The Comox Harbour Fish Trap Complex: A Large-Scale, Technologically Sophisticated Intertidal Fishery from British Columbia

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Abstract. Results of highly detailed mapping and radiocarbon dating at a vast and largely unknown intertidal fish trap complex indicate a large-scale, technologically sophisticated Aboriginal trap fishery operated at Comox Harbour, Vancouver Island, British Columbia between about 1,300 and 100 years ago. Two temporally and morphologically distinct trap types were utilized, and the shift from the Winged Heart trap type to the Winged Chevron trap type ca. 700 B.P. appears abrupt and closely coincident with Little Ice Age climatic conditions and increased importance of salmon at Aboriginal village sites on west coast Vancouver Island, at Haida Gwaii (Queen Charlotte Islands) and south coast Alaska. Drawing comparisons from closely analogous historical and contemporary North American large-scale traps designed with knowledge of fish behaviour, the Winged Heart and Winged Chevron traps were likely designed to mass harvest herring and salmon, respectively. This study contributes to the wider consideration of marine adaptation on the Pacific Northwest Coast.

Résumé. La cartographie très détaillée et la datation au radiocarbone à un intertidale complexe de piège poissons vaste et largement inconnu indiquent une grande échelle, technologiquement sophistiqué pêcherie autochtone exploité à Comox Harbour, île de Vancouver, en Colombie-Britannique entre 1,300 et 100 ans. Deux types de pièges temporellement et morphologiquement distinctes ont été utilisées, et le changement du type de piège « Winged Heart » à type de piège « Winged Chevron » environ de 700 A.A. semble abrupte et étroite coïncide avec le passage à Petit Âge Glaciaire conditions climatiques et l'importance accrue de saumon sur les sites des villages autochtones sur la côte ouest de l'île de Vancouver, à Haida Gwaii (îles de la Reine-Charlotte) et la côte sud de l'Alaska. D'établir des comparaisons de très analogues pièges à grande échelle en Amérique du Nord historiques et contemporains conçus avec la connaissance du comportement des poissons, les pièges « Winged Heart » et « Winged Chevron » ont probablement été conçues pour la récolte massive du hareng (et autres bancs de poissons pélagiques similaires) et le saumon, respectivement. Cette étude contribue à l'examen plus large de l'adaptation maritime sur la côte nord-ouest du Pacifique.

> *Variations in trap devices depended on the species of fish, the type of environment, the building materials available, and the cultural background of the people. The wide variety of traps seems to underline the Indian's keen observation of marine life, and reflect his ingenuity in harvesting the resources of the sea* [Stewart 1977:99].

This paper reports on a multi-year highly detailed mapping and

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radiocarbon dating study of remarkably well-preserved, large-scale intertidal wood-stake fish traps at Comox Harbour, east-central Vancouver Island, British Columbia (Figures 1a and 1b). Associated with salmon rivers and herring spawning grounds, the trap complex is a vast archaeological resource that was little understood archaeologically prior to this study. During the course of the research, archaeological sites DkSf–43 (Comox Bay Fish Trap site) and DkSf–44 (Goose Spit Fish Trap site) were recorded (Figure 1c) and two temporally and morphologically distinct trap types identified. The large sizes, shapes, and complexity of the Winged Heart and Winged Chevron trap features (Figure 2) have not been recorded previously within the Northwest Coast culture area (Hilary Stewart, personal communication 2004). Following reporting of initial results (Greene 2004, 2005), further mapping and ^{14}C dating (Greene 2010) were conducted to refine interpretation of trap design and function. This paper reviews the ethnographic, archaeological, environmental and paleoenvironmental setting of the study area, introduces data about modern, large-scale stationary trap design and fish behaviour, summarizes methods and results of research and concludes with detailed descriptions of the traps, how they functioned and fish species targeted.

This research not only contributes to knowledge of the technological and functional variability in NWC trap/weir features (cf. Moss and Erlandson 1998:193), but also directly relates to several topics of broader interest in Northwest Coast archaeology. Among these topics are the development of maritime adaptation (Grier 2014), the utilization of intertidal resource management features such as fish traps and clam gardens (e.g., Caldwell et al. 2012; Duer and Turner 2005; Harper et al. 1995; Langdon 2006; Lepofsky and Caldwell 2013; Williams 2006) and a better understanding of the role and significance of herring (McKechnie et al. 2014) relative to salmon (Cannon 2001; Coupland et al. 2010, Finney et al. 2002). Grier notes that there has been an

> approach to accounting for Northwest Coast precontact history [that] overemphasized ... an evolutionary march towards the cultural complexity evident in the ethnographic pattern [and] ... highlighted specialization in salmon resources [Grier 2014:135].

He calls for increasing contextualization of research based on a more refined articulation of local environments and social landscapes (Grier 2014:136). This paper provides an examination of specialized fish traps within the distinct ecological setting of Comox Harbour.

Background

Ethnography

The study area lies within traditional territory of speakers of the Pentlatch language, a component of the Northern Coast Salish division of the Northwest Coast culture area (Kennedy and Bouchard 1990). A wealth of terrestrial and marine resources were available to people living at Comox Harbour (Bouchard 1999; Kennedy and Bouchard 1990; Mackie 1995). Salmon particularly and herring were important to the Pentlatch, but also to other Aboriginal groups who came to Comox to fish or trade for seasonal foods (Kennedy and Bouchard

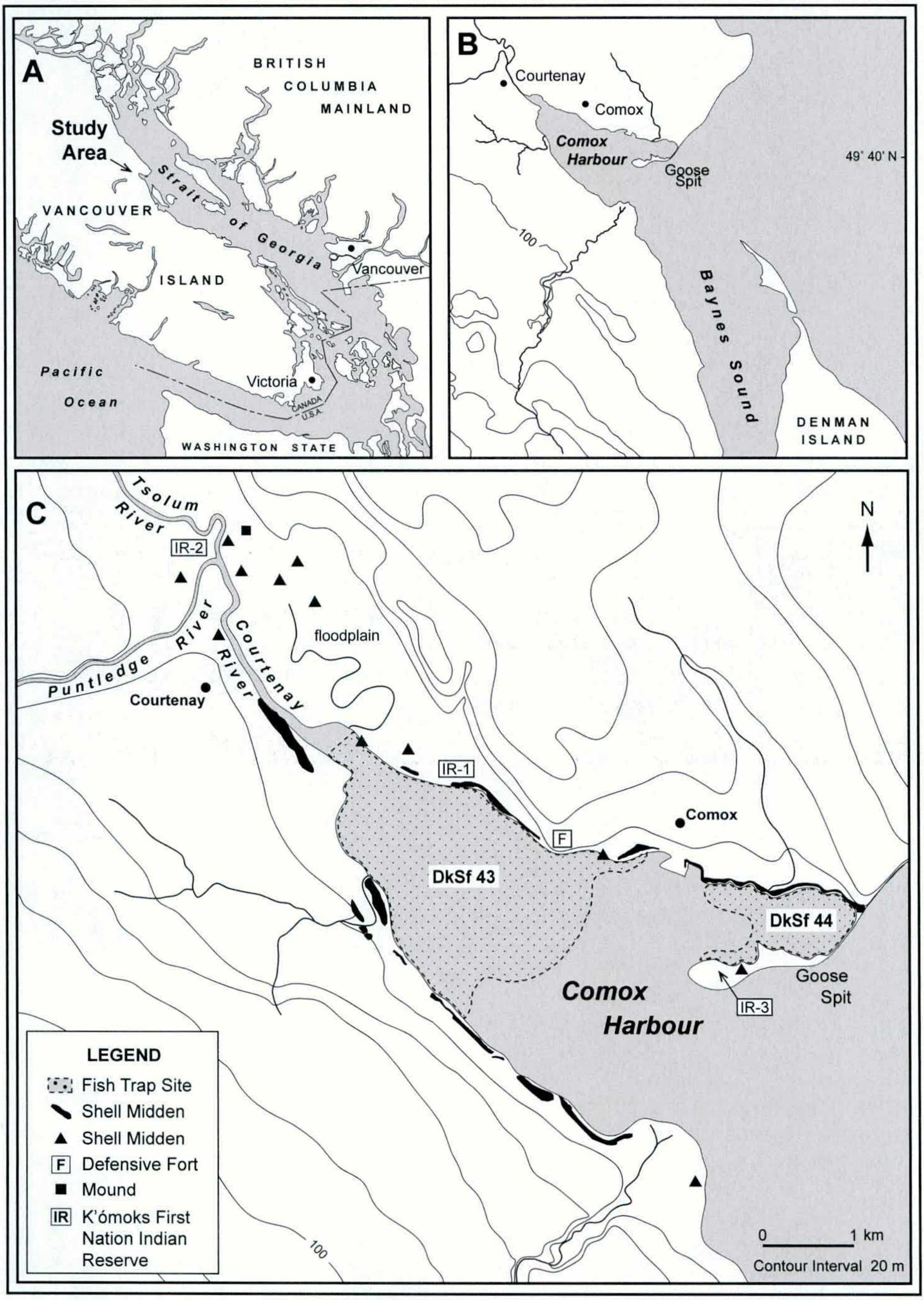

FIGURE 1. Location of the study area. Locations of Comox Bay Fish Trap site (DkSf–43), Goose Spit Fish Trap site (DkSf–44) and other archaeological sites in the area are also indicated.

