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A post-glacial sea level hinge on the central Pacific coast of Canada

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A B S T R A C T

Post-glacial sea level dynamics during the last 15,000 calendar years are highly variable along the Pacific coast of Canada. During the Last Glacial Maximum, the Earth's crust was depressed by ice loading along the mainland inner coast and relative sea levels were as much as 200 m higher than today. In contrast, some outer coastal areas experienced a glacial forebulge (uplift) effect that caused relative sea levels to drop to as much as 150 m below present levels. Between these inner and outer coasts, we hypothesize that there would have been an area where sea level remained relatively stable, despite regional and global trends in sea level change. To address this hypothesis, we use pond basin coring, diatom analysis, archaeological site testing, sedimentary exposure sampling, and radiocarbon dating to construct sea level histories for the Hakai Passage region. Our data include 106 newly reported radiocarbon ages from key coastal sites that together support the thesis that this area has experienced a relatively stable sea level over the last 15,000 calendar years. These findings are significant in that they indicate a relatively stable coastal environment amenable to long-term human occupation and settlement of the area. Our results will help inform future archaeological investigations in the region.

1. Introduction

During the peak of the Last Glacial Maximum of the Pleistocene, global eustatic sea level was as low as 120 m below present (Fairbanks, 1989; Peltier and Fairbanks, 2006) and many coastal regions that were located away from ice sheets saw an appreciable drop in relative sea level. With post glacial eustatic sea level rise, past shorelines are now deeply submerged along most of the earth's coasts. In contrast, parts of the Pacific coast of Canada that were covered by several hundreds of metres of ice during the last glaciation have relict shorelines that are submerged, while others are stranded above current sea level as a result of the complex interplay between regional glacial isostatic depression, global eustatic responses, and tectonic plate displacements (e.g., Clague et al., 1982; Clague and James, 2002). Over the late Quaternary, relative sea level dynamics in the region have been highly variable and dependent, in large part, on proximity to ice loading during the Last Glacial Maximum (Clague et al., 1982; Clague, 1983). Shugar et al. (2014) provide a regional synthesis of relative sea level changes on the Pacific coast of North America and identify the central Pacific coast of Canada as a region requiring further research. During the late Pleistocene, ice proximal parts of the coast were subject to appreciable isostatic depression, resulting in relative sea level positions up to 200 m higher than today (Clague et al., 1982; James et al., 2009). Much of the outer coast was located further away from ice loading and was uplifted by a forebulge that formed through differential vertical displacement of the crust from inland to the edge of the continental shelf (Clague, 1983). As a result, relative sea level in outer coastal areas was up to 150 m lower than today (Luternauer et al., 1989; Josenhans et al., 1997; Barrie and Conway, 2002a). Sea level curves from various locations on the Canadian Pacific coast show regional variations to this trend and illustrate that tectonics can also be a significant factor in

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sea level change in particular after 10,000 Cal BP (Fig. 1 and also Shugar et al., 2014).

Our research developed in the context of these rapid and regional sea level histories. This research was guided by the following question: is there a region between the inner and outer coasts where sea levels have remained relatively stable since late Pleistocene times? This hypothesized phenomenon is referred to as a "sea level hinge" (cf. McLaren, 2008). The concept of the sea level hinge is different from an "isostatic hinge" or "zone of flexure" in the earth's crust. The sea level hinge is dependent on both isostatic and eustatic factors and can be thought of as a place where the shoreline is stable. The sea level hinge lies between two areas with very different relative sea level histories, to the east with higher than today relict shorelines, and to the west with lower than today relict shorelines. In this paper, we identify the Hakai Passage area of the central coast of British Columbia as a sea level hinge.

1.1. Study area

The Hakai Passage region, located on the central Pacific coast of Canada, provides an opportunity to search for evidence to test our hypothesis (Fig. 2). Located 30 km to the west of Hakai Passage is Goose Bank – a now-drowned coastal platform approximately 45 km wide and extending 20–90 km offshore of the outer islands of the central coast. During the late Pleistocene when relative sea level was about 135 m lower than today, Goose Bank was a low, flat island (Luternauer, 1989; Barrie and Conway, 2002a). Contrasting with this, 110 km to the east of Hakai Passage, in the Bella Coola valley, relative sea level was between 150 and 200 m higher than today following deglaciation (Andrews and Retherford, 1978).

Previous sea level histories developed for the Hakai Passage region (e.g., Retherford, 1972; Andrews and Retherford, 1978; Cannon, 2000) are contradictory and do not corroborate well with recently obtained archaeological data. These inconsistencies are likely a consequence of data limitations and collation of data from a large geographic area. For instance, data points used in

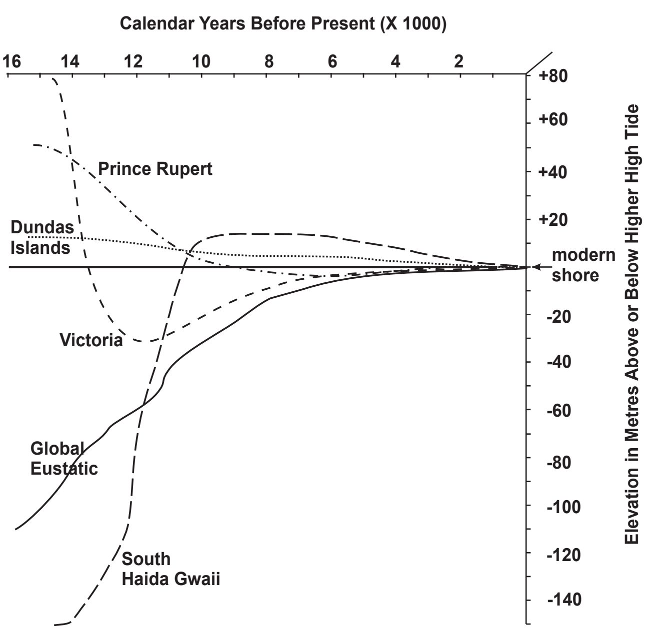

Fig. 1. Regional sea level curves constructed for the Pacific Coast of Canada. Victoria: Fedje et al. (2009) and James et al. (2009); Dundas: McLaren et al. (2011); Prince Rupert (including data from Port Simpson) and south Haida Gwaii: Fedje et al. (2005); global eustatic: Peltier and Fairbanks (2006). This figure illustrates the diversity of relative sea level curves on the Northwest Coast.

Andrews and Retherford (1978) extend along the outer coast islands as well as the mainland shore in areas both distal and proximal to major Wisconsin glacial ice loading.

Stable, relict shorelines are of interest for both geomorphic research that reconstructs relative sea level histories as well as for archaeological research as they favour and often preserve long-term accumulation of sedimentary and archaeological materials in a relatively constrained region (as opposed to being spread across the landscape during gradual sea level regression or transgression). The use of relative sea level histories and geomorphic interpretation of relict shorelines has been key to locating archaeological sites of different ages along the Northwest Coast of North America (e.g., Fedje and Christensen, 1999; Mackie et al., 2011; McLaren et al., 2011). The hypothesized central coast sea level hinge is a location where late Pleistocene and early Holocene shorelines would be close to modern sea level. This presents a significant opportunity for locating long-term archaeological sites and evidence of early post-glacial human occupation. Fedje et al. (2004) proposed that the east side of Hecate Strait to the north, between Haida Gwaii and the mainland, would be a suitable place for this type of investigation. McLaren (2008) investigated the sea level history of the Dundas Island Archipelago, northeast of Haida Gwaii, and found that relative sea level dropped only 14 m over the last 15,000 years[1] and characterized this phenomenon as being the result of the presence of a sea level hinge.

1.2. Regional setting

The central Pacific coast of Canada remains a remote region only accessible by boat or aircraft. The research presented here was undertaken in the territories of the Heiltsuk, Wuikinuxv, and Nuxalk First Nations. Field research was based out of the Hakai Beach Institute on Calvert Island, just south of Hakai Passage. The physiography of the Hakai Passage area is characterized by the Coast Mountains to the east (which reach elevations of up to 4000 m above sea level), and isolated rocky islands and skerries to the west. Marine channels intersect the landscape increasingly with distance from the mainland. Inner shores consist of steep-sided fjords, whereas the outer shores are exposed, consisting generally of flat islands with irregular, steep bedrock intertidal zones or smaller embayed sedimentary beaches. A few sandy, dune- or bluff-backed beaches exist on the northern and western shores of the larger Calvert Island, which also hosts mountain plateaus, saddles, and peaks reaching 1000 m above sea level. Glaciers are found today only on the mainland, in the far eastern part of the region (Fig. 2). Average yearly rainfall is high, between 240 and 330 cm per year. The area is located in the Coastal Western Hemlock biogeoclimatic zone (Meidinger and Pojar, 1991) and with the exception of higher alpine areas, most of the region is heavily forested by conifers which can grow to be massive and over 1000 years old (Fig. 3). Areas of low relief found on the outer coast often host sphagnum vegetation and have developed into bogs and bog forests (Fig. 4).

The timing of the Last Glacial Maximum is not well known in the study area. Paleontological and vegetation evidence from southeast Alaska and Haida Gwaii, to the northwest of the study area, indicate that the Last Glacial Maximum occurred between 20,500 and 19,000 calendar years ago (Warner et al., 1982; Heaton and Grady, 2003). Parts of the west coast of Vancouver Island to the south were ice free at this time and the Last Glacial Maximum occurred later, between 19,000 and 17,700 calendar years ago (Ward et al., 2003).

[1] All dates are in calendar years before present (1 sigma with a datum of AD 1950) unless otherwise noted.

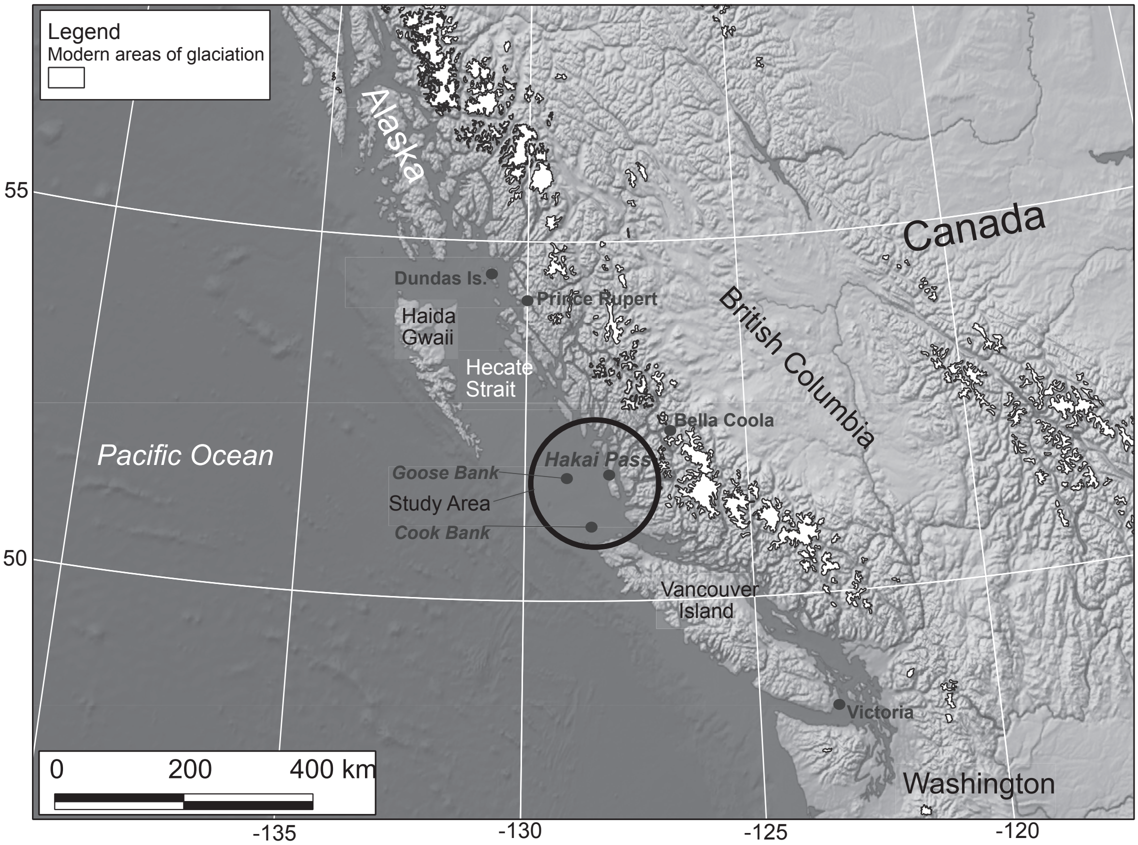

Fig. 2. Location of the study area on the Northwest Coast of North America.

At this time, during a period known locally as the Vashon Stade of the Fraser Glaciation (Clague and James, 2002), the Cordilleran ice sheet covered most of the Coast Mountains on the mainland, although some outer coastal islands may have been ice free (e.g., Heusser, 1989; Clague et al., 2004). For example, the now submerged terrain of Goose Bank may not have been over-ridden by ice due to its distance from the main ice mass during the Fraser Glaciation. However, close to the continental shelf, ice streams

Fig. 3. Forested and mountainous landscape on the east side of Fitz Hugh Sound (Hakai East) looking towards the mouth of the Koeye River from above Fitz Hugh Sound. Photo by Duncan McLaren.

Fig. 4. View of flat topography and exposed beaches on the exposed west side of Calvert Island. Other parts of the outer coast are characterized by low lying skerries and small rocky shored islands. Large and exposed sand beaches are fairly rare, but are found on Calvert Island. Photo by Duncan McLaren.

were likely present both to the north and south of the bank. Troughs from these features are evident in the shaded bathymetry presented in Fig. 5 (also see Luternauer and Murray, 1983; Mathews, 1991; Barrie and Conway, 2002b). By 11,400 calendar years ago, the extent of glacial ice cover in the Coast Mountain was similar to that of today (Clague, 1981, 2000). Tidewater glaciers are still present to the north in southeast Alaska.

