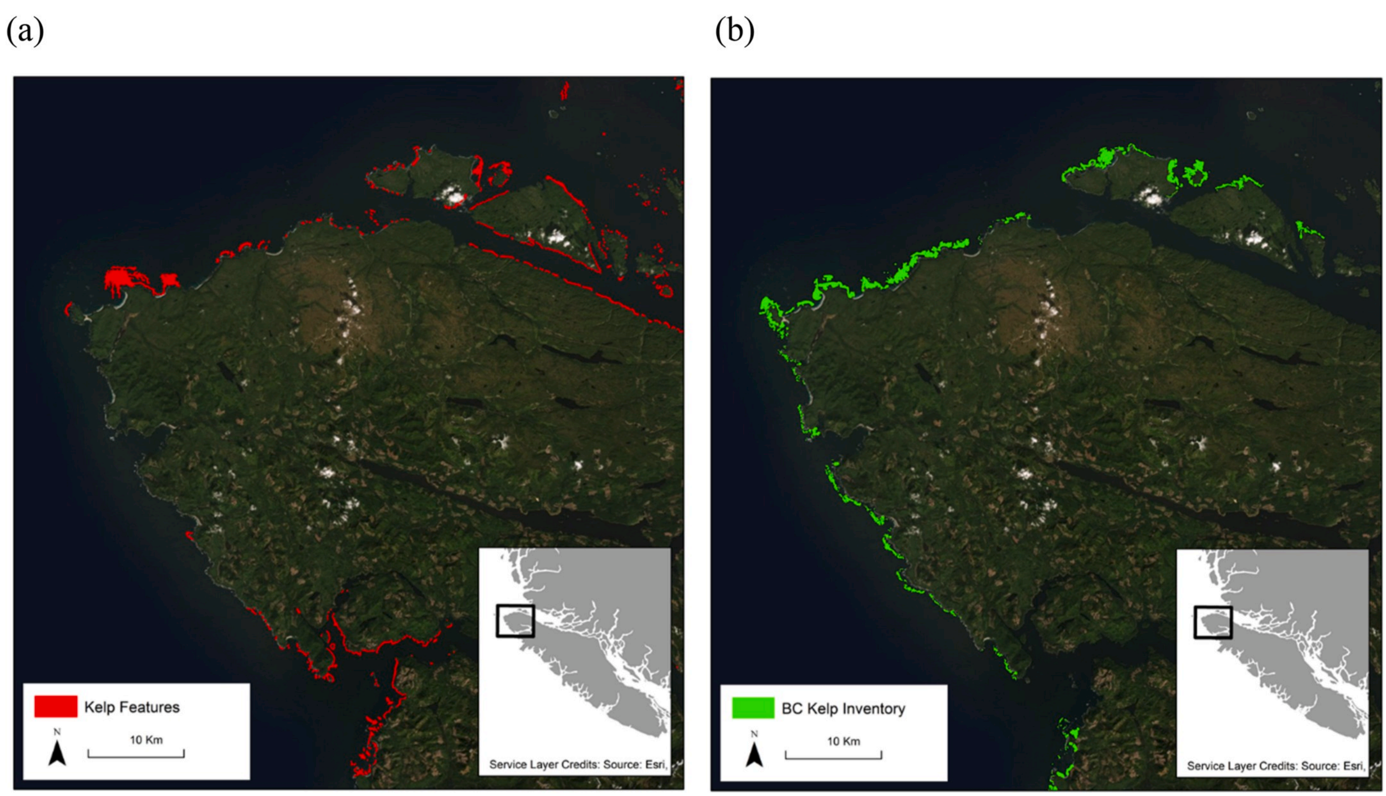

Fig. 7. Example showing the north of Vancouver Island illustrating the possible role of scale on generalization of kelp feature. (a) BA map and (b) BCMCA maps (BCMCA, 2011).

2017), which is appropriate for observation of the floating kelp canopies. Further, the kelp cover varies seasonally and annually, so the time of year that the survey was taken would affect the presence of kelp observed. It is likely that the surveys were taken during peak canopy cover since it was considered a danger to navigation (Bowditch, 1802; Naval Training Commend, 1972), and vast knowledge of kelp life cycles existed locally (Cameron, 1916). Indeed, the spatial location of kelp shown in Cameron (1916) for selected areas around the northeast and central-east of Vancouver Island are similar to the areas in the BA charts. Another source of uncertainty to consider is the artistic ability of the cartographer when transcribing the information from the surveys to the BA charts. Uncertainties exist about the degree of generalization or elaboration in this process, although the quality and content of the work transcribed to the charts improved under experienced guidance and systematic methodology, including triangulation (Day, 1967), which translated to more accurate surveys throughout the century. Preliminary or sketch surveys became less frequent as the world's coastlines became increasingly surveyed, and trade increased (Field & Wharton, 1920).

4. Summary and conclusion

Here we present a map of kelp presence corresponding to the period between 1858 and 1956 for an area that includes the BC coast and extends to portions of the Washington and Alaska coasts. Kelp features were digitized from 137 BA charts to define a historical baseline of kelp distribution on the BC coast. Charts were scanned and georeferenced, kelp features were digitized in a continuous, non-overlapping manner prioritizing large-scale charts, and a reliability index for each kelp feature was defined based on the alignment of the features with bathymetry. We defined a 40 m depth threshold for the reliability analysis to account for residual geolocation issues, kelp preferential depth range and length, canopy movement with tide and currents, and possible inconsistencies in the notation of kelp features with different styles. The result was a high degree of reliability for the locations where the kelp features were delineated, with 99% of the features occurring at least partially in areas in which the depth is shallower than 40 m. Further, a comparison with recent kelp inventories for this region showed similar spatial distributions of canopy kelp. Several sources of uncertainties were noted, which result from working with historical charts as well as kelp, which is a dynamic species in a complex environment.

The results of this work generated a historical baseline previously unavailable, providing a deeper temporal timestamp of kelp forests on Canada's Pacific coast. This dataset will allow a better understanding of the dynamics, spatial resilience, and changes over time of this ecologically important habitat, which has been identified as a conservation priority for the ongoing marine protected area network planning process in BC (Gale et al., 2019). This data will be openly and freely available to the public through the Canadian Hydrographic Service (https://open.canada.ca/en/open-data/nature and environment/historical distribution of kelp forests on the coast of British Columbia: 1858–1956).

CRediT authorship contribution statement

Maycira Costa: Writing - original draft, Writing - review & editing, Methodology, Conceptualization, Formal analysis. **Nicole Le Baron:** Writing - original draft, Methodology, Data curation, Formal analysis. **Kim Tenhunen:** Methodology, Data curation. **Jessica Nephin:** Methodology, Formal analysis, Writing - review & editing. **Peter Willis:** Writing - review & editing, Conceptualization. **James P. Mortimor:** Writing - review & editing. **Sarah Dudas:** Writing - review & editing, Methodology. **Emily Rubidge:** Writing - review & editing, Methodology.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apgeog.2020.102230.

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