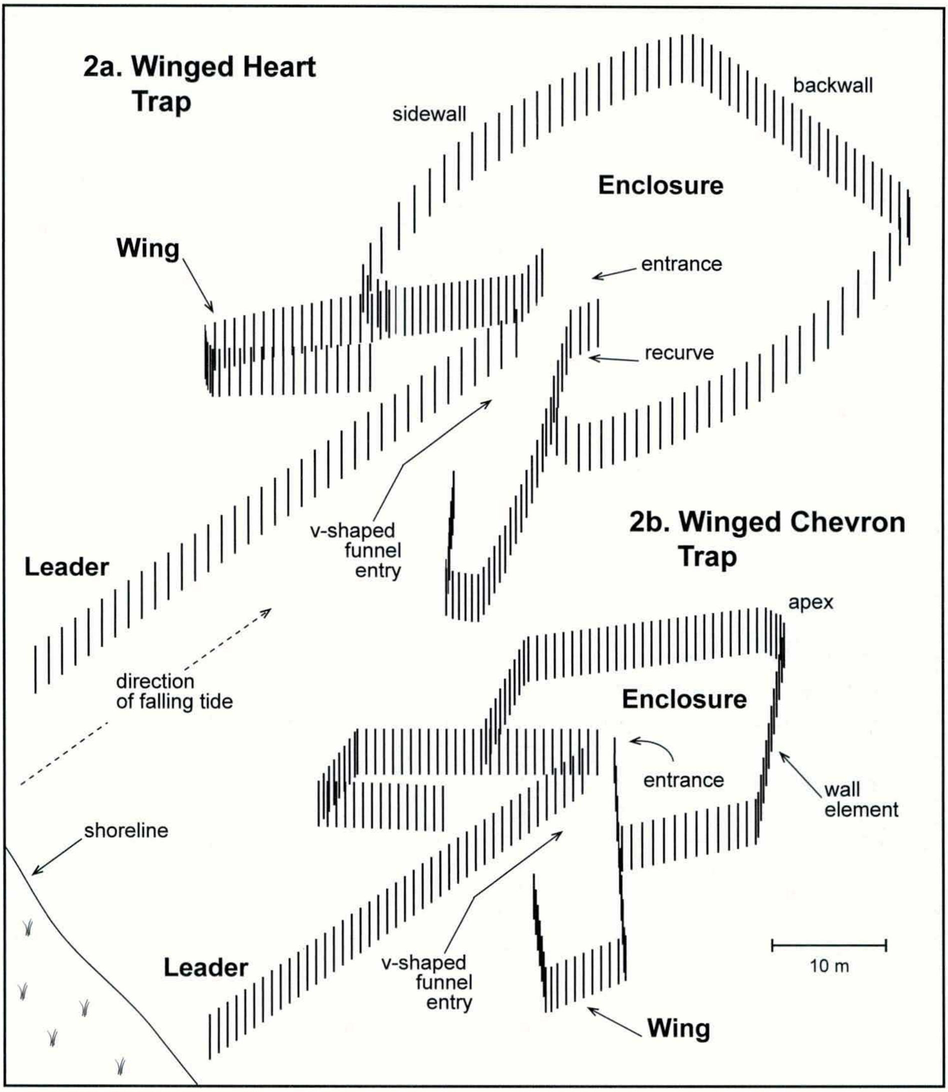

FIGURE 2. Schematic diagrams of the Winged Heart trap and Winged Chevron trap types. Each type is a composite structure built with three components (leader, bilaterally positioned wings and enclosure) arranged along a central line.

1990). Among these, the Lekwiltok (a Kwakwaka'wakw group) "annually visited fisheries at Comox Harbour" (Kennedy and Bouchard 1990:444; also Curtis 1970b:19, 108; Mackie 1995:49). The modern K'ómoks First Nation village (IR-1) (Figure 1c), the most recent version of the ethnographically-known village *q*ʷ*úmuʔx*ʷ*s* (known as the "land of plenty") (Bouchard 1999:13; also Kennedy and Bouchard 1990:443), draws its identity from "Pentlatch, Coast Salish and Kwakiulth traditions" (K'ómoks First Nation 2014; also Everson 2000).

Archaeology

In 1898, Harlan Smith (1907) observed extensive shell midden deposits along the northern shore of the estuary, and remains of immense rectangular houses at IR 1 and in forest near Goose Spit lagoon (Figure 1c). Archaeological research along the estuarine shore suggests occupation for at least 2,000 years (Capes 1964, 1977; Simonsen 1990a) and upland sites extend Aboriginal use of the area to at least 4,000 years ago (Capes 1964; Mitchell 1988; also Pegg et al. 2007:43). Few detailed faunal analyses at midden sites directly associated with trap features have been conducted and these only along the northern shore. Herring typically dominate assemblages and a wide variety of fish taxa are present generally in low frequencies including flatfish, dogfish, salmon, sculpin, skate, rockfish, cod and perch (Caldwell 2008, 2011; Hewer 1998; Simonsen 1990a). Based on the dominance of herring at four auger test sites and in one column sample near IR 1, Caldwell (2008:144) concludes that the Comox Harbour fish traps "were used to target herring and not salmon." Four ^{14}C dates obtained from shell span the period between ca. 1535–1025 cal B.P., and one additional sample dates to approximately 270 cal B.P. (Caldwell 2008:79).

Previous Studies of Fishing Structures at Northwest Coast Intertidal Sites

A review of archaeological research conducted at Northwest Coast intertidal fishing sites indicates widespread use of rock-wall and wood-stake fishing structures to intensively harvest a variety of fish species, particularly salmon (Moss 2013:328). Archaeologists investigating features include Byram 1998, 2002; Caldwell 2008, 2011; Caldwell et al. 2012; Elder et al. 2014; Eldridge and Acheson 1992; Langdon 2006, 2007; Losey 2010; Mobley and McCallum 2001; Monks 1987; Moss et al. 1990; Pomeroy 1976; Schalk and Burtchard 2001; Smethurst 2014; Smith 2011; Tveskov and Erlandson 2003; and White 2006, 2011). Dated sites indicate wood-stake traps/weirs were constructed between ca. 5500 cal B.P. and the twentieth century (Moss 2013).

Environment

Comox Harbour, also known as the Courtenay River estuary, is located on the margin of a narrow, low-relief coastal plain (the Nanaimo Lowland) in the rain shadow of glacially-sculpted peaks and remnant ice fields rising to 2,200 m in elevation (Clague and Bornhold 1980; Morris et al. 1979). The estuary's watershed includes deep-water Comox Lake and the Puntledge and Tsolum rivers which converge to form Courtenay River at the head of a broad, low gradient delta (Figure 1c). Delta sediments are mainly silts and sands, firm under foot, and Goose Spit lagoon is muddy. The estuary is relatively well protected from storm waves by Goose Spit, Denman Island (Figure 1b) and a shallowly submerged bar at the harbour's entrance (Clague 1976). These physiographic features and relatively low historical industrial impact in the estuary (Mackie 2000:212) likely are factors contributing to the excellent preservation of trap features.

Historically, the Puntledge and Tsolum rivers have been significant producers of salmon (*Oncorhynchus spp.*), particularly odd-and even-year pink (*O. gorbuscha*), chum (*O. keta*) and summer and fall-run chinook (*O. tshawytscha*), but also coho (*O. kisutch*), steelhead (*O. mykiss*), cutthroat trout (*O. clarki*) and possibly sockeye (*O. nerka*) salmon (Hamilton et al. 2008; Hancock and Marshall 1985; Hourston 1962). While current sockeye salmon escapement is near non-existent (Department of Fisheries and Oceans [DFO] 1958:12), K'ómoks First Nation traditional knowledge suggests sockeye were present prehistorically (Barnett 1935–1936; Bouchard 1999; Frank 1962; also Hancock and Marshall 1985:85; Jacob 2009). Comox Harbour and the biologically contiguous Baynes Sound estuary (Figure 1b) also support important shellfish and herring (*Clupea pallasii*) fisheries. The area is ranked historically as the most utilized herring spawning area on the British Columbia coast (DFO 2014).