2. Data and methods

This study collates relative sea level elevations derived from relict shorelines and/or shoreline proximal features (e.g., middens, etc.) from previously published and recent geological and archaeological sources. This dataset includes 106 samples collected from sediment basin coring, archaeological investigations, and geomorphic research within the study region by the authors. Following the methods of Shennan et al. (2006) only samples of known location, age and altitude were included. Each sample also needed to have some indicative meaning as to its position relative to the intertidal zone (Table 1). For consistency, all sample elevations have been adjusted relative to higher high tide (hht = higher high water, large tide) datum which is 5.161 m above Chart Datum (or low low water, large tide) at Adams Harbour (CHS station #8865) on Calvert Island (see Bartier and Sloan, 2007 for an in-depth discussion of sea level datums on the Pacific coast of Canada). In some instances, corrections were made for data points measured to mean water level by subtracting 2.5 m from each elevation measurement. Other data points have been adjusted from measurements to the barnacle line by adding 1 m (Plafker, 1969). In some instances, LiDAR data was drawn upon to refine elevation measurements. All elevation measurements are given as metres above higher high tide (ahht) or below higher high tide (bhht).

Sediment basin coring was undertaken using Reasoner (1986) and Livingstone (1955) type coring devices. Pond samples were taken from elevations between 94.5 and 0.5 m ahht. Three lagoons, with rock sills between 1.5 and 2 m bhht, were also sampled. Sampling was conducted from a floating coring platform with a guide tube to stabilize and align the coring device. Sub-bottom sediments were then sampled by driving the coring device into the substrate and retrieving the core using a portable winch. Elevations for each sample were measured relative to the observed rock sill of the pond or lagoon using hand held altimeters and survey traverses employing a laser range finder and reflector. Following Cannon (2000), elevation estimates were made to the barnacle line (1 m bhht). Estimates of elevation measurement error for each sample are provided in Table 2. Cores were transported back to the Archaeology Lab at the University of Victoria and stored in a refrigerator.

Cores were logged and sampled with specific attention to identifiable stratigraphic transitions. Slides for diatom analysis were prepared and examined. For clay-rich samples, the sediment was first wet sieved through 10-micron mesh to remove the clay fraction. Using a modified version of Renberg's (1990) protocol, samples were treated with HCl and H_2O_2 to remove carbonates and organic matter, then rinsed with distilled water, and plated onto microscope slides using Naphrax™.

Slides were assessed for the presence of diagnostic diatoms for determination of relative salinity of the environment represented by transitional stratigraphic units. Slides were analyzed using Leica DM2500 (Université du Québec à Chicoutimi) and Nikon Optiphot-2 (University of Victoria) transmitting light microscopes with 40× and 100× objectives. For each slide, a minimum of 5 transects were undertaken at 400× magnification. Detailed analysis of some diatoms employed 1000× (oil).

Observed diatom flora were compared to those identified in Campeau et al. (1999), Pienitz et al. (2003), and Witkowski (2000) for identification. The salinity tolerance of identified flora was then used to assess whether the samples were derived from freshwater, brackish, or marine environments.

Archaeological deposits were sampled using a variety of methods including coring using an Environmentalist's Sub-Soil Probe (ESP), auger testing, sampling of cultural deposits in natural exposures, shovel testing, and controlled excavation. Radiocarbon samples were taken from the base of cultural bearing

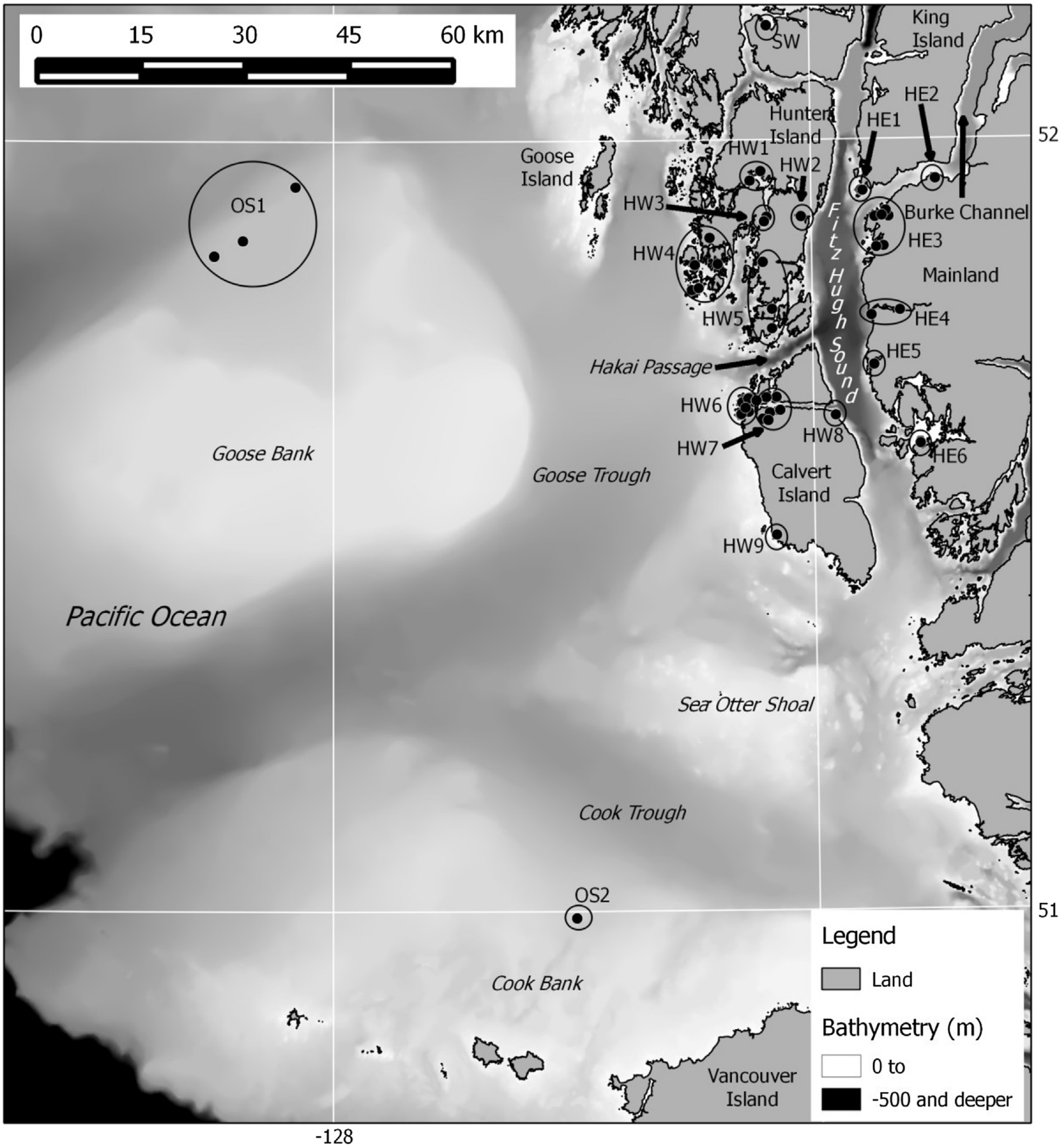

Fig. 5. Locations of data points referred to in this publication organized by sub-regions and crossed-referenced with information provided in Table 2: OS = offshore, HW = Hakai west, HE = Hakai east, SW = outlier. Major offshore troughs and banks are situated offshore and highlight by shaded bathymetry.

deposits and/or organic soil horizons found in the stratigraphic sections encountered. In some cases, overlying stratigraphic units were selected for dating as well to investigate lengths of site occupation. Methods for measuring data point elevations were the same as those described above for pond coring.

Radiocarbon age samples from pond cores and archaeological sites were sent to the W.M. Keck AMS Laboratory in Irvine, California (UCIAMS). Plant macrofossils were preferentially selected for dating to avoid problems such as dating old wood or marine reservoirs, if available. Charcoal and shell fragments were also selected. All radiocarbon ages are reported here in calendar years before present (Cal BP). Calibrations were undertaken using Calib 6.1.1 and are reported on here as 1 sigma ranges. For consistency, all dates reported by other researchers drew from their uncalibrated conventional ages prior to calibration to calendric years. Radiocarbon ages obtained from terrestrial organic material was calibrated using the Intcal09 dataset, while marine samples were assigned a 331 ± 80 Delta R correction and calibrated using the Marine09 dataset (McNeely et al., 2006).

3. Results

A total of 138 dating samples were gathered to construct relative sea level curves for the Hakai Pass region (Fig. 5, listed in Table 1). Of these, 32 were drawn from the existing literature and the remaining 106 new samples were collected as a part of the research we present here. These new data points were sampled in two subregions: Hakai West and Hakai East in order to limit conflation of data from too large an area. All of the radiocarbon age data shown in Fig. 5 and listed in Table 1 are coded by the subregion from which they are sampled: Offshore – OS1 and 2, Hakai West – HW1 through 9, Hakai East – HE1 through 6, and Shearwater – SW.

Table 1
Table showing indicative meaning of samples collected.

Sea level position	Indicator type	Indicative meaning	Limitation
Above	Archaeology site, habitation site and/or shell midden, charcoal rich, with lithics and other artifacts	Most habitation sites in the region are situated adjacent to the shoreline but above the high tide line	Limited to indicating that intertidal zone was below the elevation of the sample. Intertidal site types such as fish traps and clam gardens are not included
Above	Freshwater diatoms sediments.	The sample or sill of the depositional basin was above high tide when deposited	Limited to indicating that the intertidal zone was below the elevation of the sample
Above	Peat deposit	The peat developed above high tide	Limited to indicating that the intertidal zone was below the elevation of the sample
Above	Organic soil	The soil developed above high tide	Limited to indicating that the intertidal zone was below the elevation of the sample
Marginal	Brackish diatoms from sediments	The sample or sill of the depositional basin was between low and high tide when deposited	Indicating that the sample was deposited in the intertidal zone
Marginal	In situ intertidal faunal remains, e.g. shellfish	The sample was in the between low and high tide when deposited	Indicating that the sample was deposited in the intertidal zone
Below	Marine diatoms from sediments	The sample or sill of the depositional basin was below low tide when deposited	Limited to indicating that the intertidal zone was above this sample
Below	In situ sub-tidal faunal remains	The sample or sill of the depositional basin was below low tide when deposited	Limited to indicating that the intertidal zone was above this sample

3.1. *Pond and lagoon sites*

Six ponds and three lagoons were cored and analyzed (Fig. 6, Table 2). Pond sites include five from the Hakai West region on Calvert Island (HW6, 7) and one in Fish Egg Inlet (HE6), east of Fitz Hugh Sound (Fig. 7). The lagoon sites were located all in the Hakai West region on Calvert Island (HW8), Sterling Island (HW5), and Hunter Island (HW1).

3.1.1. *Pond and lagoon cores from Hakai West*

Three lakes were cored at altitudes of 9 m ahht or more in Hakai West (HW6, 7): Pond B at 94.5 m ahht, Pond D at 22.5 m ahht, and SBD Lake at 9.5 m ahht. All lack marine or brackish diatom indicators (Table 3) that, combined with basal radiocarbon ages, demonstrate that sea level has remained below 9 m ahht since 14,587–14,173 Cal BP (UCIAMS 118020).

In contrast to these higher elevation lakes, diatom flora in the basal sediments of Big Spring Lake (HW7) include marine and brackish species (Table 3) revealing that sea water last washed into this basin (6 m ahht) 14,463–14,001 year ago (UCIAMS 134867). Sediments deposited after this are derived from freshwater contexts.

Pond C (HW7) on northwestern Calvert Island is situated lower at 0.4 m ahht and is impounded by a coastal dune or berm. The record from this lake is much different from those at higher elevations (Fig. 6). Only mid to late Holocene deposits were recovered during coring. Brackish and marine diatoms and foraminifera (Table 3) suggest that this was an active nearshore beach environment between 5885 and 4895 Cal BP (UCIAMS 118049). No diatoms were found in the coarse sand that overlies these beach deposits. However, there is an abrupt transition from this coarse sand to gyttja between 720 and 676 Cal BP (UCIAMS 118016), presumably when the lake became impounded.

The three lagoons cored in Hakai West are Kildidt Lagoonlet (a small bounded lagoon within the larger Kildidt Lagoon) on Hunter Island (sill is 1.5 m bhht – HW1), Stirling Lagoon on north Stirling Island (sill is 1.75 m bhht – HW5), and Kwakfitz Lagoon on Calvert Island (sill is 1.75 m bhht – HW8). Sediment cores sampled from all three lagoons demonstrate a similar stratigraphy. At Kwakfitz Lagoon, brackish and marine diatoms are present in the earliest part of the core recovered which dates between 14,681 and 14,212 Cal BP (UCIAMS 128298), revealing that high tide was near modern at that time. A similar very early marine signature is found in the basal sediments of the Stirling Lagoon and Kildidt Lagoonlet cores but no material suitable for dating was recovered (Fig. 6; Table 3). All three Hakai West lagoon cores have significant zones with freshwater diatoms, that reveal relative sea level was lower than modern between 14,200 and 10,700 Cal BP. A brackish diatom assemblage replaces freshwater indicators between 10,693 and 10,591 Cal BP (UCIAMS 128295) at Kwakfitz lagoon. Sediments at the top of all lagoon cores have the appearance of intertidal sands with brackish or marine diatom flora, indicating the sills were near or below modern higher high tide after 10,700 Cal BP.

3.1.2. *Pond cores from Hakai East*

The results from Hakai West can be contrasted with the single pond cored in Hakai East (Gildersleeve Pond – HW6), which is situated at 13 m ahht (Fig. 7). The lowest sediments sampled have associated marine diatoms and *Mytilus edulis* (blue mussel) shell fragments which reveal a higher sea level stand that extends back in time to between 14,577–14,181 (UCIAMS 128291) and 14,345–14,243 Cal BP (UCIAMS 128330). A periwinkle shell found right at the transition from marine to overlying freshwater sediments dates to 14,601–14,071 Cal BP (UCIAMS 134627). Gyttja dominates the upper part of the core. The base of the freshwater gyttja unit dates to 13,717–13,511 Cal BP (UCIAMS 134826) indicating that relative sea level had dropped below 13 m before this time and has remained beneath this elevation since that time.

3.2. *Archaeological sites*

Eighty-four radiocarbon ages (69 from this project and 15 from other researchers) with measured elevations were acquired from 24 archaeological sites (Table 2). Of these, 39 are from ESP cores, one is from an auger test, seven are from cut bank exposures, and 37 are from excavations. Most ESP samples were intended to date either the beginning of human occupation and/or the start of organic soil accumulation. Data points from excavated archaeological strata include basal occupation ages and other cultural bearing strata. All samples dated from archaeological sites are assumed to be above high tide at the time of occupation and/or organic soil development.

3.2.1. *Archaeological samples from Hakai West*

There are 61 archaeological data points from 14 sites in Hakai West (Fig. 5 – HW1, 2, 3, 4, 5, 6, and 7). Of these, six basal ages are reported by Cannon (2000) and two by Andrews and Retherford (1978). The remaining 53 are new samples obtained by the present authors. Age ranges of the samples help to constrain the sea level curve over the last 13,500 years. Three of the more intensively investigated and dated archaeological sites have records spanning the past 10,000 years.

Cultural deposits at the Triquet Island Site (EkTb9 – HW4) include an early component with lithics, faunal remains, and charcoal (Fig. 8A, Table 1). The lowest cultural level dates to between 11,396 and 11,285 years Cal BP (UCIAMS 118001) and is 1.7 m ahht. Overlying the basal component is a sharp contact with a peat layer containing cultural material, including preserved wooden artifacts dating between 7300 and 4400 years Cal BP. Later Holocene cultural deposits include a thick shell midden up to 5 m deep, which started forming 6250 Cal BP. Upper strata have not been dated but the depth of this deposit suggests that it was used well into the late Holocene. In addition to these data from archaeological site EkTb9, intertidal testing on the west side of Triquet Island (WTB) intersected a terrestrial soil with plant macrofossils, charcoal, and sclerotia (2.2 m bhht) dating between 10,666–10,499 Cal BP (UCIAMS 102763 and 102764) Fig. 9.

The basal palaeosol at the Kildidit Narrows Site (ElTa18 – HW3) contained abundant charcoal and sclerotia dating as old as 13,673 – 13,454 years Cal BP (UCIAMS 118046)(4.2 m ahht), but no unequivocal artifacts were recovered (Fig. 8B, Table 1). By 10,757–10,701 Cal BP (UCIAMS 117997), cultural remains are well represented and include stone tools, charcoal, and faunal material. Later Holocene archaeological strata are also present (Table 1 – HW3). An intertidal test found organic and peaty soil with preserved wood 0.5 m bhht and dating 10,645–10,519 Cal BP (UCIAMS) suggesting that relative sea level was lower at this time.

The earliest intact cultural deposits and features at the Pruth Bay Site (EjTa15 – HW7) date between 10,653 and 10,562 years Cal BP (UCIAMS 128290) and are 0 m ahht suggesting that sea level was close to modern during this period. From these archeological deposits, a hearth feature, associated with stone tools and a post hole, dates to between 10,151 and 9924 years Cal BP (UCIAMS 128265). Underlying sand deposits contain water-rolled flakes suggesting the possibility of older cultural deposits. Sediments bearing archaeological materials overlie these lower components indicating repeated usage of this site in later time periods as well (Fig. 8C, Table 1).

3.2.2. Archaeological samples from Hakai East

From the Hakai East region, we consider a total of 23 dating samples from nine archaeological sites, including a basal date from excavations at Namu (Carlson, 1996; Cannon, 2000; Rahemtulla, 2006) and six basal occupation ages from ESP tests at archaeological sites reported on by Cannon (2000). Our study provides an additional 16 ages from ESP testing at four other archaeological sites.

At the Namu site (ElSx1 – HE3), the earliest deposits bearing cultural materials date between 11,252 and 10,789 years Cal BP (WAT 452) and are situated 6.4 m ahht. Only the basal age at Namu is considered here as a constraining factor of sea level. Other ages from the site demonstrate that occupation was continuous at the site since the early Holocene (Carlson, 1996; Rahemtulla, 2006) with dated cultural material and evidence of occupation from each subsequent millennia.

Basal archaeological occupations recorded through ESP testing by Cannon (2000) span from 6672 to 1090 years Cal BP. Like the early deposits at Namu, the two earliest sites tested are situated at higher elevations: ElSx10 (HE3) (6177-5944 Cal BP – Beta 105480) at 3.4 m ahht and ElSx5 (HE1) (6791-6549 Cal BP – Beta 1096241) at 2.1 m ahht. Later Holocene basal occupations recorded by Cannon that post-date 3000 Cal BP are below 1.25 m ahht (HE1, 3 and 4).

ESP cores sampled by our research team targeted archaeological site locations above 3.5 m ahht as Cannon (2000) had revealed that early Holocene site deposits tended to be at or above this elevation. Both early and late Holocene deposits were found, with the earliest deposits on a raised terrace (14.2 m ahht) at ElSx4 (HE1) dating between 8285 and 8165 Cal BP (UCIAMS 102756). All four archaeological sites tested were occupied in the last 2000 years. EkSw3 was the highest elevation site tested at approximately 18 m ahht with basal cultural deposits dating between 500 and 474 Cal BP (UCIAMS 102743). EkSx11 (HE5), in Kwakume Inlet was found to have basal deposits (2.9 m ahht) dating between 1988 and 1932 Cal BP (UCIAMS 102745). ElSx11 (HE3), on Strawberry Island in Namu Lake (9.3 m ahht) was found to date between 1345 and 1183 Cal BP (UCIAMS 102746). This pattern of higher elevation occupation sites in the late Holocene does not constrain the sea level. Rather, the elevations of the sites may relate to their use as defensive sites; a late Holocene pattern that is consistent elsewhere on the Northwest Coast (Ames and Maschner, 1999). Other contemporaneous late Holocene ages associated with archaeological sites suggest that sea level was lower than present by 1 m between 1000 and 500 Cal BP, including deposits sampled at ElSx4 and EkSx11 and others reported on by Andrews and Retherford (1978).

3.3. Ages from sedimentary exposures

A total of 15 data point points are included from nearshore sedimentary exposures that do not include archaeological deposits. These include seven data points published by Andrews and Retherford (1978), five of which are proxy indicators for terrestrial deposits. Two of their samples indicated relict marine deposits above present day sea level at Hvidsten Point and Shearwater. Hvidsten Point is situated in Burke Channel (Fig. 5 – HE2) and the sample is described as marine deposited sediments at approximately 6 m ahht dating between 12,364 and 11,412 year Cal BP (Gak 3715). However, they observed no shell, diatoms, or other marine indicators to corroborate this interpretation. We sampled clay from 5 to 6.5 m ahht from this same locale. The observed diatom flora is indicative of a freshwater environment. It is possible that at least a part of Burke Channel was blocked by sediment or ice in this area resulting in a freshwater deposition environment in the late Pleistocene. A sample of charcoal associated with the freshwater deposits was dated to 12,628–12,569 Cal BP (UCIAMS 131386).

In contrast, clay sediments examined at the Shearwater site (Fig. 5 – SW) at approximately 12 m ahht produced shells that date between 13,735 and 12,978 Cal BP (GSC 1351).

New age data from sedimentary exposures on Calvert Island presented here include a total of ten samples (HW6 and 9). One data point comes from the base of a sedimentary sequence that Andrews and Retherford (1978) record as a glacial advance at Foggy Cove on northwest side of Calvert Island. However, Andrews and Retherford did not date this feature. Our crew revisited this exposure selected a sample from an organic palaeosol at the base of this sequence that was assessed with an age of 15,025 to 14,641 years Cal BP (UCIAMS 128336). Another data point is from a log found embedded in a glaciomarine clay 2.2 m bhht. This log may be driftwood and dates between 14,729 and 14,231 Cal BP (UCIAMS 115817). The other eight new data points provide terrestrial indicators such as peat or dunes ranging from 16.25 m ahht to 1.75 bhht and dating between 10,750 and 1570 Cal BP.

3.4. Ages from ocean cores

The dataset presented here includes offshore samples reported in Luternauer et al. (1989), Barrie and Conway (2002a), and Hetherington et al. (2004). From Cook Bank (Fig. 5 – OS2), 75 km

Table 2
List of all data points with information pertinent to the construction of sea level curves for the Hakai region. The 'Map ID' column cross-references with point groups on Fig. 5 and classifies points based on the sea level curve that they have been applied toward: OS = offshore, HW = Hakai west, HE = Hakai east, SW = outlier. Sample are from the following regions: OS1 = Goose Bank, OS2 = Cook Bank, MS = McMullen Ground, SW = Shearwater, HW1 = Kildidt Lagoon, HW2 = eastern Hunter Island, HW3 = Kildidt Narrows, HW4 = Nulu west, HW5 = Nulu east, HW6 = Calvert beaches, HW7 = Kwakshua Channel, HW 8 = Kwak-Fitz Lagoon, HW 9 = SW Calvert, HE1 = southwestern King Island, HE2 = Hvidsten Point, HE3 = Namu area, HE4 = lower Koeye River, HE5 = Kwakume Inlet, HE6 = Gildersleeve Pond. Calendar range is 1 sigma. The 'Sea Level Position' indicates A (above), M (marginal), B (below).

Map ID	Lab	Lab#	Site and test	14C age BP	±	Calendar range (older)	Calendar range (recent)	Lat	Long	Material for dating (submitted)	Proxy indicator	Elevation – m ahht	±	Source/Lab	Method	Sea level position
HW7	UCIAMS	118006	EjTa15-T2 A2	90	15	251	35	51.66039	−128.1191	Sclerotia (*Cenococcum* sp.)	Top of archaeological deposit	1.1	0.5	McLaren	Excavation	A
HE1	UCIAMS	128276	ElSx4A	345	20	378	320	51.93216	−127.8921	Charcoal	From top of archaeological deposit – shell midden	12.5	2	McLaren	Excavation	A
HW7	UCIAMS	118005	EjTa15-T2 A1	270	20	419	291	51.66039	−128.1191	Charcoal	Archaeological deposit	1.1	1	McLaren	Excavation	A
HE4	UCIAMS	102743	EkSw3 A	395	15	500	474	51.77671	−127.8175	Disperse charcoal	Archaeological deposit – basal organic silt in association with fire cracked rock	18	2	McLaren	ESP	A
HE4	UCIAMS	102744	EkSw3 B	405	15	502	482	51.77672	−127.8175	Disperse charcoal	Archaeological deposit – basal shell midden	18.5	2	McLaren	ESP	A
HW3	UCIAMS	102761	ElTa18C	1355	15	655	535	51.89267	−128.1	*Strongylocentrotus* sp. spine fragments	Archaeological deposit – basal shell midden	5.3	1	McLaren	ESP	A
HE1	UCIAMS	102758	ElSx4 IT	660	20	663	567	51.93228	−127.8929	*Tsuga heterophylla* needle	Intertidal test with underlying archaeological deposits	−2.7	0.5	McLaren	ESP	A
HW7	UCIAMS	118007	EjTa15-T2 B	710	15	674	664	51.66039	−128.1191	Charcoal	Archaeological deposit	0.6	0.5	McLaren	Excavation	A
HW7	UCIAMS	118016	Pond C 20	770	15	720	676	51.66412	−128.126	*Tsuga heterophylla* needles	Pond core sediments – brackish-marine diatoms	0.5	1	McLaren	Pond core	M–B
HE1	UCIAMS	102754	ElSx4 C	1425	15	722	566	51.93216	−127.8923	Clam shell fragments	Archaeological deposit – basal shell midden	11.9	2	McLaren	ESP	A
HW5	Beta	105289	ElTa3	770	50	729	673	51.84034	−128.1027	Charcoal	Archaeological deposit – base of organic soil	0.1	2	Cannon 2000	ESP	A
HE5	UCIAMS	102747	EkSx11 D2	1530	20	824	663	51.7063	−127.8729	*Balanus* sp. shell	Archaeological deposit intertidal shell midden	−3.1	2	McLaren	ESP	A
HW4	UCIAMS	102749	ElTb34 E2	1540	15	832	670	51.83699	−128.245	Clam shell fragments	Archaeological deposit – basal shell midden	6.6	1	McLaren	ESP	A
HE3	UCIAMS	102691	ElSx11 B	1715	15	1032	841	51.86005	−127.8495	*Mytilus* sp. shell and fish bone fragments	Archaeological deposit – basal shell midden	9.4	1	McLaren	ESP	A
HW7	UCIAMS	128260	EjTa15A	1225	20	1226	1088	51.66039	−128.1191	Wood	Top of peat deposit	1	0.5	McLaren	Excavation	A
HE3	Beta	105288	ElSx16	1240	50	1261	1090	51.89843	−127.8386	Charcoal	Archaeological deposit – base of organic soil	0.4	1	Cannon 2000	ESP	A
HE3	UCIAMS	102753	ElSx11 B	1990	15	1292	1131	51.86005	−127.8495	*Mytilus* sp. and *Balanus* sp. shell fragments	Archaeological deposit – basal organic soil	9.3	1	McLaren	ESP	A
HE5	UCIAMS	102746	EkSx11C	2050	15	1345	1183	51.70631	−127.8729	*Mytilus* sp. shell fragments	Basal shell midden	2.9	1	McLaren	ESP	A
HE1	UCIAMS	128278	ElSx4A	1475	25	1386	1336	51.93216	−127.8921	Sclerotia (*Cenococcum* sp.)	From peat-like layer	−0.5	2	McLaren	Excavation	A
HW4	UCIAMS	102748	ElTb34 E2	1595	15	1526	1418	51.83699	−128.245	Disperse charcoal	Base of organic soil	8.5	2	McLaren	ESP	A
HE4	DIC	329	Koeye	1570	65	1528	1396	51.7705	−127.8771	Basal peat	Basal peat	−2.7	1	Andrews and Retherford 1978	Exposure	A
HW9	UCIAMS	128333	CIRC9	1725	30	1694	1571	51.486	−128.08	Charcoal	From base of paleosol	16.25	1	Walker	Exposure	A
HW1	Beta	109627	ElTa21	1730	50	1701	1569	51.95818	−128.1055	Charcoal	Archaeological deposit – base of organic soil	0.7	1	Cannon 2000	ESP	A
HE1	UCIAMS	128277	ElSx4A	1770	15	1713	1630	51.93216	−127.8921	Charcoal	From peat layer	11.5	2	McLaren	Excavation	A
HW6	UCIAMS	115764	CIRC-5	2410	15	1752	1548	51.664	−128.135	Shell	Archaeological deposit – base of shell midden in exposure	3.4	1	Walker	Exposure	A
HW7	UCIAMS	128261	EjTa15A	1820	20	1811	1717	51.66039	−128.1191	Conifer charcoal	Bottom of peat 1	1	0.5	McLaren	Excavation	A
HE3	Beta	105286	ElSx8	2480	55	1853	1617	51.89811	−127.8673	Clam Shell	Archaeological deposit – basal midden	1.2	1	Cannon 2000	ESP	A
HW4	Beta	109629	ElTb2	1880	50	1878	1739	51.87215	−128.2135	Charcoal	Archaeological deposit – base of organic soil	0.2	1	Cannon 2000	ESP	A