Paleoenvironment

At Comox Harbour, the interaction of changing sea levels and coastal geomorphological processes over millennia have altered the coastal landscape and affected human use patterns (cf. Elder et al. 2014). Here, evidence suggests a sea level about 4 m above present about 6500 cal B.P. (Hutchinson et al. 2004; also Hutchinson 1992), and an average sea level two metres above present ca. 3,000 years ago (Eldridge 1987:iii) likely associated with midden deposits (Mitchell 1988) located near the probable strand line of a "paleo-lagoon" (Hutchinson 1991; Simonsen 1990b) in the area of the modern Courtenay River floodplain (Figure 1c). A "paleo-spit" was situated at the lagoon's seaward terminus (Hutchinson 1991). Subsequently, falling sea levels stabilized about 2,000 years ago, as evidenced by age-altitude relations of archaeological shell midden deposits situated along the modern shoreline (Capes 1964, 1977; Simonsen 1990a), and sea level change since that time has been (at most) on the order of a few decimeters (Ian Hutchinson, personal communication 2005). Evidence suggests the present-day estuary has provided a relatively stable platform for a wood-stake trap fishery for about 2,000 years. Time depth of Northwest Coast intertidal wood-stake trap fishing extends to about 5000 B.P. (Eldridge and Acheson 1992; Moss 2013; Moss and Erlandson 1998; Smith 2011) and Comox Harbour fishing structures older than 2000 B.P. may be buried in the area of the floodplain (cf. Byram 2010), probably the location of the "original estuary of the Puntledge and Tsolum rivers" (Simonsen 1990b:5).

Changes in terrestrial and marine ecologic conditions also may have occurred at Comox Harbour during the period of trap use. High-resolution paleoecological studies from southwestern British Columbia suggest prolonged periods of drought and relatively high wildfire frequency ca. 2400–1300 cal B.P. during the Fraser Valley Fire Period (FVFP) and subsequent Medieval Warm Period (Hallett et al. 2003; Lepofsky et al. 2005; see also Gavin et al. 2003; Lucas and Lacourse 2013). Lepofsky et al. (2005) hypothesize that FVFP conditions likely resulted in summer low freshwater flow, high stream temperatures and decreased salmon abundance particularly at low-elevation, drier locations within the region (e.g., along eastern Vancouver Island). Today, similar conditions in Comox Harbour's watershed and estuary adversely affect salmon productivity (Bravender et al. 2002; Hamilton et al. 2008; Jensen et al. 2006). About 850 B.P., a sharp decline in low elevation west coast Vancouver Island fires (Gavin et al. 2003; also Hallett et al. 2003) appears synchronous with a marked increase in Pacific Northwest precipitation (Steinman et al. 2012), regional cooler-thannormal air temperatures (Luckman and Wilson 2005; Pitman and Smith 2012) and early Little Ice Age (LIA) glacier advance in the southern British Columbia Coast Mountains (Koch and Clague 2011) and Vancouver Island Ranges (Lewis and Smith 2004). Pitman and Smith (2012) suggest coastal alpine British Columbia summer air temperatures were most cool (perhaps greater than two degrees below present) ca. A.D. 1350 (about 600 B.P.). At this time, Pacific Northwest glacially-influenced summer stream temperatures were also likely cool (Fellman et al. 2014) and coastal sea surface temperatures were probably below average (cf. Mantua et al. 1997). Today, such conditions are associated with enhanced growth and survival of salmon in southern British Columbia streams (e.g., Hamilton et al. 2008), and for at least some salmon stocks in marine waters (e.g., Sharma et al. 2013). Similar conditions at the beginning of the LIA may have affected the productivity and availability of fish resources at Comox Harbour.

Methods

This research was conducted in several overlapping phases that each resulted in more precise data regarding wood-stake features visible at the surface of the tidal flats. Here, the term *feature* is defined as a relatively discrete concentration of upright stakes positioned in an alignment or in a non-discernable pattern (cf. Langdon 2007:245). Upon detailed mapping and analyses, some features were defined as fish traps, and when more than one trap was identified they were termed complexes.

During the course of the project all features were recorded on approximately 500 ha of tidal flats and two classes of data were compiled. The first class of data, compiled during pedestrian survey in 2002 (and then periodically as tidal flat sediments shifted and exposed features), included georeferenced feature locations (obtained using a real-time submeter Trimble Pro XRS GPS receiver) and feature descriptions. To facilitate survey at DkSf–43, a temporary large-scale UTM grid was employed in areas of high stake density to help orient the field crew in the relatively nondescript delta landscape. Differential GPS-referenced positions of some grid stakes were later used as survey control points during detailed mapping.

A second class of data was compiled during detailed mapping of features in various areas of DkSf–43 in 2003, and again in 2006 and 2009. Detailed mapping was not conducted at DkSf–44. This phase comprised recording georeferenced positions of individual stakes at selected well-exposed features using either a Nikon DTM330 or a Leica-Wild TC1000 total station. Following recording, data (UTM coordinates) were uploaded into a GIS and highly detailed maps were produced. During recording an effort was made to place the total station's prism reflector on each pin-flagged stake to minimize positional error. Blanket recording of stakes, including stakes found shallowly covered by sediment, was conducted at all features except stake dense linear alignments interpreted as leaders. Here, only spot recordings were made to record orientation and length of the alignments.

A judgmental selection of 56 stakes was sampled for ^{14}C dating from features at DkSf–43 and one stake was selected from site DkSf–44 to establish a chronology of trap construction. Of the 57 stakes dated, 11 were selected in 2004 and 46 stakes were sampled in 2009. Detailed maps of trap features were essential to develop a radiocarbon dating plan to guide selection of samples from individual trap elements. All conventional radiocarbon dates (Table 1) were calibrated to calendar ages using CALIB 7.0 (Stuiver and Reimer 1993) using the IntCal13 dataset (Reimer et al. 2013) and, unless noted otherwise, calibrated dates (cal B.P. median) are used in the text.

TABLE 1. Summary data for radiometric carbon dates (^{14}C) on 56 wooden stakes selected from archaeological site DkSf–43, one stake from DkSf–44 and a large basketry fragment.

Sample # (DkSf–)	Trap Type/ Component Type	^{14}C Age (B.P.)	$\delta^{13}C$ (‰)	2σ Range (cal B.P.)[1]	Cal B.P. Median[2]	Beta Lab Number[3]	Wood Species[4]
Stakes selected from features at archaeological site DkSf-43							
43-003-1	Heart/enclosure	1120 ± 60	–27.1	1178–930	1040	191580	Df
43-003-2	Chevron/enclosure	110 ± 40	–25.5	273–10	120	191581	Df
43-003-3	Chevron/enclosure	490 ± 40	–25.9	626–485	520	269746	Df
43-003-4	Heart/enclosure	1130 ± 40	–27.4	1174–960	1040	269747	Df
43-003-5	Heart/enclosure	1360 ± 40	–26.0	1343–1184	1290	269748	Df
43-003-6	Heart/enclosure	980 ± 60	–27.4	983–743	880	269749	Df
43-004-1	Chevron/enclosure	90 ± 50	–27.4	273–10	120	269771	WH◆
43-004-2	Chevron/enclosure	450 ± 40	–27.1	543–334	510	270479	Df
43-009-1	Chevron/enclosure	220 ± 40	–25.2	318–0	190	191582	Df
43-009-2	Chevron/wing	190 ± 40	–27.6	305–0	180	191583	Df
43-009-3	Heart/enclosure	1060 ± 50	–25.7	1077–828	980	191584	WH
43-009-4	Chevron/enclosure	390 ± 40	–25.6	513–316	450	270480	Df
43-009-5	Chevron/enclosure	430 ± 40	–27.3	536–326	490	270481	Df
43-009-6	Chevron/enclosure	360 ± 60	–26.4	507–305	410	270482	Df
43-012-1	Chevron/enclosure	400 ± 40	–26.3	518–318	460	270483	Df
43-019-1	?/linear alignment	190 ± 60	–26.3	315–0	180	191585	Bm
43-034-1	Chevron/enclosure	490 ± 60	–26.4	649–434	530	269772	Df
43-048-1	Chevron/enclosure	440 ± 60	–26.9	551–315	480	269773	Df
43-048-2	Chevron/enclosure	430 ± 40	–25.9	536–326	490	270484	Df
43-060-1	Heart/enclosure	1100 ± 50	–26.6	1147–928	1020	269750	Df
43-064-1	Heart/enclosure	1220 ± 60	–25.4	1281–989	1150	191587	Df
43-064-2	Heart/enclosure	1210 ± 70	–27.6	1278–981	1140	269751	TF
43-065-1	Heart/enclosure	980 ± 60	–27.4	983–743	880	269752	RA
43-065-2	Chevron/wing	310 ± 60	–26.2	502–282	380	269753	TF
43-065-3	Chevron/enclosure	490 ± 60	–27.1	649–434	530	269754	TF
43-065-4	Chevron/leader	460 ± 40	–27.5	549–335	510	270485	Df
43-066-1	Heart/leader	1140 ± 60	–28.1	1182–933	1060	269755	Df
43-066-2	Heart/enclosure	970 ± 60	–28.1	976–739	870	269756	Df
43-066-3	Heart/enclosure	940 ± 40	–25.6	931–767	850	270486	Df
43-066-4	Heart/enclosure	1150 ± 60	–26.6	1184–935	1070	269757	Df
43-066-5	Heart/wing	1340 ± 60	–30.7	1367–1172	1270	269758	Df
43-067-1	Heart/enclosure	980 ± 60	–26.0	983–743	880	269759	WH
43-067-2	Heart/enclosure	890 ± 60	–26.2	922–700	810	269760	WH
43-067-3	Heart/enclosure	1220 ± 60	–25.1	1281–989	1150	269761	Df
43-067-4	Heart/enclosure	1280 ± 60	–28.1	1298–1068	1210	269762	WH◆

TABLE 1 continued.

Sample # (DkSf–)	Trap Type/ Component Type	^{14}C Age (B.P.)	δ^{13}C (‰)	2σ Range (cal B.P.)[1]	Cal B.P. Median[2]	Beta Lab Number[3]	Wood Species[4]
43-067-5	Heart/wing	1160 ± 60	–29.7	1244–955	1090	269763	Df
43-067-6	Heart/wing	1170 ± 60	–24.8	1257–962	1100	269764	WH
43-067-7	Heart/leader	930 ± 70	–25.3	960–723	840	269765	Df
43-068-1	Heart/leader	1040 ± 40	–27.7	1057–906	950	269766	WH
43-068-2	Heart/wing	1160 ± 60	–27.9	1244–955	1090	269767	TF
43-068-3	Heart/wing	1040 ± 60	–25.6	1071–793	960	269768	Df
43-068-4	Heart/wing	1310±60	–30.2	1318–1073	1240	270487	TF
43-068-5	Heart/wing	1320±60	–27.4	1338–1083	1240	269769	WH◆
43-068-6	Heart/enclosure	990±60	–26.2	1050–764	890	269770	Df
43-083-1	Chevron/enclosure	130±60	–25.4	283–0	140	270488	Df
43-085-1	Chevron/enclosure	190±50	–28.6	307–0	180	269774	Df◆
43-085-2	Chevron/enclosure	510±40	–29.1	632–500	530	270489	Df◆
43-120-1	Chevron/enclosure	110±60	–27.7	281–5	130	270490	TF◆
43-120-2	Chevron/enclosure	130±50	–30.0	281–5	140	269775	TF◆
43-120-3	Chevron/leader	180±40	–26.9	301–0	180	269776	Df
43-121-1	Chevron/enclosure	220±30	–27.7	308–0	180	269777	Df
43-121-2	Chevron/leader	210±40	–25.9	315–0	180	269778	Df
43-122-1	Chevron/enclosure	190±40	–28.3	305–0	180	269779	Df
43-188-1	?/probable leader	150±50	–29.0	285–0	150	191588	RA
43-230-1	Chevron/enclosure	280±50	–29.3	485–150	370	191589	WH
43-269-1	Chevron/enclosure	590±40	–25.5	654–535	600	191590	WH
Stake selected from a feature at archaeological site DkSf-44							
44-012-3	Unidentified feature	870±60	–29.0	914–691	790	193293	WH
Basketry fragment recovered from archaeological site DkSf-43							
43-019-2	Basketry fragment	230±40	–24.9	429–0	210	191586	warp/weft RC◆ wrapping Spruce

[1] 2-sigma calibrations were obtained using CALIB 7.0 and the IntCal13 dataset (Reimer et al. 2013).
[2] Calibrated median calendar ages are rounded to nearest decade.
[3] All but Beta numbers 191580, 191590, 193293, 269760, 269762, 269768, 270482, 270486 and 270487 have multiple intercepts on the calibration curve.
[4] Wood Species: Douglas-fir (Df) *Pseudotsuga menziesii* (Mirb) Franco.; Western Hemlock (WH) *Tsuga heterophylla* (Raf.) Sarg.; True Fir (TF) *Abies* spp.; Red Alder (RA) *Alnus rubra* Bong.; Broadleaf maple (Bm) *Acer macrophyllum* Pursh; Western redcedar (RC) *Thuja plicata* D. Don; Sitka Spruce (SS) *Picea sitchensis* (Bong.). Carr. A diamond (◆) indicates a probable identification. Mary-Lou Florian (Victoria, British Columbia) conducted wooden stake species analyses; Dale Croes and Kathleen Hawes (Pacific Northwest Archaeological Services) conducted analyses and stabilization of the basketry fragment.

Field Survey Results

Locations of 186 wood-stake features were recorded at archaeological site DkSf–43 and ten features were recorded at DkSf–44 (Figure 3). At DkSf–43, features are densely distributed within a 2,300-m-long band of the upper intertidal zone along the southwestern shore of the estuary, in the central area of the delta low in the intertidal profile and in a narrow 1,000-m-long almost continuous band along the northern shore. Stake feature descriptions include spatial relationships of stake alignments, their orientation to the nearest shore and/or direction of the falling tide, functional

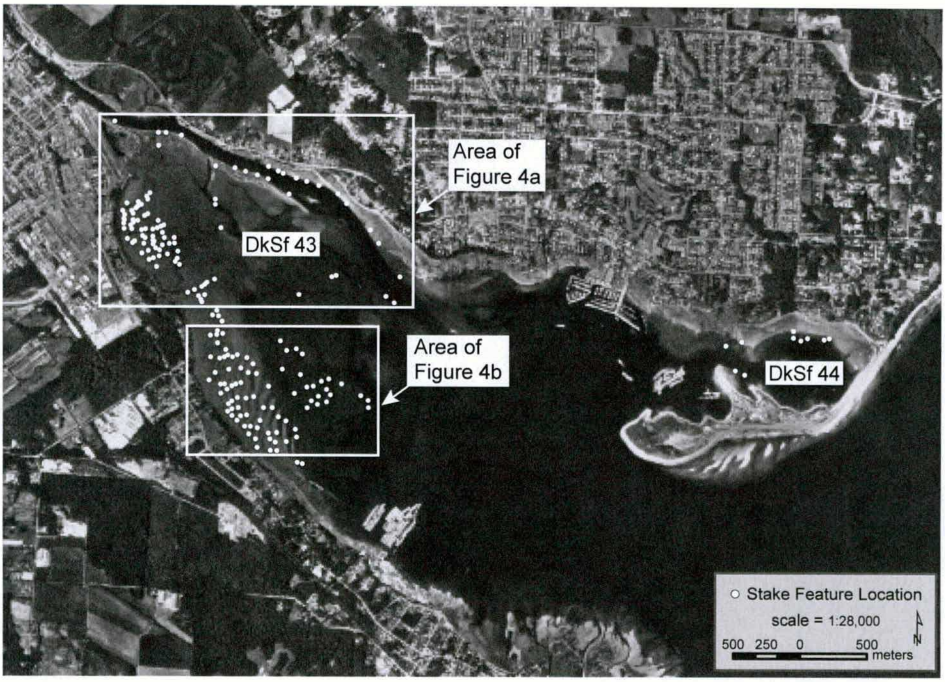

FIGURE 3. Map of Comox Harbour showing the distribution of 186 stake feature locations at archaeological site DkSf–43 and ten features at DkSf–44.

attributes and production of a sketch map, but also may include stake type (i.e., stem or split stakes), density, spacing, diameter, preservation and presence/absence of bark, side branches, or surface modifications. For the purposes of this paper, some of these data are incorporated into feature analyses presented further below, whereas all feature descriptions are presented in Greene (2015). Larger and more stake-dense features at DkSf–43 may display more than a thousand stakes arranged in complexes of overlapping linear, curvilinear and/or v-shaped alignments, and some features display near complete forms characteristic of the trap types (Figures 2a and 2b). Following initial detailed mapping of features and identification of the two trap types, we were able to identify characteristic trap feature elements that enabled assignment of trap type during subsequent survey. Some alignments positioned at an angle to the main Courtenay River tidal channel traversing the northern margin of the estuary could not be assigned to a trap type, and some of these may fall within channel functional feature types described by Byram (1998, 2002). Features recorded in the lagoon at DkSf–44 display small numbers of upright stakes organized in diffuse alignments or non-discernable patterns.

Detailed Mapping and Radiocarbon Dating

UTM coordinates of 13,602 stakes were recorded at 19 of the 186 stake feature locations at archaeological site DkSf–43. These include 11 features situated along the southwestern shore of the estuary, seven in the central area and one feature near the northern shore (see Figures 4a and 4b). Multiple episodes of trap construction were recorded at each location and each feature is a complex of superimposed traps. Summary data of detailed mapping are presented in Table 2 and, for this paper, brief descriptions of mapping conducted at 13 of the 19 complexes are presented further below. All results of detailed mapping are presented in Greene (2015). A summary of the total number of traps (n = 323) and trap types recorded during both field survey and detailed mapping is presented in Table 3. Trap types (Figures 2a and 2b) include 72 Winged Heart traps, 169 Winged Chevron traps and 82 discrete linear stake alignments, interpreted as leaders, which are counted as traps of unknown type. Discrete concentrations of stakes at an additional 62 locations are positioned in non-discernable patterns. These features may comprise unidentified components of Winged Heart or Winged Chevron traps, or perhaps other types of fishing structures that functioned in a different manner or during a different time.