(continued on next page)

Table 2 (*continued*)

Map ID	Lab	Lab#	Site and test	14C age BP	±	Calendar range (older)	Calendar range (recent)	Lat	Long	Material for dating (submitted)	Proxy indicator	Elevation – m ahht	±	Source/Lab	Method	Sea level position
HE5	UCIAMS	102745	EkSx11C	2005	20	1988	1932	51.70631	–127.8729	Disperse charcoal	Archaeological deposit – black organic silt	2.7	2	McLaren	ESP	A
HW3	UCIAMS	102762	ElTa18C	2260	15	2337	2208	51.89267	–128.1	Disperse charcoal	Archaeological deposit – basal organic soil	5.1	1	McLaren	ESP	A
HW6	UCIAMS	118013	EjTa5 60-55 abd	2370	15	2362	2346	51.66418	–128.1342	Charcoal	Archaeological deposit – shell midden	1.6	0.5	McLaren	Exposure	A
HW6	UCIAMS	118012	EjTa5 35-30 abd	2475	15	2700	2488	51.66418	–128.1342	Charcoal	Archaeological deposit – shell midden	1.3	0.5	McLaren	Exposure	A
HW4	Beta	109628	ElTb1	2540	50	2744	2503	51.83807	–128.197	Charcoal	Archaeological deposit – base of organic soil	–0.7	1	Cannon 2000	ESP	A
HW3	UCIAMS	117998	ElTa18 137-142	2665	20	2775	2754	51.89286	–128.0993	Charcoal	Archaeological deposit	5.5	1	McLaren	Excavation	A
HW5	Gak	3716	EkTa19	3230	90	2781	2474	51.75398	–128.085	Shell	Archaeological deposit – basal shell midden	–1.2	1	Andrews and Retherford 1978	Exposure	A
HE1	Beta	109623	ElSx4	2620	50	2785	2716	51.93239	–127.8925	Charcoal	Archaeological deposit – base of organic soil	0.4	2	Cannon 2000	ESP	A
HW3	UCIAMS	128269	ElTa18C	2745	20	2858	2793	51.89391	–128.0976	Conifer charcoal	Archaeological feature – hearth	1.5	1	McLaren	Auger Test	A
HW6	GSC	1828	EjTa5	3290	210	2988	2413	51.66376	–128.1346	Shell	Archaeological deposit – basal shell midden	0.2	0.5	Andrews and Retherford 1978	Exposure	A
HW6	UCIAMS	118011	EjTa5 35-40 dbd	3020	15	3316	3172	51.66418	–128.1342	Charcoal	Archaeological deposit – shell midden	0.7	0.5	McLaren	Exposure	A
HW7	UCIAMS	118008	EjTa15-T2 C	3080	20	3354	3265	51.66039	–128.1191	Charcoal	Archaeological deposit	0.4	0.5	McLaren	Excavation	A
HW3	UCIAMS	112261	ElTa18 190-195	3155	15	3389	3364	51.89286	–128.0993	Charcoal	Archaeological deposit	5	1	McLaren	Excavation	A
HW6	UCIAMS	118010	EjTa5 80-85 dbd	3260	20	3553	3447	51.66418	–128.1342	Charcoal	Archaeological deposit – shell midden	0.2	1	McLaren	Exposure	A
HW7	UCIAMS	118009	EjTa15-T2 D	3310	15	3564	3484	51.66039	–128.1191	Charcoal	Archaeological deposit	0.3	0.5	McLaren	Excavation	A
HE3	Beta	109625	ElSx18	3900	55	3576	3351	51.90593	–127.8442	Clam Shell	Archaeological deposit – basal shell midden	0.7	1	Cannon 2000	ESP	A
HE1	UCIAMS	102757	ElSx4 E	3350	20	3630	3568	51.93209	–127.8921	Disperse charcoal	Archaeological deposit – base of organic soil	9.6	2	McLaren	ESP	A
HW7	UCIAMS	102740	EjTa13C2	3970	15	3639	3436	51.66487	–128.0773	Clam and *Mytilus* sp. shell fragments	Archaeological deposit – basal shell midden	7.5	1	McLaren	ESP	A
HW7	UCIAMS	102739	EjTa13C1	4025	20	3709	3486	51.66487	–128.0773	*Mytilus* sp. shell fragments	In discrete archaeological deposit	8.5	1	McLaren	ESP	A
HW7	UCIAMS	102741	EjTa13C2	3480	15	3823	3703	51.66487	–128.0773	Disperse charcoal	Archaeological deposit – basal organic soil in dark grey sand	7	1	McLaren	ESP	A
HW3	UCIAMS	128270	ElTa18C	3420	150	3844	3479	51.89391	–128.0976	Conifer charcoal	Archaeological deposit	1	1	McLaren	Excavation	A
HE1	UCIAMS	128275	ElSx4A	3750	20	4148	4087	51.93216	–127.8921	Charcoal	Archaeological deposit – from sediment under lithic	11.5	2	McLaren	Excavation	A
HW2	Beta	101924	ElTa25	4510	65	4404	4122	51.89908	–128.0219	Clam Shell	Archaeological deposit – basal shell midden	2.2	1	Cannon 2000	ESP	A
HW4	UCIAMS	102751	EkTb9 E2	4775	20	4770	4515	51.80693	–128.2367	Clam shell fragments	Archaeological deposit – basal shell midden	0.8	1	McLaren	ESP	A
HW6	Gak	3717	Surf Cove Dune	4020	100	4804	4317	51.6608	–128.146	Humic sediment	Buried Humic Layer in Dune	9	1	Andrews and Retherford 1978	Exposure	A
HW7	UCIAMS	118048	Pond C	4780	35	5230	4959	51.66412	–128.126	Charcoal, Foraminifera, micro-crustacean claw	Pond core sediments – foraminifera and brackish-marine diatoms	0.4	1	McLaren	Pond core	M–B
HW7	UCIAMS	118017	Pond C 36	4520	15	5295	5071	51.66412	–128.126	Deciduous leaf	Pond core sediments – brackish-marine diatoms	0.4	1	McLaren	Pond core	M–B
HW6	UCIAMS	128331	CIRC6	4680	20	5464	5325	51.658	–128.149	Wood	Top of peat layer from which CIRC1 was collected	0.7	1	Walker	Exposure	A

HW4	UCIAMS	117999	EkTb9 120-125	4930	20	5658	5610	51.80702	−128.2373	Charcoal	Archaeological deposit	2.8	1	McLaren	Excavation	A
HW4	UCIAMS	118002	EkTb9 140-145	4965	15	5712	5657	51.80702	−128.2373	*Sambucus racemosa* seed	Archaeological deposit	0.6	1	McLaren	Excavation	A
HW7	UCIAMS	118049	Pond C	5035	25	5885	5733	51.66412	−128.126	Charcoal, sclerotia, unidentified seed, needle fragments	Pond core sediments − brackish-marine diatoms	0.4	1	McLaren	Pond core	M−B
HW6	UCIAMS	115816	CIRC-2	5045	20	5886	5744	51.664	−128.135	Cone	From base of peat	0.4	1	Walker	Terrestrial excavation	A
HW7	UCIAMS	102742	EjTa4 A2	5800	20	5925	5735	51.66443	−128.0987	Clam shell fragment	Archaeological deposit − shell midden	1	2	McLaren	ESP	A
HW4	UCIAMS	102750	EkTb9 E2	5865	20	6026	5794	51.80693	−128.2367	*Mytilus* shell fragments	Archaeological deposit − basal sediments shell in grey sand	−0.5	1	McLaren	ESP	A
HE3	Beta	105480	ElSx10	5270	60	6177	5944	51.89966	−127.8527	Charcoal	Archaeological deposit − basal organic	3.4	1	Cannon 2000	ESP	A
HW3	UCIAMS	102759	ElTa18 B	5350	25	6207	6023	51.89269	−128.1	Disperse charcoal	Archaeological deposit − basal organic	5	1	McLaren	ESP	A
HW4	UCIAMS	102752	EkTb9 F1	6155	20	6338	6161	51.80669	−128.237	Clam, *Mytilus* sp. and *Balanus* sp. shell fragments	Archaeological deposit − basal shell midden	0.3	1	McLaren	ESP	A
HW6	UCIAMS	118052	LL 138	5730	25	6560	6478	51.6475	−128.1427	Moss (*Pleurozium schreberi*)	Peat	51.4	2	McLaren	Pond core	A
HW6	UCIAMS	115815	CIRC-1	5790	20	6638	6564	51.658	−128.149	Branch	Peat	0.3	1	Walker	Exposure	A
HW6	UCIAMS	128332	CIRC8	5870	20	6720	6700	51.663	−128.136	Wood	Woody peat	−0.3	1	Walker	Exposure	A
HW4	UCIAMS	118003	EkTb9 175-180	5885	20	6726	6674	51.80702	−128.2373	*Tsuga heterophylla* needle	Archaeological deposit	2.25	1	McLaren	Excavation	A
HE1	Beta	109624	ElSx5	6560	55	6791	6549	51.93263	−127.8958	*Mytilus* sp. shell	Archaeological deposit − basal shell midden	2.1	1	Cannon 2000	ESP	A
HW4	UCIAMS	118000	EkTb9 Mat Needle 196	6300	20	7261	7177	51.80702	−128.2373	*Taxus brevifolia* wood	Archaeological deposit	2	1	McLaren	Excavation	A
HW7	Gak	3719	Calvert Island BC Tel Peat	6500	100	7497	7314	51.64473	−128.0916	Peat	Basal peat	6	1	Andrews and Retherford 1978	Exposure	A
HW3	UCIAMS	102760	ElTa18 B	6740	20	7610	7580	51.89269	−128.1	Disperse charcoal	Archaeological deposit − base of organic soil	5.1	1	McLaren	ESP	A
HW4	UCIAMS	118004	EkTb9 222-225	6840	20	7689	7630	51.80702	−128.2373	*Sambucus racemosa* seeds	Archaeological deposit	1.8	1	McLaren	Excavation	A
HW7	UCIAMS	128289	EjTa15D	7190	20	8010	7976	51.66039	−128.1191	Disperse charcoal	Archaeological deposit	0	0.5	McLaren	Excavation	A
HE1	UCIAMS	102755	ElSx4 C	7345	25	8190	8055	51.93216	−127.8923	Disperse charcoal	Archaeological deposit − basal organic soil	11.7	2	McLaren	ESP	A
HE1	UCIAMS	102756	ElSx4 C	7370	25	8285	8165	51.93216	−127.8923	Disperse charcoal	Archaeological deposit − base of organic soil	11.7	2	McLaren	ESP	A
HW7	UCIAMS	128262	EjTa15A	7870	20	8683	8599	51.66039	−128.1191	Disperse charcoal	Top of peat 2	0.5	0.5	McLaren	Excavation	A
HW7	UCIAMS	128266	EjTa15B	8095	20	9025	9005	51.66039	−128.1191	Disperse charcoal	Archaeological deposit − associated with lithics	0	0.5	McLaren	Excavation	A
HW7	UCIAMS	128264	EjTa15C	8455	20	9515	9467	51.66039	−128.1191	Disperse charcoal	Archaeological deposit − associated with lithics	0	0.5	McLaren	Excavation	A
HW3	UCIAMS	128271	ElTa18C	8670	70	9697	9543	51.89391	−128.0976	Sclerotia (*Cenococcum* sp.)	Archaeological deposit − base of organic soil	0	1	McLaren	Excavation	A
HW3	UCIAMS	128272	ElTa18C	8785	25	9888	9709	51.89391	−128.0976	Disperse charcoal	Archaeological deposit − base of organic soil	0	1	McLaren	Excavation	A
HW6	UCIAMS	128279	SBDL Pond	8800	25	9898	9766	51.6455	−128.135	Wood	Pond core sediments, gyttja	10	1	McLaren	Pond core	A
HW7	UCIAMS	112262	EjTa15-T2; 140-150	8835	20	10116	9787	51.80702	−128.2373	Charcoal	Archaeological deposit	0.1	0.5	McLaren	Excavation	A
HW7	UCIAMS	128265	EjTa15C	8885	20	10151	9924	51.66039	−128.1191	Conifer twig charcoal	Archaeological deposit − from hearth feature	0	0.5	McLaren	Excavation	A
HW7	UCIAMS	128263	EjTa15A	8905	20	10160	9940	51.66039	−128.1191	Conifer charcoal	Bottom of peat 2	0	0.5	McLaren	Excavation	A
HW4	UCIAMS	112263	EkTb9; 220-225	9140	25	10288	10238	51.80702	−128.2373	Charcoal	Archaeological deposit	1.8	1	McLaren	Excavation	A
HW8	UCIAMS	128296		9280	20	10515	10426	51.641	−127.9543			−1.75	1	McLaren	Lagoon core	B-A

(*continued on next page*)

Table 2 (*continued*)