TABLE 2. Summary data of detailed mapping conducted at 19 trap complexes at DkSf–43.

Complex # (DkSf–)	Tide Level*	Number of Each Trap Type		Number of Stakes Recorded	Approx. Area Mapped (m^2)
		Winged Heart	Winged Chevron		
43-003	3.4	4	3	1,106	1,600
43-004	1.5	–	9	626	3,400
43-009	1.5	1	4	1,143	2,400
43-011	1.6	1	4	599	2,000
43-012	1.7	–	2	330	600
43-034	1.7	–	5	646	1,700
43-048	3.0	–	8	1,186	5,000
43-060	4.0	1	–	100	400
43-064	3.8	2	–	365	300
43-065	–	1	2	2,203	3,200
43-066	3.6	4	–	899	1,500
43-067	3.4	5	–	1,008	1,700
43-068	3.3	4	–	680	1,500
43-085	1.8	–	9	769	5,800
43-120	3.4	–	2	235	600
43-121	3.5	–	1	170	500
43-122	3.7	–	1	52	200
43-130	1.5	1	5	424	4,200
43-230	–	–	7	1,061	6,000
Grand Total:		**24**	**62**	**13,602**	**42,600**

*Tide Levels are in meters above chart datum: Maximum Tidal Range is 5.4 m; Mean Higher High Water is 4.7 m; Mean Water is 3.3 m; Mean Lower Low Water is 1.3 m (CHS 2001).

Chronology

Results of radiocarbon dating indicate the Comox Harbour fish traps were constructed from about 1300 B.P. to 100 B.P. (Figure 5). Further, the calibrated range of dates indicate features cluster into two distinct periods that define the range of use of the two trap types: 27 dates obtained from elements of Winged Heart traps at archaeological site DkSf–43 and one date from an unidentified feature at Goose Spit lagoon (sample 44-012-3) cluster between approximately 1300 B.P. and 800 B.P., and 28 dates selected from Winged Chevron trap features fall into a second cluster between about 600 B.P. and 100 B.P. One stake (sample 43-019-1), selected from an alignment associated with an excavated basketry fragment (described further below), cannot be assigned to a known trap type and is included with the Winged Chevron trap cluster of dates based on its age.

Trap Complexes

Results of detailed mapping conducted at 13 complexes most representative of the trap types are presented below. Complexes 43-003, 43-064, 43-065, 43-066, 43-067, 43-068, 43-120, 43-121 and 43-122 are located along the southwestern shore and complexes 43-004, 43-009, 43-034 and 43-085 are situated low in the intertidal zone in the center of the delta.

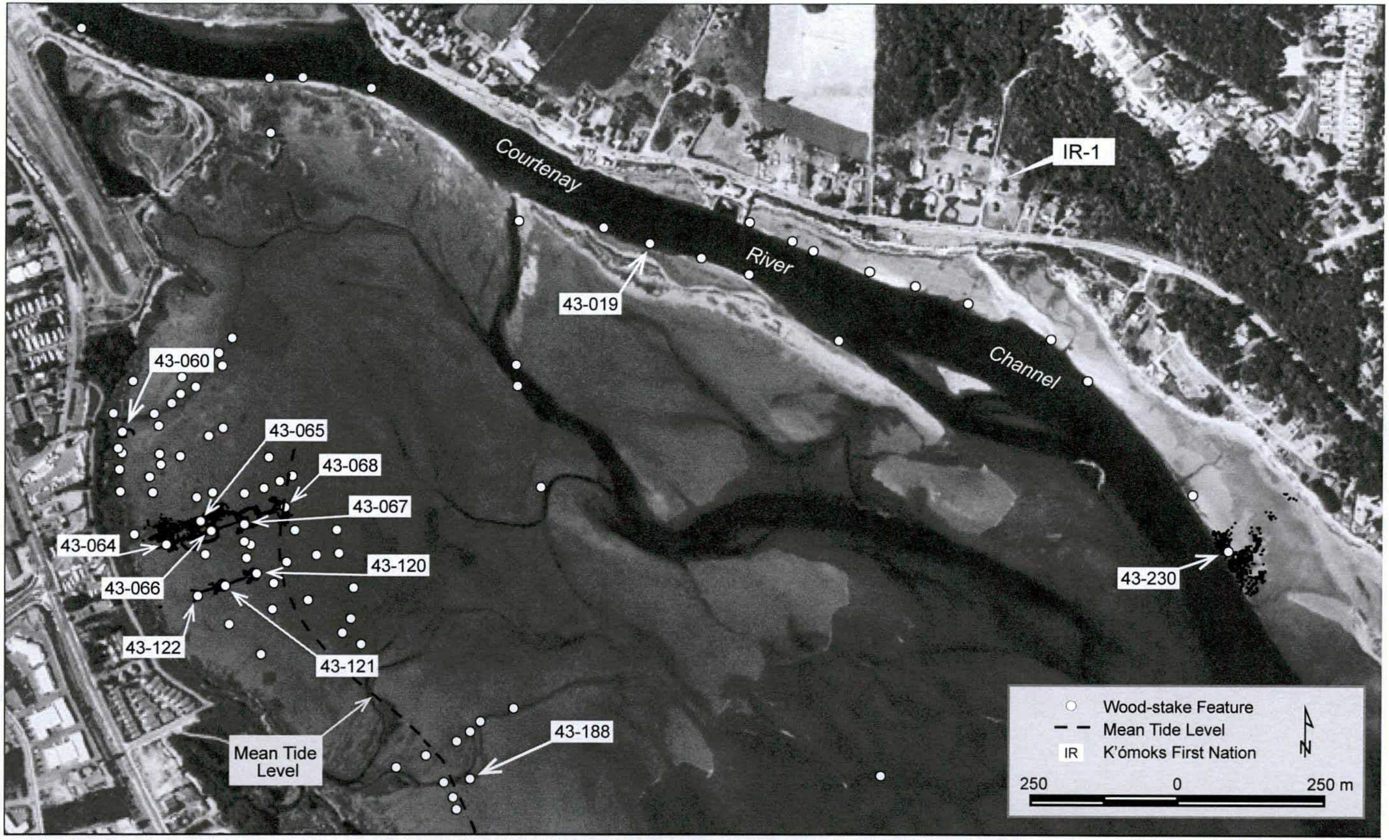

FIGURE 4a. Map of the northern portion of archaeological site DkSf–43. White dots indicate locations of stake features recorded during survey and small-scale representations of trap complexes mapped in detail are shown in black. Features 43-019 and 43-188 were radiocarbon dated but not mapped in detail. Mean tide level (3.3 m) is indicated.