Map ID	Lab	Lab#	Site and test	14C age BP	±	Calendar range (older)	Calendar range (recent)	Lat	Long	Material for dating (submitted)	Proxy indicator	Elevation – m ahht	±	Source/Lab	Method	Sea level position
			Kwak-Fitz Lagoon 126							Conifer needles, seed, deciduous twig	Lagoon core sediments – brackish-freshwater diatoms					
HW4	UCIAMS	102764	WTB	9310	25	10566	10499	51.80451	−128.2516	Sclerotia (*Cenococcum* sp.)	Terrestrial organic layer below intertidal deposits	−2.2	0.5	McLaren	ESP	A
HW3	UCIAMS	134857	ElTa18 2013 D 30-40	9355	25	10645	10519	51.89286	−128.0993	Wood	Archaeological deposit – above wood chip	−0.5	1	McLaren	Excavation	A
HW7	UCIAMS	128290	EjTa15D	9370	25	10653	10562	51.66039	−128.1191	Disperse charcoal	Between two discrete archaeological deposits	0	0.5	McLaren	Excavation	A
HW4	UCIAMS	102763	WTB	9400	30	10666	10583	51.80451	−128.2516	Seeds	Terrestrial organic layer below intertidal deposits	−2.2	0.5	McLaren	ESP	A
HW8	UCIAMS	128295	Kwak-Fitz Lagoon 81	9420	25	10693	10591	51.641	−127.9543	Conifer needles and cone bract	Pond core sediments – brackish diatoms	−1.75	0.5	McLaren	Lagoon core	M
HW6	UCIAMS	128335	CIRC 12	9465	20	10737	10681	51.642	−128.152	Wood	Woody peat	−1.75	1	Walker	Exposure	A
HW3	UCIAMS	117995	ElTa18 262-267	9475	20	10745	10692	51.89286	−128.0993	Charcoal	Archaeological deposit	4.3	1	McLaren	Excavation	A
HW3	UCIAMS	117997	ElTa18 217–222 A	9490	20	10757	10701	51.89286	−128.0993	Charcoal	Archaeological deposit	4.7	1	McLaren	Excavation	A
HW9	UCIAMS	128337	CIRC 11	9600	25	11092	10795	51.486	−128.08	Leaf	From top of organic soil	16.2	1	Walker	Exposure	A
HW1	UCIAMS	128293	Kildidt Lagoonlet 121	9620	20	11124	10868	51.94593	−128.1284	*Sphagnum* stem	Lagoon core sediments – freshwater diatoms	−1.5	0.5	McLaren	Lagoon core	A
HW6	UCIAMS	128280	SBDL Pond	9705	25	11196	11146	51.6455	−128.135	*Tsuga heterophylla* and *Picea sitchensis* needles	Pond core sediments –gyttja	10	1	McLaren	Pond core	A
HE3	WAT	452	ElSx1	9720	140	11252	10,789	51.85883	−127.8649	Charcoal	Base of archaeological deposits	6.4	1	Cannon 2000	Excavation	A
HW4	UCIAMS	118001	EkTb9 230-235	9960	25	11396	11,285	51.80702	−128.2373	Charcoal	Archaeological deposit	1.7	1	McLaren	Excavation	A
HW3	Beta	109626	ElTa18	9940	50	11,591	11,247	51.89883	−128.0938	Charcoal	Archaeological deposit – base of organic soil	3.6	1	Cannon 2000	ESP	A
OS2	RIDDL	979	Cook Bank	9940	75	11,600	11,243	50.99	−128.5	Plant matter	Ocean core sediments – marine sand	−97.7	2	Luternauer et al., 1989	Marine core	B
HW5	UCIAMS	128300	Stirling Lagoon 182	10,030	30	11,610	11,403	51.7792	−128.0845	Deciduous twig	Lagoon core sediments -freshwater diatoms	−1.75	0.5	McLaren	Lagoon core	A
HE2	Gak	3715	Hvidsten Point	10,200	150	12,364	11,412	51.9468	−127.7397	Wood	Sediments in exposure – freshwater diatoms	6	0.5	Andrews and Retherford 1978	Exposure	A
OS2	RIDDL	983	Cook Bank	10,290	80	12,376	11,836	50.99	−128.5	Wood	Ocean core sediments – marine sand	−98	1	Luternauer et al., 1989	Marine core	B
OS1	TO	1342	Goose Bank	11,030	70	12,320	11,901	51.85	−129.25	*Zirfaea pilsbryi*	Ocean core sediments – intertidal shell	−125	2	Barrie and Conway 2002a	Marine core	M
OS2	RIDDL	985	Cook Bank	10,470	75	12,554	12,220	50.99	−128.5	Root	Ocean core sediments – organic soil	−98.4	1	Luternauer et al., 1989	Marine core	A
OS2	RIDDL	981	Cook Bank	10,485	70	12,562	12,222	50.99	−128.5	Wood	Ocean core sediments – marine sand	−97.9	1	Luternauer et al., 1989	Marine core	B
HE2	UCIAMS	131386	Hvidsten Point	10,660	30	12,628	12,569	51.9468	−127.7397	Charcoal	Sediments in exposure – freshwater diatoms	6	0.5	McLaren	Exposure	A
OS1	TO	1254	Goose Bank	11,440	70	12,718	12,412	51.94	−129.08	*Macoma incongura*	Ocean core sediments – intertidal shell	−135.5	3	Barrie and Conway 2002a	Marine core	M
OS1	TO	1256	Goose Bank	11,450	80	12,735	12,412	51.87	−129.19	*Spisula falcata*	Ocean core sediments – intertidal shell to −50m	−123.5	2	Barrie and Conway 2002a	Marine core	M
OS1	TO	1257	Goose Bank	11,460	80	12,746	12,418	51.87	−129.19	*Saxidomus giganteus*	Ocean core – intertidal to subtidal shell	−122.5	1	Hetherington et al., 2004	Marine core	M–B
HW7	UCIAMS	134858	Big Spring Lake 282	10,855	35	12,779	12,638	51.6479	−128.07	*Pinus contorta* needle	Pond core sediments – freshwater diatoms	6	1	McLaren	Pond core	A
HW3	UCIAMS	117996	ElTa18 267–272 A	10,920	25	12,858	12,701	51.89286	−128.0993	Charcoal	Pond core sediments – basal organic soil	4.2	1	McLaren	Excavation	A
HW5	UCIAMS	128301		10,990	25	12,926	12,753	51.7792	−128.0845	Deciduous twig		−1.75	0.5	McLaren	Lagoon core	A

			Stirling Lagoon 206								Pond core sediments – fresh water diatoms					
OS2	RIDDL	984	Cook Bank	10,650	350	12,931	11,999	50.99	−128.5	Wood	Ocean core sediments -organic soil	−98.3	1	Luternauer et al., 1989	Marine core	A
HW7	UCIAMS	128292	Big Spring Lake 262	11,020	30	13,048	12,768	51.6479	−128.07	*Picea sitchensis* needle	Pond core sediments – freshwater diatoms	6	1	McLaren	Pond core	A
HW6	UCIAMS	118019	SBDL 182-183	11,565	25	13,443	13,341	51.64582	−128.1354	*Pinus contorta* seed, *Picea* seed and needle fragments	Pond core sediments – freshwater diatoms	9.4	1	McLaren	Pond core	A
HW3	UCIAMS	118046	ElTa18 267–272 B	11,720	80	13,673	13,454	51.89286	−128.0993	Sclerotia (*Cenococcum* sp.)	Archaeological site – basal organic soil	4.2	1	McLaren	Excavation	A
HE6	UCIAMS	134826	Gildersleeve Pond	11,770	30	13,717	13,511	51.60326	−127.7786	Wood	Pond core sediments – freshwater diatoms	13	1	McLaren	Pond core	A
SW	GSC	1351	Shearwater	12,210	330	13,735	12,978	52.1473	−128.0903	Shell	Sediments in exposure – glaciomarine clay	12	2	Andrews and Retherford 1978	Exposure	M
HW8	UCIAMS	128297	Kwak-Fitz Lagoon 310	12,040	30	13,945	13,822	51.641	−127.9543	*Pinus contorta* needles	Lagoon core sediments – brackish diatoms	−1.75	0.5	McLaren	Lagoon core	B
HW1	UCIAMS	128294	Kildidt Lagoonlet 229	12,075	30	13,981	13,851	51.94593	−128.1284	*Picea sitchensis* needle	Lagoon core sediments – freshwater diatoms	−1.5	0.5	McLaren	Lagoon core	A
HW7	UCIAMS	118018	Pond D 321-322	12,250	35	14,178	14,015	51.63655	−128.1064	*Pinus contorta* needle fragments	Pond core sediments – freshwater diatoms	22.4	0.5	McLaren	Pond core	A
HE5	UCIAMS	128330	Gildersleeve Pond 538	13,225	30	14,345	14,243	51.60326	−127.7786	Mussel shell	Pond core sediments – marine and brackish diatoms	13	0.5	McLaren	Pond core	B
HW7	UCIAMS	134857	Big Spring Lake 287-9	12,275	50	14,463	14,001	51.6479	−128.07	Seed, needle fragment, leaf fragment	Pond core sediments – fresh and marine diatoms	6	1	McLaren	Pond core	A and B
HW7	UCIAMS	118015	Pond B 139	12,335	35	14,511	14,095	51.63482	−128.095	Deciduous leaf fragments, *Pinus contorta* needle base, Cyperaceae seed	Pond core sediments – freshwater diatoms	94.4	1	McLaren	Pond core	A
HE5	UCIAMS	128291	Gildersleeve Pond 545	12,400	25	14,577	14,181	51.60326	−127.7786	Seed	Pond core sediments – marine and brackish diatoms	13	1	McLaren	Pond core	B
HW7	UCIAMS	118014	Pond B 136	12,400	30	14,582	14,177	51.63482	−128.095	*Pinus contorta* needle fragments, *Potamogeton* seed	Pond core sediments – freshwater diatoms	94.4	1	McLaren	Pond core	A
HW6	UCIAMS	118020	SBDL 204-205	12,400	35	14,587	14,173	51.64582	−128.1354	*Sphagnum* sp., charcoal, needle fragments, sclerotia, conifer seed	Pond core sediments – freshwater diatoms	9.4	1	McLaren	Pond core	A
HE6	UCIAMS	134627	Gildersleeve Pond 525	13,075	94	14,601	14,071	51.60326	−127.7786	*Littoria* shell, winkle	Pond core sediments – intertidal shellfish	13	1	McLaren	Pond core	M
HW8	UCIAMS	128298	Kwak-Fitz Lagoon 319	12,440	25	14,681	14,212	51.641	−127.9543	Deciduous twig	Lagoon core – marine diatoms	−1.75	0.5	McLaren	Lagoon core	B
HW6	UCIAMS	115817	CIRC-4	12,455	30	14,729	14,231	51.643	−128.151	Branch wood	In glacio-marine clays exposed at low tide in the modern beach.	−2.2	0.5	Walker	Exposure	B
OS1	TO	1255	Goose Bank	13,180	90	14,865	14,204	51.94	−129.08	*Serpulid*	Ocean core sediments – intertidal shell	−135.5	3	Barrie and Conway 2002a	Marine core	M
HW6	UCIAMS	128336	CIRC 14	12,575	25	15,025	14,641	51.651	−128.142	Plant material	In woody fibre-dominated silt/fine sand layer at base of glacial advance sequence	1.5	0.5	Walker	Exposure	A
OS1	TO	9309	Goose Bank	13,340	140	15,146	14,257	51.94	−129.08	*Balanus glandula*	Ocean core sediments – intertidal shell	−135.5	4	Hetherington et al., 2004	Marine core	M
OS1	TO	9305	Goose Bank	13,510	100	15,557	14,905	51.87	−129.19	*Mytilus trossulus*	Ocean core sediments – intertidal shell	−123.5	1	Hetherington et al. 2004	Marine core	M

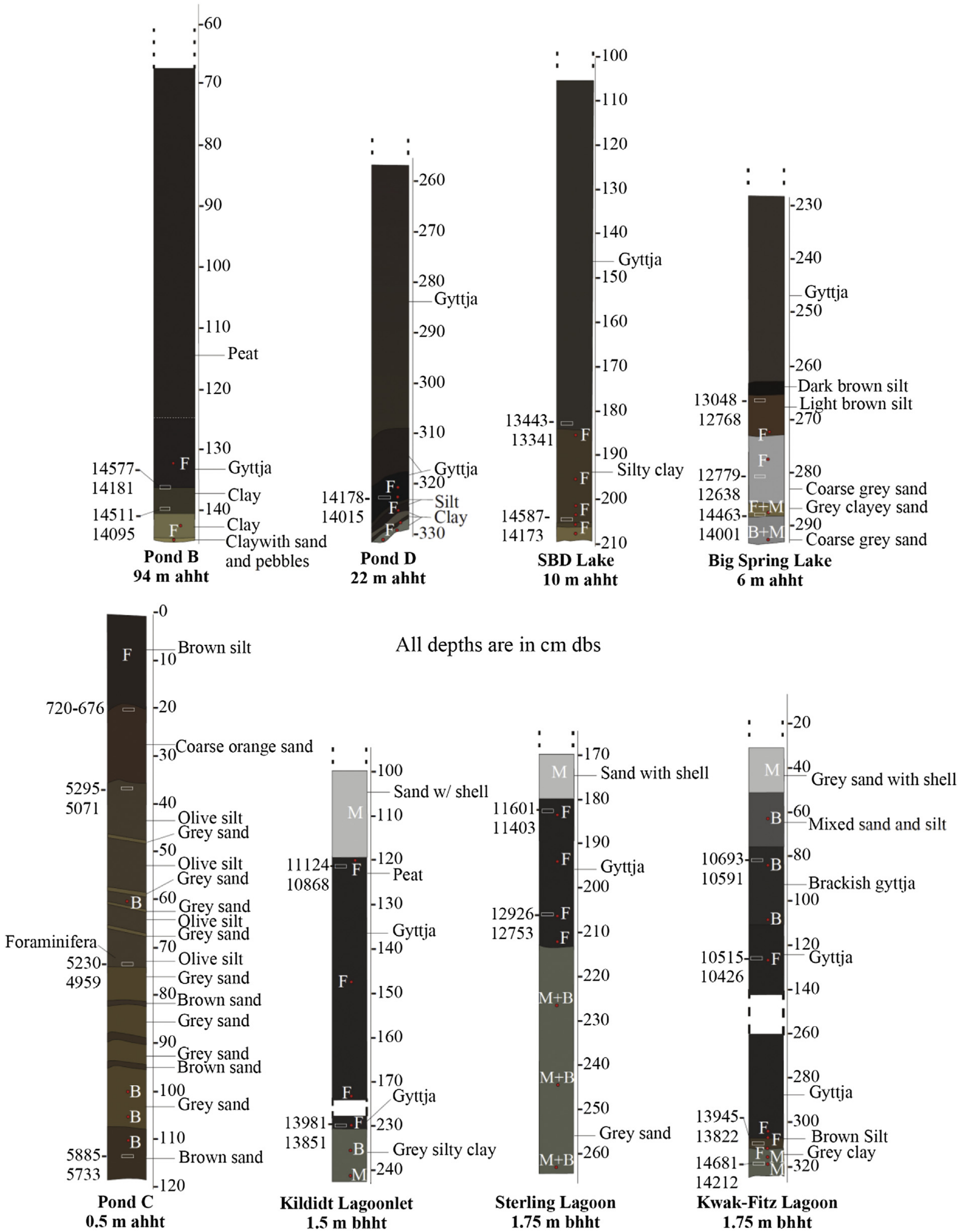

Fig. 6. Isolation basin core stratigraphy from Hakai West. F = freshwater diatoms, B = brackish diatoms, M = marine diatoms. Elevation estimates for the sill of each pond or lagoon core is given below each core log. All basins were impounded by rock sills with the exception of Pond 'C' which is dune or berm impounded. All radiocarbon dates are Cal BP.

southwest of Hakai Passage, Luternauer et al. (1989) provide core samples obtained from a depth of 98.5 m bhht. Terrestrial sediment from this depth contained the remains of rooted plants and wood revealing that relative sea level was lower than 98.5 m bhht from at least 12,400 to 12,100 Cal BP. After this time it rose above 98.5 m bhht.