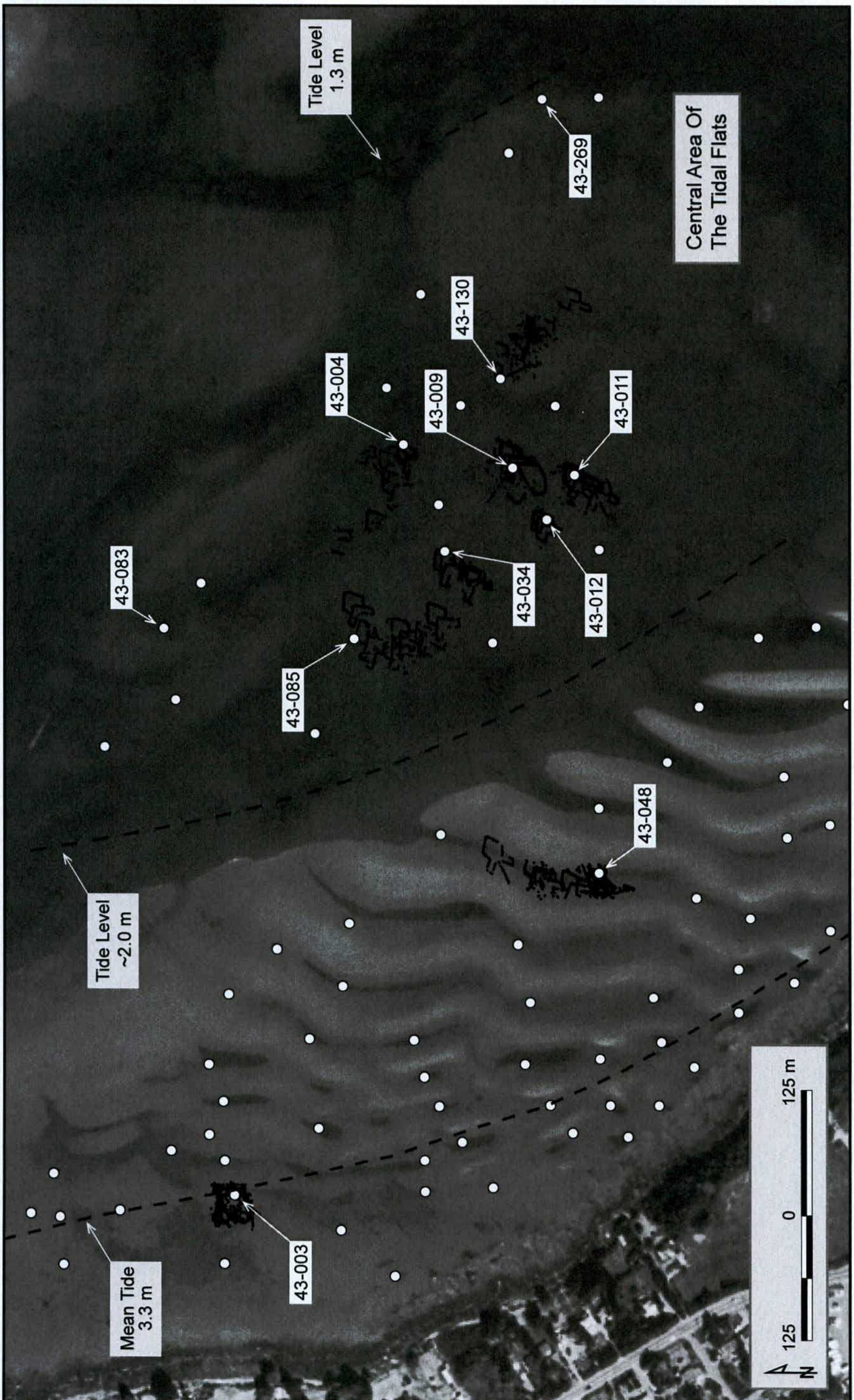

FIGURE 4b. Map of the southern portion of DkSf–43. White dots indicate stake feature locations recorded during survey and small-scale representations of trap complexes mapped in detail are shown in black. Features 43-083 and 43-269 were radiocarbon dated but not mapped in detail.

TABLE 3. Summary of trap numbers (n = 323) and types recorded at sites DkSf-43 and DkSf-44.

Feature # (DkSf–)[1]	Trap Type				Mapping Type		Feature # (DkSf–)[1]	Trap Type				Mapping Type	
	Winged Heart	Winged Chevron	Unknown[2]	Unidentified Feature	Detailed	Field only		Winged Heart	Winged Chevron	Unknown[2]	Unidentified Feature	Detailed	Field only
43-003	4	3			x		43-068	4				x	
43-004		9			x		43-069				x		x
43-005		2				x	**43-079**		3				x
43-006	3	2				x	**43-080**		2				x
43-008		2				x	**43-081**		2				x
43-009	1	4			x		**43-083**		1				x
43-010		1				x	**43-084**		2				x
43-011	1	4			x		**43-085**		9			x	
43-012		2			x		43-087		2				x
43-013				x		x	43-088		2				x
43-015				x		x	43-089	1		1			x
43-016				x		x	43-090		2				x
43-017				x		x	43-091		1				x
43-018				x		x	43-092				x		x
43-019				x		x	43-093		2				x
43-023		2	2			x	43-094		2				x
43-024		2				x	43-095		1				x
43-025		2				x	43-096		1	1			x
43-026		2				x	43-098		1				x
43-027				x		x	43-099		1				x
43-028		2	3			x	43-100				x		x
43-029		2	1			x	43-101				x		x
43-030		3				x	**43-103**				x		x
43-031				x		x	**43-104**				x		x
43-032				x		x	**43-105**		1				x
43-033		3				x	**43-106**		3				x
43-034		5			x		**43-107**				x		x
43-035		2				x	43-108				x		x
43-036		3				x	43-109				x		x
43-044			1			x	43-110				x		x
43-045		1	4			x	43-111				x		x
43-046		1				x	43-112				x		x
43-047			2			x	43-113				x		x
43-048		8			x		43-114				x		x
43-050	1	1				x	43-115				x		x
43-051	1	1				x	43-116				x		x
43-052			4			x	43-119		1				x
43-053				x		x	43-120		2			x	
43-054			2			x	43-121		1			x	
43-055		2				x	43-122		1			x	
43-056				x		x	**43-130**	1	5			x	
43-058			1			x	43-131				x		x
43-059		2	2			x	43-132	1	1				x
43-060	1				x		43-133	1					x
43-061			1			x	43-135	1					x
43-062	1					x	43-136				x		x
43-064	2				x		43-137		1				x
43-065	1	2	4		x		43-138		1				x
43-066	4				x		43-139			1			x
43-067	5				x		43-140	1					x
43-142		1				x	43-213				x		x
43-144			1			x	43-214	1	2				x
43-145			1			x	43-215		1				x

TABLE 3 continued.

Feature # (DkSf–)[1]	Trap Type				Mapping Type		Feature # (DkSf–)[1]	Trap Type				Mapping Type	
	Winged Heart	Winged Chevron	Unknown[2]	Unidentified Feature	Detailed	Field only		Winged Heart	Winged Chevron	Unknown[2]	Unidentified Feature	Detailed	Field only
43-146			1			x	43-216	1					x
43-147				x		x	43-217				x		x
43-148				x		x	43-218		2	2			x
43-151			2			x	43-219	1					x
43-152			1			x	43-221			2			x
43-153		1	2			x	43-222		1				x
43-154			1			x	43-223			3			x
43-156		3				x	43-230		7			x	
43-157				x		x	43-235		1				x
43-158	2		2			x	43-236			1			x
43-159			1			x	43-237				x		x
43-163				x		x	43-238			1			x
43-164		3				x	43-239		1				x
43-169		3				x	43-240				x		x
43-170				x		x	43-241			1			x
43-171			1			x	43-242			1			x
43-173		3				x	43-244	1					x
43-175	2					x	43-246	1					x
43-176	3	1				x	43-247	3					x
43-177			1			x	43-248	3					x
43-178	2					x	43-249				x		x
43-179	2	1				x	43-250				x		x
43-180		1				x	43-259	3					x
43-181		1				x	43-260		1				x
43-182				x		x	43-261				x		x
43-183				x		x	43-262		1	2			x
43-184				x		x	43-263		1				x
43-185				x		x	43-264	2					x
43-186				x		x	43-266	4					x
43-187		1				x	43-267	4					x
43-188			3			x	**43-269**		1				x
43-190	1	1				x	**43-270**				x		x
43-191		2				x	**43-271**				x		x
43-192			4			x	44-001				x		x
43-193				x		x	44-002				x		x
43-200	1					x	44-003				x		x
43-201			1			x	44-004				x		x
43-202		1				x	44-005				x		x
43-203			1			x	44-006				x		x
43-205			1			x	44-007				x		x
43-206			2			x	44-008				x		x
43-207				x		x	44-009				x		x
43-208				x		x	44-010				x		x
43-209			8			x	**Grand Totals**	**72**	**169**	**82**	**62**	**19**	**177**
43-210			5			x							
43-211		1				x			**323**			**196**	
43-212				x		x							

[1] Feature numbers shown in bold indicate features located in the central area of the tidal flats low in the intertidal profile; all other features are situated above or near mean tide.

[2] A linear alignment of stakes that is oriented perpendicular to the shore (interpreted as a leader) and is not associated with a recorded Winged Heart or Winged Chevron trap is counted as a trap of unknown type.

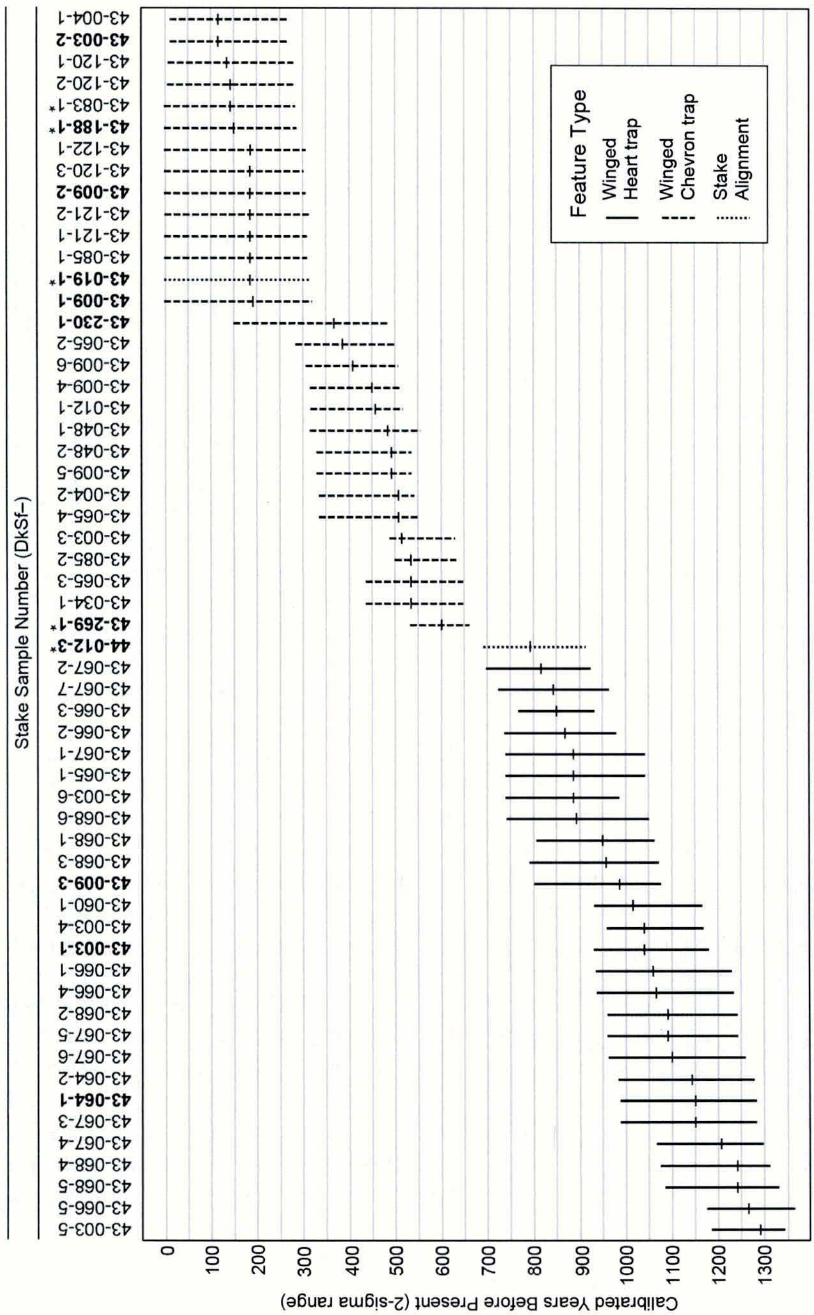

FIGURE 5. Temporal distribution of 56 calibrated [14]C dates obtained from stake features at archaeological site DkSf–43 and one stake from DkSf–44 (sample 44-012-3). Vertical bars show the error range at 2-sigma and horizontal bars show cal B.P. median. Sample numbers in bold type indicate stakes selected in 2004 and other stakes were sampled in 2009. An asterisk indicates a stake selected from a feature not mapped in detail.

Complex 43-003

This complex is situated at an approximately 3.3 m tidal elevation (present-day mean water level) about 150 m from the southwestern shore of the estuary (Figure 4b). Positions of 1,106 upright stakes distributed over approximately 1,600 m² were recorded, and results of mapping and ^{14}C dating indicate at least four Winged Heart traps and three Winged Chevron traps were built and rebuilt in the same footprint over about 1,000 years between 1290 B.P. and 120 B.P. (Figure 6). Trap enclosures of both trap types, built with relatively robust stakes, are the most well-preserved components, while linear alignments interpreted as leaders and wing wall elements built with relatively small diameter stakes are less well preserved. All trap entrances open toward the shore and a 17 m linear arrangement of stakes (Feature 43-003-3), interpreted as a Winged Chevron trap leader, is oriented perpendicular to the shore and aligned with the direction of the falling tide.

Complexes 43-064, 43-065, 43-066, 43-067 and 43-068

The most dramatic features at Comox Harbour are displayed in a large cluster of discrete trap complexes (hereafter the 064-068 series) located in a feature-dense area close to the southwestern shore of the estuary (Figure 4a). Here, as sediments shifted and exposed new features over several years, we recorded the positions of more than 5,000 stakes distributed over approximately 8,000 m² resulting in the production of a highly detailed composite map dominated by large-scale Winged Heart trap features (Figure 7). Twenty-one stake samples were selected to ^{14}C date Winged Heart trap features and three stakes were selected from Winged Chevron traps. Results indicate multiple episodes of trap construction between approximately 1270 and 380 B.P.

Results of mapping and ^{14}C dating also suggest that at least some of the Winged Heart traps may have functioned as components of a larger design of traps connected sequentially across depths along a central line using leaders (Figure 7). When median calibrated radiocarbon dates are compared within traps at complexes 43-064, 43-066, 43-067 and 43-068, these suggest that serially linked traps were constructed or reconstructed at approximately the same time (Figure 8). In this example, a series of linked Winged Heart traps was constructed at approximately 1270–1210 B.P. (i.e., median dates 1270–1210–1240–1240 B.P. at complexes 43-066, 43-067, 43-068); possibly again about 1150 B.P. (median dates 1140–1150–1150 B.P. at complexes 43-064 and 43-067); then rebuilt between 1100–1060 B.P. (median dates 1070–1060–1100–1090–1090 B.P. at complexes 43-066, 43-067, 43-068); perhaps again about 960 B.P. (median dates 960–950 B.P. at complex 43-068); once again between 890–870 B.P. (median dates 870–880–890 B.P. at complexes 43-066, 43-067, 43-068); and then again between 850–810 B.P. (median dates 850–840–810 B.P. at complexes 43-066 and 43-067). These sequences of dates suggest that the linked Winged Heart trap systems may have been rebuilt at about 40–110 year intervals, and used for about 400 years between about 1240 and 840 B.P. (Figure 8, right column).

The serially linked Winged Heart trap systems were constructed with traps that incorporated large enclosures and recurved walls on either side of a trap's wide entrance (Figure 7; and cf. Figure 2a). An approximately 5 m wide entrance into one well-preserved

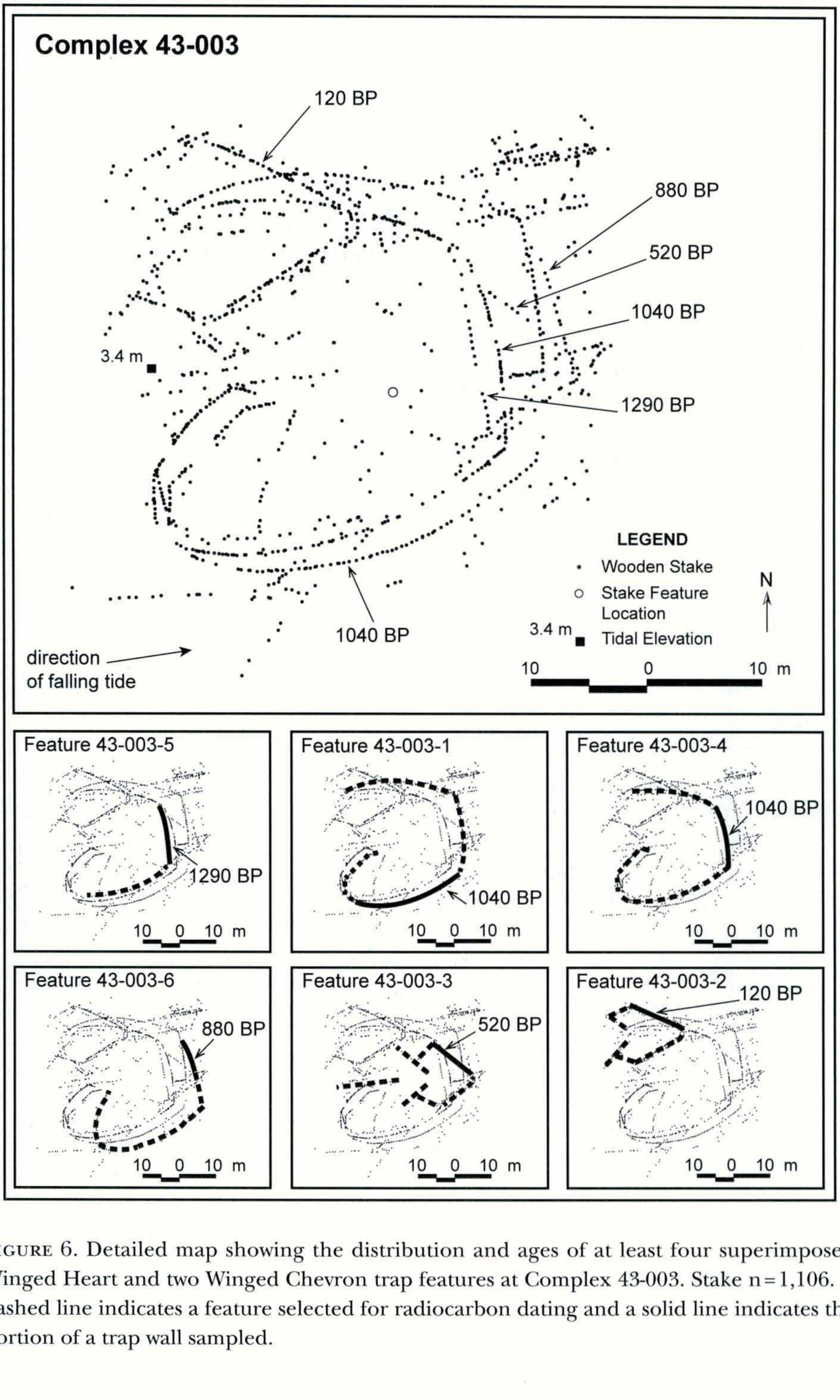

FIGURE 6. Detailed map showing the distribution and ages of at least four superimposed Winged Heart and two Winged Chevron trap features at Complex 43-003. Stake n = 1,106. A dashed line indicates a feature selected for radiocarbon dating and a solid line indicates the portion of a trap wall sampled.