From Goose Bank, 40 km northwest of Hakai Pass, Barrie and Conway (2002a) report on samples recovered from offshore

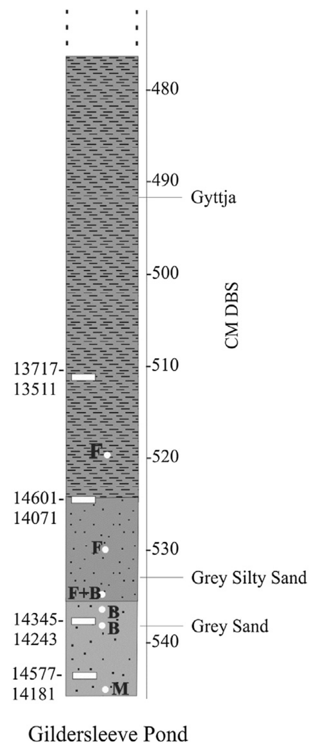

Fig. 7. Isolation basin core stratigraphy from Hakai East, Gildersleeve pond 13 m ahht. F = freshwater diatoms, B = brackish diatoms, M = marine diatoms. The stratigraphic record demonstrates that high tide was more elevated than this position before 14,345–14,243 Cal BP.

coring operations (Fig. 5 – OS1). Three additional data points from this work are given in Hetherington et al. (2004). These researchers identify a palaeo-shoreline based on the recovery of intertidal shellfish and their data reveal that relative sea level was between 135.5 and 123.5 m bhht during the time spanning 15,000 and 12,000 Cal BP.

3.5. Sea level curves for the Hakai region

To interpret the variability within the broader relative sea level dataset, we grouped the data into respective sub-regions for Hakai West, Hakai East, Cook Bank, and Goose Bank and graphed each by elevation (relative to hht) and by calibrated age range. These regional relative sea level curves thus approximate changes in the higher high tide position through time. Data points from basal archaeological deposits are assumed to be above higher high water. In some cases, these basal occupations may have been several metres above higher high water and, for this reason, these data only limit sea level to some elevation below. Most habitation sites on this part of the Northwest Coast are in close proximity to the high tide mark having been occupied by people reliant on the sea for transportation and diet.

3.5.1. Hakai West sea level curve

The Hakai West relative sea level curve includes islands to the west of Fitz Hugh Sound on the north and south sides of Hakai Pass (Fig. 10 and Fig. 12). The earliest data point is from terrestrial deposits below what may be a glacial advance sequence (cf Andrews and Retherford, 1978), suggesting that relative sea level was below 1.5 m ahht 15,025–14,641 Cal BP. Soon after (14,681–14,001 Cal BP), marine diatoms were deposited in the basal sediments of the three lagoon cores and Big Spring Lake, which indicates that relative sea level rose to above 6 m ahht. Around 14,500 Cal BP, relative sea level began to regress and, between 14,000 and 10,500 Cal BP, relative sea level dropped to a lower position than today as indicated by freshwater diatoms in the lagoon cores. Between 10,700 and 10,500 Cal BP, relative sea level rose from this lower position to 1.75 m bhht and all of the lagoons cores have intertidal sediments from this time onwards. Archaeological deposits constrain the upper end of high tide after 10,700 BP to within 2 m of present. One small transgression (1–2 m ahht) appears to have occurred between 6000–5000 Cal BP.

3.5.2. Hakai East sea level curve

The Hakai East relative sea level curve is specific to the region on the east side of Fitz High Sound and includes Fish Egg Inlet to the south and the southwestern tip of King Island to the north (Figs. 11 and 12). The earliest ages for this curve come from Gildersleeve Pond with a sill elevation of 13 m ahht, revealing that it was inundated by marine and brackish water between 14,345 and 14,243 Cal BP (UCIAMS 128330). Basal (terrestrial) ages for archaeological deposits at Namu indicate that relative sea level was below 6 m ahht between 11,252 and 10,789 Cal BP. All remaining data points on the curve after this time are terrestrial and suggest that sea level dropped below 2 m ahht over the next 5000 years (sites ElSx4, ElSx5, ElSx10, Table 1). In the late Holocene, relative sea level drops to modern or slightly below modern levels, which is consistent with the trend seen in the Hakai West curve.

3.5.3. Cook Bank sea level curve

The data for Cook Bank reveals that sea level was lower than 98.5 m bhht from at least 12,931 to 11,999 Cal BP (RIDDL 984) (Luternauer et al., 1989). Wave cut terraces at 102.5 m bhht suggest that relative sea level may have been at least 4 m lower than this. At this time, Cook Bank would have been a low-lying coastal plain connected to the north end of Vancouver Island (see shaded bathymetry in Fig. 5). Subaerial exposure of this landform was the result of isostatic uplift, or a glacial forebulge effect (Clague, 1983) that was sufficient to raise the area above global sea level. Transgression of the core site occurred sometime around 11,400 Cal BP, which resulted in drowning of the Cook Bank plain from the combined effects of forebulge collapse, following regional deglaciation, and eustatic sea level rise.

3.5.4. Goose Bank sea level curve

Recovery of intertidal shellfish in deposits on Goose Bank at depths as deep as 135.5 m bhht provided data for the construction of a regional relative sea level curve (Barrie and Conway, 2002a; Hetherington et al., 2004). The Goose Bank data suggest that relative sea level was 135.5 m bhht between 14,599 and 13,980 Cal BP (TO 9309) and then it rose to 122 m bhht between 11,600–11,243 Cal BP (RIDDL 979). At this time, Goose Bank would have been a large, low-lying island (approximately 50 km × 40 km).

3.5.5. Outlying data points

One data point, from Shearwater, does not fit conformably with the relative sea level curves generated for our sub regions (Andrews and Retherford, 1978). This data point reveals that Shearwater was submerged more than 12 m ahht between 13,735 and 12,978 Cal BP (GSC 1351). This is the most northerly, and therefore the most likely to be glacial proximal of the data points considered and it may have been more affected by isostatic depression accounting for it being an outlier. The next closest data point is Kildidt Lagoonlet, 22 km to the south of Shearwater and has near contemporaneous dates of

Table 3
Diatom flora observed in samples analyzed.

Sample ID	Sub-region	Sample depth	Dominant diatom types identified and other indicators	Proxy for
Pond B	HW7	134	*Aulacoseira* spp.	Freshwater pond
Pond B	HW7	142, 144	*Tabellaria flocculosa*, *Gomphonema gracile* and *Epithemia* spp.	Freshwater pond
Pond C	HW7	25	Barren	N/A
Pond C	HW7	60	*Diploneis stroemii* and *Cocconeis* cf. *discrepans* with some *Aulacoseira cf. lirata*	Brackish with some freshwater influence
Pond C	HW7	100, 105, 110	*Diploneis stroemii* and *Cocconeis* cf. *discrepans, C. pseudomarginata, C. costata* var. *pacifica, Opephora marina, O. mutabilis* and *Navicula eidrigiana*	Benthic brackish marine
Pond C	HW7	173–203	*Aulacoseira* cf. *lirata* and other *Aulacoseira* spp., *Pinnularia mesolepta*, *Stauroneis anceps*, and numerous *Eunotia* spp.	Freshwater
Pond D	HW7	320	*Aulacoseira* spp.	Freshwater pond
Pond D	HW7	326–330	*Nitzschia* spp. (*Nitzschia fonticola*, *N. inconspicua, etc.*), *Diploneis pseudovalis*, *D. parma*, *Planothidium lanceolatum*, *Achnanthes nodosa*, *Epithemia adnata*, *Cymbella silesiaca*, *C. minuta*, *Cocconeis placentula* and *Navicula cryptocephala. Fragilarioid-type* taxa were also present including *Staurosirella pinnata*, *Staurosira construens,* and *Pseudostaurosira brevistriata.*	Freshwater pond
Gildersleeve Pond	HE6	520	*Frustulia rhomboides, Aulacoseira lirata, Cyclotella meneghiniana, Semiorbis hemicyclus, Tabellaria flocculosa, Pinnularia streptoraphe, Neidium iridis,* and *Surirella linearis*	Freshwater pond
Gildersleeve Pond	HE6	530	*Aulacoseira distans, Semiorbis hemicyclus, Stauroneis anceps, Eunotia serra, Pinnularia decrescens, Gomphonema lanceolatum,* and *Tabellaria flocculosa*	Freshwater pond
Gildersleeve Pond	HE6	535	*Cyclotella antiqua, Aulacoseira cf. lirata, Epithemia adnata, Rhopalodia gibba, Gomphonema lanceolatum, Gomphonema truncatum,* and *Eunotia flexuosa*	Slightly brackish pond
Gildersleeve Pond	HE6	536	*Cyclotella antiqua, Rhopalodia gibba, Gomphonema acuminatum, Epithemia adnata, Mastogloia smithii, Pleurosigma elongatum, Stauroneis anceps, Pinnularia brebissonii, Diploneis bomboides,* and *Cymbella neocistula*	Brackish lagoon
Gildersleeve Pond	HE6	538	*Rhopalodia gibba, Diploneis bomboides, Epithemia adnata, Mastogloia smithii, Mastogloia elliptica, Trachyneis aspera,* and *Staurosirella pinnata*	Brackish lagoon
Gildersleeve Pond	HE6	545	*Grammatophora oceanica, Diploneis subcincta, Rhabdonema sp.,* abundant *Mytilus* fibers, marine shell hash	Marine embayment
Stone Beaver Dam Lake	HW6	185, 195,	*Aulacoseira* cf. *lirata* and other *Aulacoseira* spp., *Pinnularia mesolepta*, *Stauroneis anceps*, and numerous *Eunotia* spp.	Freshwater pond
Stone Beaver Dam Lake	HW6	201, 203	*Aulacoseira* cf. *lirata* and other *Aulacoseira* spp., *Pinnularia mesolepta*, *Stauroneis anceps*, and numerous *Eunotia* spp.	Freshwater pond
Stone Beaver Dam Lake	HW6	205, 207	*Staurosirella pinnata*, *Staurosira construens*, *Pseudostaurosira brevistriata*, *Opephora martyii*, *Staurosirella leptostauron*, *Fragilaria exigua*, *Achnanthes calcar*, *Planothidium. oestruppii*, *Achnanthidium* minutissimum (sensu lato), and *Navicula pseudoscutiformis*, *N. cryptocephala, Reimeria sinuata*, *Aulacoseira* spp. and chrysophycean cysts	Freshwater pond
Big Spring Lake	HW7	273	*Aulacoseira distans, Frustulia rhomboides, Surirella biserata,* and *S. linearis*	Freshwater pond
Big Spring Lake	HW7	278	*Aulacoseira distans, Frustulia rhomboides, Staurosirella pinnata, Navicula leptostrata,* and *Nitzchia cf. fonticola*	Freshwater pond
Big Spring Lake	HW7	288	*Aulacoseira distans, Frustulia rhomboides, Cyclotella triparta, Gyrosigma balticum, Coscinodiscus radiatus, C. apiculatus, Bacillaria socialis, Cocconeis scutellum,* and *C. costata*	Freshwater pond with some marine washes
Big Spring Lake	HW7	294	*Frustulia rhomboides, Eunotia incisa, Gyrosigma arcticum, Cocconeis costata, C. scutellum, C.* cf. *kamtchatkensis, Cosconodiscus apiculatus,* and *Rhaphoneis* sp.	Brackish-marine embayment with minor freshwater input
Stirling Lagoon	HW5	179	Shell (biogenic sand)	Intertidal
Stirling Lagoon	HW5	183, 193	*Aulacoseira distans, Aulacoseira lirata, Cocconeis placentula, Eunotia tibia, E. faba, Pinnularia gibba, P. stomatophora,* and *Diploneis ovalis*	Freshwater
Stirling Lagoon	HW5	208	*Eunotia* spp. and *Pinnularia* spp.	Freshwater
Stirling Lagoon	HW5	212	*Stauroneis anceps, Pinnularia mesolepta, P. subgibba, P. brauniana, P. microstauron, P. krasskei, Cymbella apera,* and *Rhopalodia gibba*	Freshwater pond
Stirling Lagoon	HW5	227		

Table 3 (*continued*)

Sample ID	Sub-region	Sample depth	Dominant diatom types identified and other indicators	Proxy for
			Grammataphora oceanica, *Rhabdonema* sp., *Coscinodiscus apiculatus*, *Thalassiosira eccentricus*, *Ctenophora pulchella*, and *Cocconeis costata*	Marine to brackish embayment
Stirling Lagoon	HW5	244	*Thalassiosira baltica*, *Thalassiosira pacifica*, *Tryblionella coarctica*, *Coscinodiscus apiculatus*, *Cocconeis costata*, *Paralia sulcata*, *Trachyneis aspera*, and *Plagiogramma staurophorum*	Marine to brackish embayment
Stirling Lagoon	HW5	263	*Coscinodiscus apiculatus*, *Thalassiosira pacifica*, *Gyrosigma acuminatum*, *G. balticum*, *Grammataphora oceanica*, *Bacillaria socialis*, *Cocconeis costata*, *C. placentula*, *Ctenophora pulchella*, *Rhoicosphenia abbreviata*, and *Rhabdonema* sp.	Marine to brackish embayment
Kildidt Lagoonlet	HW1	121	*Cyclotella triparta*, *C. stelligera*, *Aulacoseira* spp., and *Staurosirella pinnata*	Freshwater pond
Kildidt Lagoonlet	HW1	147	*Tabellaria flocculosa*, *Aulacoseira distans*, *A. granulata*, *A. lirata*, *Frustulia rhomboides*, *Cyclotella* spp., *Gyrosigma balticum*, *Pinnularia subgibba*, *Staurosirella pinnata*, *Diploneis cf. vacillans*, *Tryblionella coarctica*, and *Cocconeis costata*	Freshwater pond
Kildidt Lagoonlet	HW1	175	*Aulacoseira distans*, *A. granulata*, *Frustulia rhomboides*, *Semiorbis hemiyclus*, *Stauroneis anceps*, *Eunotia tibia*, *E. faba*, *E. serra*, and *Pinnularia subgibba*	Freshwater pond
Kildidt Lagoonlet	HW1	230	*Aulacoseira distans*, *Stauroneis anceps*, *Eunotia flexuosa*, *Eunotia serra*, *Surirella bifrons*, *Pinnularia stomatophora*, *Pinnularia brauniana*, and *Cymbella subcuspidata*	Freshwater pond
Kildidt Lagoonlet	HW1	235	*Plagiogramma staurophorum*, *Grammataphora oceanica*, *Gyrosigma acuminatum*, *Surirella brightwellii*, *Paralia sulcata*, *Trachyneis aspera*, *Diploneis subcincta*, *Diploneis bomboides*, *Rhabdonema* sp., and *Cocconeis pseudomarginata*	Brackish lagoon
Kildidt Lagoonlet	HW1	241	*Cocconeis scutellum*, *Rhopalodia* cf. *pacifica*, *Grammatophora oceanica*, and *Chaetoceros subsecundus*	Marine embayment
Kwakfitz Lagoon	HW8	61	*Gyrosigma* spp., *Diploneis didyma*, *Coscinodiscus* spp.	Brackish/Marine
Kwakfitz Lagoon	HW8	82	*Gyrosigma* spp. very abundant	Brackish, lagoon
Kwakfitz Lagoon	HW8	106	*Aulacoseira granulata*, *Gyrosigma balticum*, *Thalassiosira eccentrica*, *Tabularia tabulata*, *Mastogloia exigua*, *Surirella brightwellii*, *Nitzschia radicula*, and *Pinnularia problematica*	Brackish, lagoon
Kwakfitz Lagoon	HW8	126	*Aulacoseira distans*, *Aulacoseira granulata*, *Frustulia rhomboides*, *Stauroneis anceps*, *Pinnularia stomatophora*, *Pinnularia problematica*, *Pinnularia* cf. *brebissonii*, *Gyrosigma balticum*, and *Tabellaria flocculosa*	Freshwater pond
Kwakfitz Lagoon	HW8	308	*Aulacoseira* spp., *Tabellaria* spp., *Surirella* spp., and *Eunotia* spp.	Freshwater pond
Kwakfitz Lagoon	HW8	311	*Aulacoseira lirata*, *Aulacoseira distans*, *Stenopterobia curvula*, *Pinnularia gibba*, *Pinnularia* cf. *brebissonii*, *Nitzschia radicula*, and *Surirella bifrons*	Freshwater pond
Kwakfitz Lagoon	HW8	314	*Caloneis* spp., *Gyrosigma* spp., *Diploneis bomboides*, and *Pinularia pluvianiformis*	Marine embayment
Kwakfitz Lagoon	HW8	319	*Cocconeis costata*, *Cocconeis scutellum*, *Cocconeis placentula*, *Coscinodiscus apiculatus*, *Ctenophora pulchella*, *Rhabdonema* sp., *Rhopalodia musculus*, *Rhopalodia gibba*, *Bacillaria socialis*, and *Grammataphora oceanica*	Marine embayment
Hvidsten Point	HE2	+197–199	*Navicula* cf. *rhynchocephala*, *Pinnularia* cf. *intermedia*, *Eunotia sudetica*,	Freshwater
Hvidsten Point	HE2	+162	*Frustulia rhomboides*, *Aulacoseira perglabra*, *Aulacoseira distans*, *Cyclotella stelligera*	Freshwater

13,981–13,851 (UCIAMS128294) to 11,124–10,868 (UCIAMS 128293) associated with a freshwater diatom flora that indicate that relative sea level in that area was below 1.5 m bhht at the same time.

Andrews and Retherford (1978) suggest that sea level was at or above 11 m ahht between 12,364 and 11,412 Cal BP at Hvidsten Point based on their interpretation of a sedimentary exposure there. However, our analysis of diatoms from the same deposit reveals that this data point is freshwater rather than marine. This data point may be associated with a localized impoundment, by sediment or ice, of Burke Channel during the late Pleistocene and may reflect this rather than relative sea level.

For the Bella Coola Valley (inland of North Bentick Arm), approximately 140 km east of the study area, Retherford (1972) reports on a number of marine terraces and deltas situated between 200 and 250 m ahht. In South Bentick Arm, 100 km to the east of Hakai Pass, similar features at about 200 m ahht are attributed to high early post-glacial sea levels (Retherford, 1972). Hall (2003) reports on a single age on marine shell collected from an exposure in the Bella Coola Valley near the mouth of Saloompt River. No elevation is given for the sample but based on the geographical description, it is above 52 ahht and dates to 11,400 Cal BP. Combined these additional data points provide further evidence of the localized contexts for sea level change in the region.

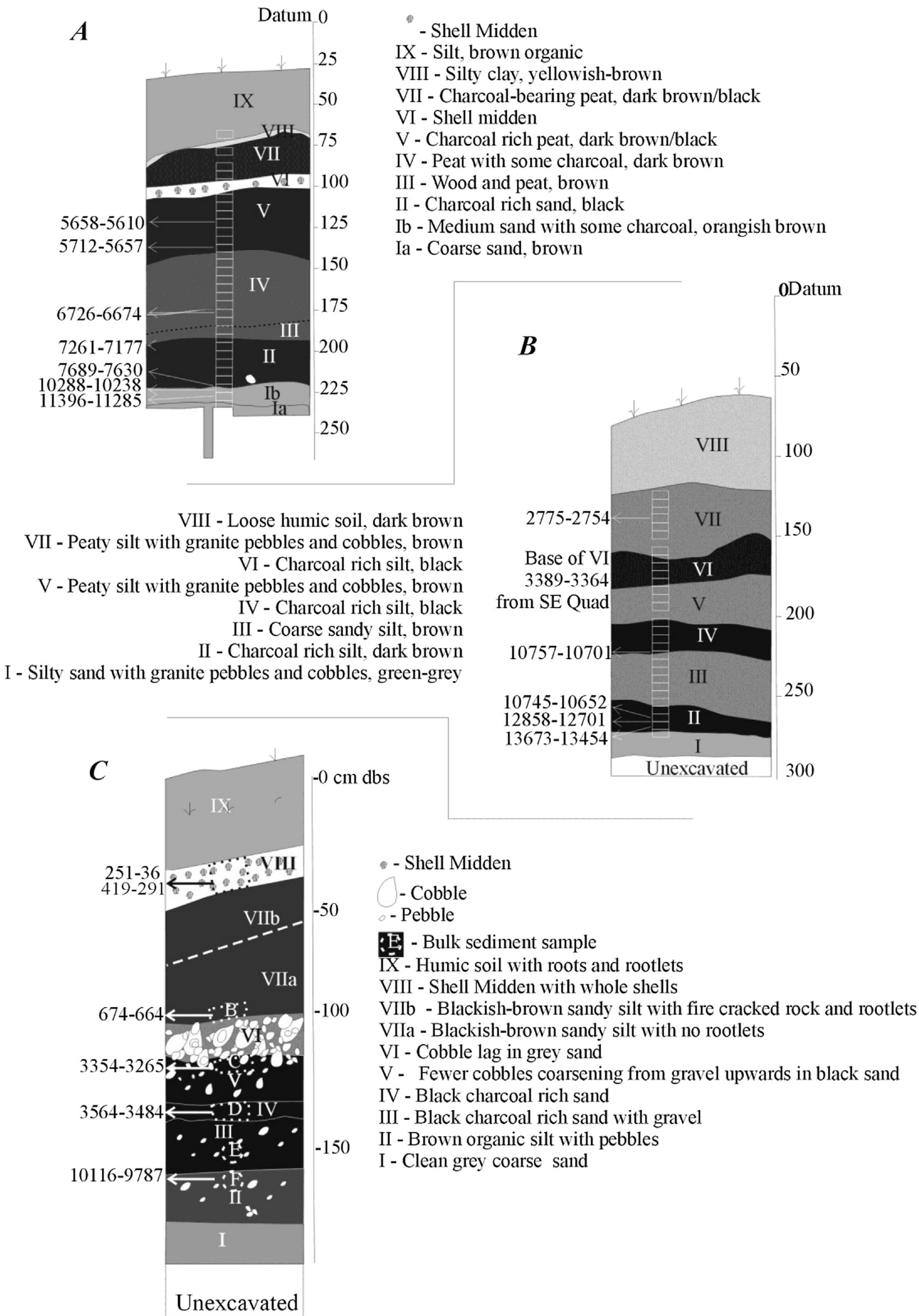

Fig. 8. Selected stratigraphic profiles from test excavations conducted at A) Triquet Island (EkTb9 – basal date is 1.7 m ahht), B) Kildidt Narrows (ElTa18 – basal date is 4.2 m ahht), and C) Pruth Bay (EjTa15 – basal date is 0.1 m ahht).

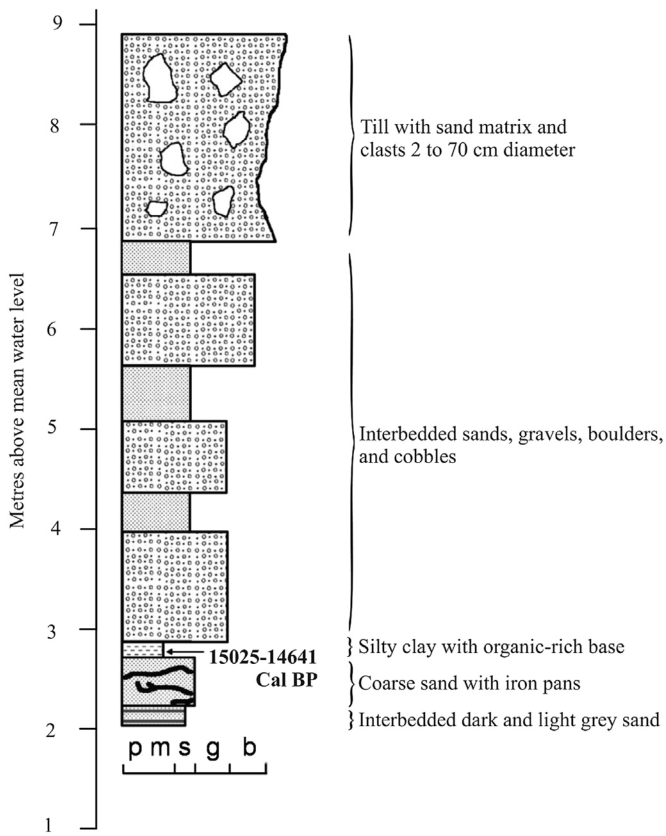

Fig. 9. Stratigraphic section from Foggy Cove showing glacial advance sequence described in Andrews and Retherford (1978). Further description and investigations of this section will be presented in co-author Jordan Eamer's upcoming PhD dissertation at the University of Victoria. The single radiocarbon date comes from organic rich silty clay below the glacial advance sequence.

4. Discussion

The Hakai West sea level curve (Fig. 12) reveals that relative sea level in the area has been within 10 m of present over the last 15,000 years. The Hakai East sea level curve shows more variation with sea level dropping 15.5 m over the same period. The data presented here demonstrate that a sea level 'hinge' existed between regions with higher and lower (than today) relative sea levels on the central Pacific coast of Canada (Fig. 13). The sea level hinge was found to be most stable in the Hakai West region. However, moraines and other glacial features on the landscape reveal that it is likely that much of the Hakai West region was under ice some time before 15,000 BP. During this time, with the increased volume of ice on land it is possible that the sea level hinge was located further offshore.

The Hakai area is a part of a larger region that extends southeast to northwest along the eastern shores of Queen Charlotte Sound, Hecate Strait, Dixon Entrance, and Clarence Channel along which we argue that a similar hinge-like area may be located (Fedje et al., 2004; McLaren, 2008; McLaren et al., 2011; Shugar et al., 2014). Migration of this hinge through time was dependent on local isostatic and global eustatic factors. The stability of any particular area within this region was dependent on localized factors pertaining to the amount of ice and tectonic activity. It is uncertain whether hinge areas as stable as Hakai West occur elsewhere along the coast.

The degree of stability of the shoreline in the Hakai region, and in the Hakai West area in particular, is remarkable. Elsewhere, the interplay between eustatic, isostatic, and tectonic factors tend to result in substantial changes to shoreline elevation through time. This stability means that, in the Hakai region, isostatic rebound was occurring at equal pace with global eustatic sea level rise at the end of the last glaciation. Between 14,000 and 10,000 Cal BP eustatic sea level rise was approximately 1.2 cm per year (Fairbanks, 1989). As relative sea level remained essentially constant, isostatic rebound rates for the Hakai West region must have been comparable. This pattern also suggests that the area has remained relatively tectonically stable over the Holocene accounting for very little change in relative sea level (see Shugar et al., 2014 for a discussion of tectonics and sea level change).

Places with stable shorelines allow relatively uninterrupted accumulation of archaeological deposits over long periods of time. In theory, these larger accumulations should be easier to find and they would be expected to retain long records of cultural and ecological information. Places where early archaeological deposits occur may be similar to places that are suitable for coastal habitation today, such as pocket beaches, harbours, and tombolos. This can be contrasted with areas such as Goose Bank, Haida Gwaii, and

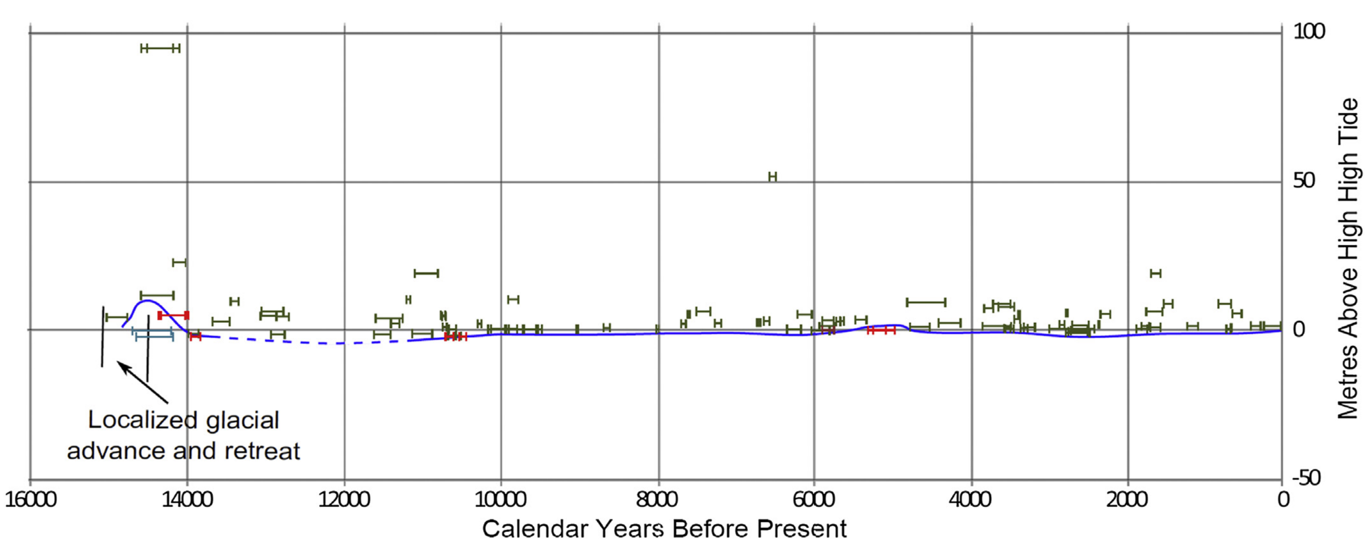

Fig. 10. Index points and sea level curve for the Hakai West region of the study area. Data points are coded as follows: green- above higher high tide, red – intertidal, blue – below low tide.

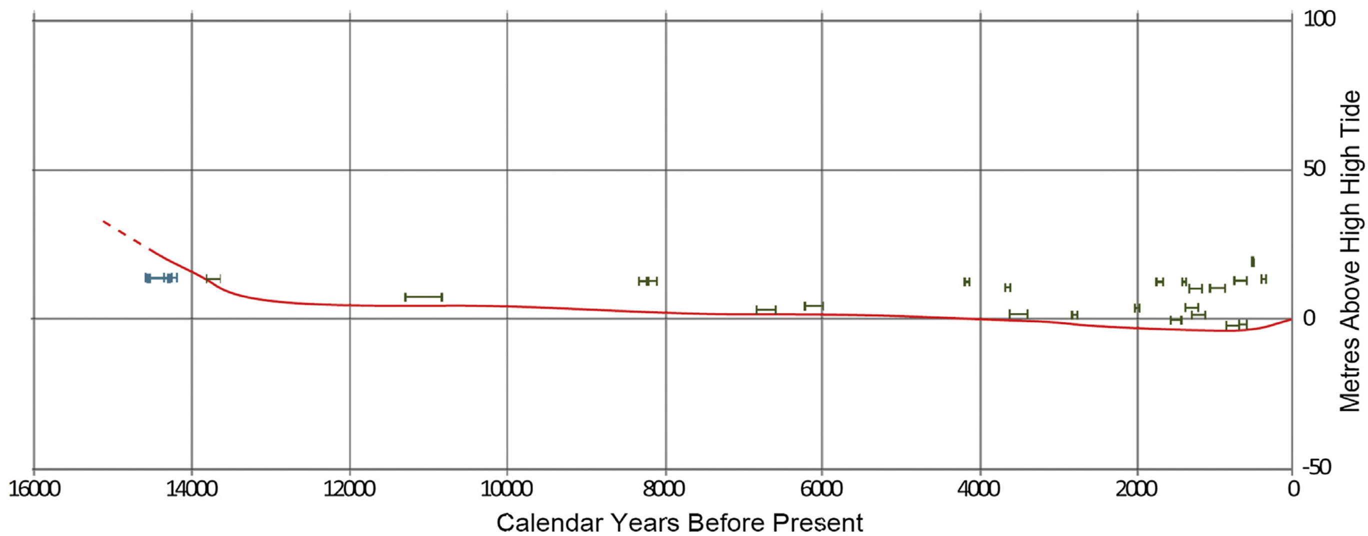

Fig. 11. Index points and sea level curve for the Hakai East region of the study area. Data points are coded as follows: green – above higher high tide, blue – below low tide.

non-glaciated regions around the globe where late-Pleistocene shorelines are drowned by up to 150 m rendering them very difficult to access, or inland areas such as Kitimat or the Fraser Valley where relative sea level was 200 m higher than today and where significant glaciations occurred up until the end of the Pleistocene.

Relative stability in sea level allows for the establishment of persistent places across the landscape. Of the archaeological sites tested, four show persistent occupation for 10,000 or more years: Namu (ElSx1), Kildidt Narrows (ElTa18), Triquet Island (EkTb9), and Pruth Bay (EjTa15). It is highly likely that there are several other sites in the area with equally long records. This pattern of site re-use and persistence differs from settlement patterns on Haida Gwaii (200 km west of the study area) where early and late period sites tend not to co-occur (Mackie and Sumpter, 2005) and where Holocene sea level rose to 15 m ahht and then fell back to modern levels.

The identification of a sea level hinge is of particular interest for investigations into early period archaeology of the Northwest Coast and the peopling of the Americas (Fedje et al., 2004; Mackie et al., 2013). Fladmark (1979) presented a compelling argument in which the Northwest Coast is depicted as the most likely route by which early human inhabitants of the Americas circumnavigated the continental ice sheets that covered much of Canada during the Last Glacial Maximum. In their comprehensive review of the timing of the Last Glacial Maximum, Clague et al. (2004) argue that post

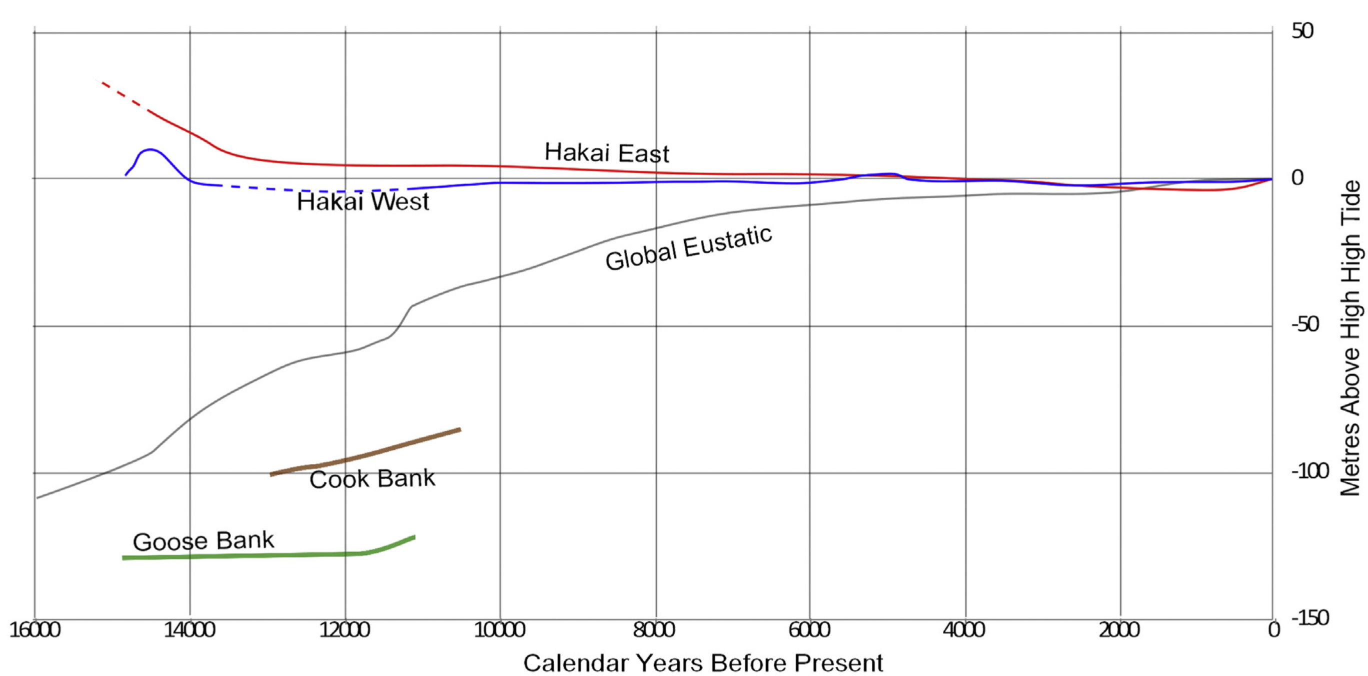

Fig. 12. Relative sea level curves for the study area including global eustatic (Peltier and Fairbanks, 2006), Hakai (West, East) and offshore relative sea level curves (Luternauer et al., 1989; Barrie and Conway, 2002a,b). Data points are coded as follows: green – terrestrial, red – intertidal, blue – marine.

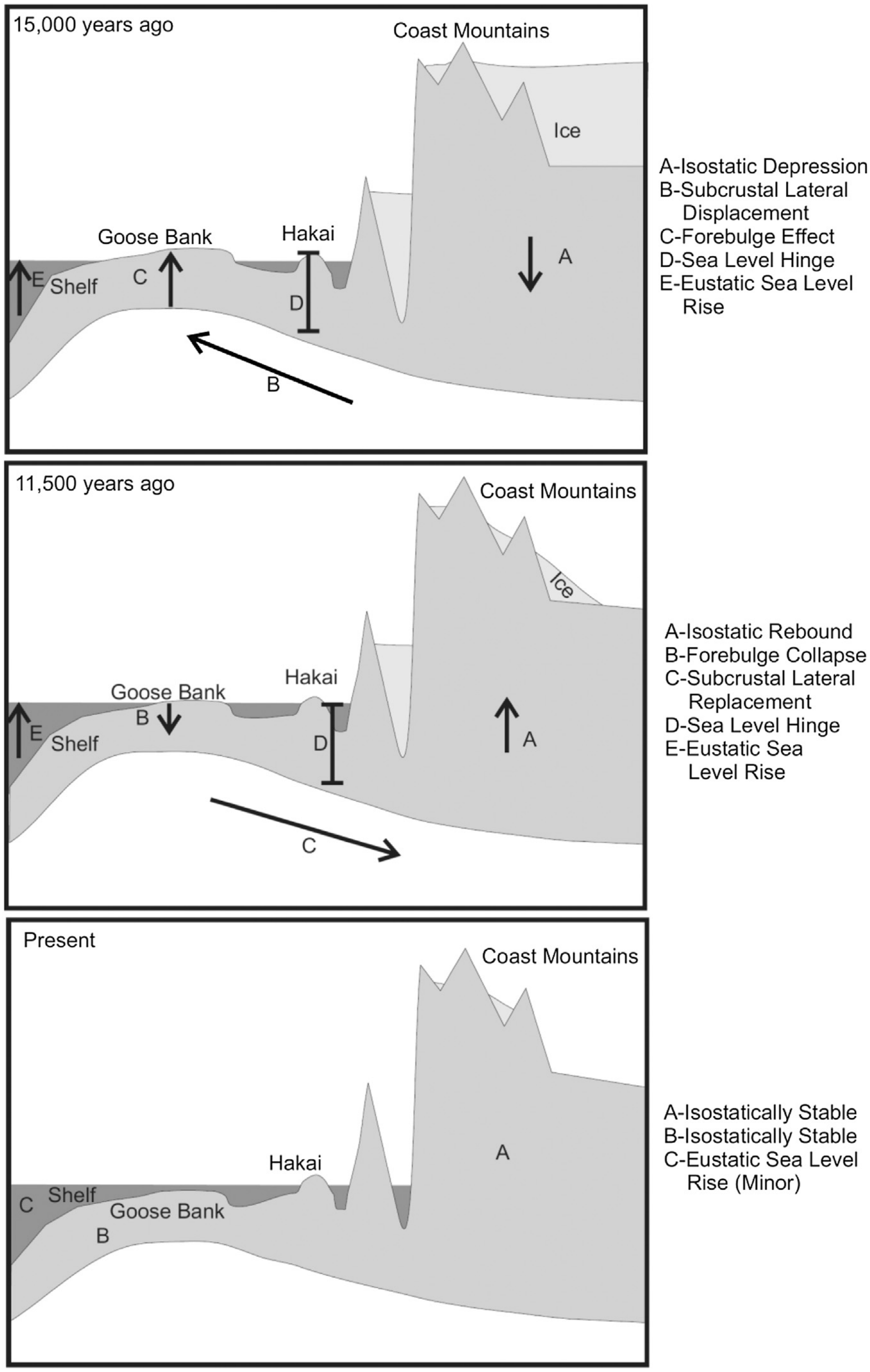

Fig. 13. Stylized cross-section of study area showing the effects of isostatic and eustatic adjustments and the presence of a forebulge on relative sea level through time.

glacial human occupation of outer coastal areas of Southeast Alaska and British Columbia could have occurred as early as 16,000 Cal BP. Early archaeological sites to the south of the ice sheets including Paisley Caves (Gilbert et al., 2008; Jenkins et al., 2012) in Oregon, and Manis Mastodon (Gustafson et al., 1979; Waters et al., 2011) in Washington State, reveal that the western margins of North America was occupied by at least 13,800 Cal BP. The research presented here has revealed potential shoreline targets for archaeological prospection up to 15,000 years old, providing potential for future investigations into the early human occupation of the Americas.

5. Conclusions

This paper describes a relative sea level history spanning the past 15,000 years for the Hakai Passage region on the central Pacific coast of Canada. Data was gathered using geological and archaeological methods. Overall, the research presented here demonstrates that relative sea level remained remarkably constant through this 15,000 year period despite the large scale changes resulting from global eustatic and regional isostatic processes during the same time period. The evidence reveals that isostatic rebound kept pace with eustatic sea level change and uplift over this period. Part of the reason for this stability is that the study area is located on a sea level hinge between a region with higher relative sea level to the east and lower relative sea level to the west. The sea level history of the study area demonstrates that sea level change in ice-proximal regions can be highly variable and localized (see also Shugar et al. 2014). Attempts to model sea level change in any region along the Pacific coast of Canada and southern Alaska need to take local, regional, and global influences into account. The sea level history presented here will enable research to more effectively target sites that have the potential to lengthen the record of human occupation in the region to early post-glacial times.

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