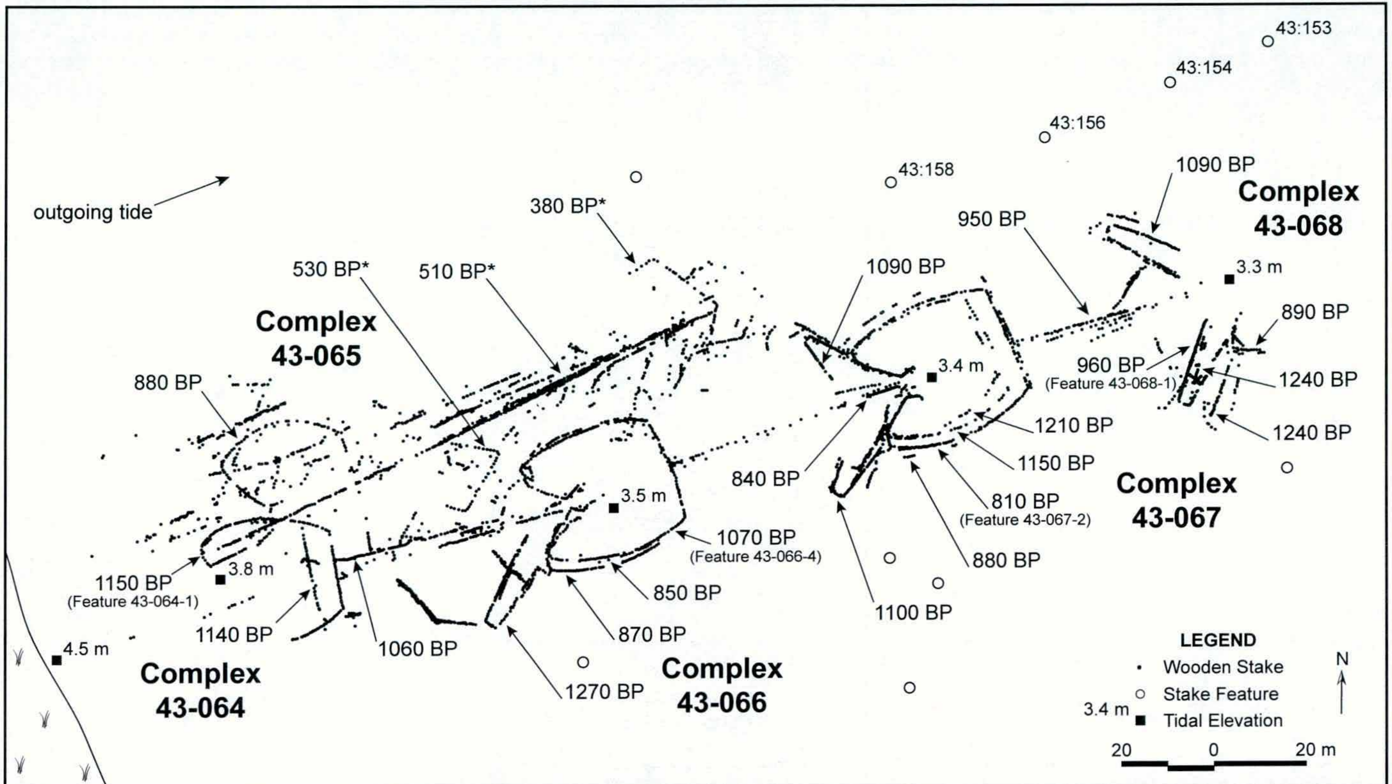

FIGURE 7. Detailed map illustrating the distribution and ages of Winged Heart and Winged Chevron trap features at complexes 43-064, 43-065, 43-066, 43-067 and 43-068. An asterisk indicates a date obtained from a Winged Chevron trap and small circles represent features recorded during survey but not mapped in detail. Winged Heart traps at complexes 43-064, 43-066, 43-067 and 43-068 appear to have functioned as components of a larger design of traps connected sequentially along a central line across depths. Mean tide level is 3.3 m.

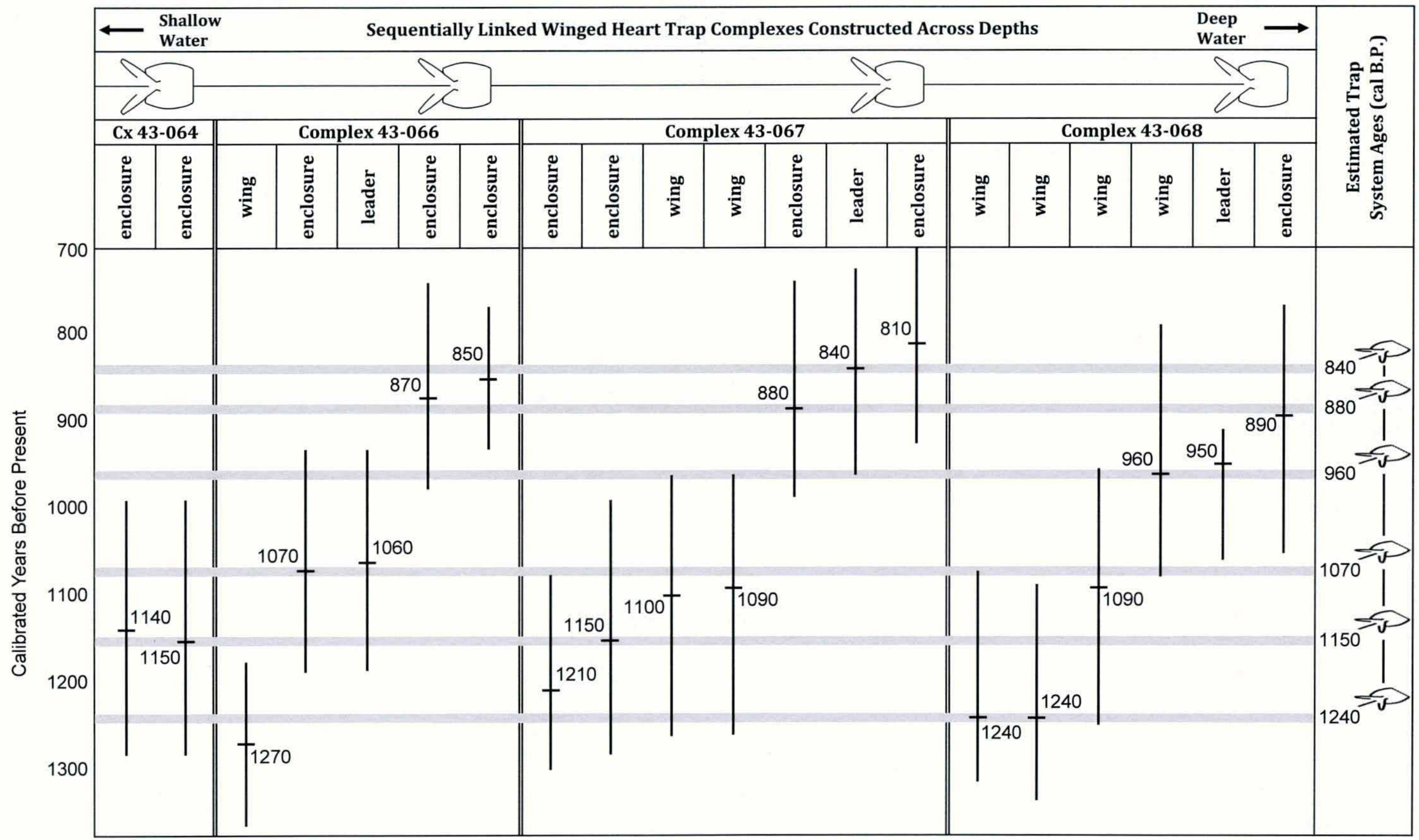

FIGURE 8. Temporal distribution of calibrated radiocarbon dates obtained from components of multiple episodes of construction of linked Winged Heart trap complexes 43-064, 43-066, 43-067 and 43-068 (Figure 7). Vertical bars show the error range of dates at 2-sigma, black horizontal bars indicate cal B.P. median and gray horizontal bars show estimated ages of the linked trap systems.

trap enclosure is illustrated at complex 43-067. If the 064-068 series extended to the western shore, the complete structure would have been at least 300 m in length. We were unable to locate remains of leader or wing components in pebbly sediment at the shoreward end of the 064-068 series, and some components at complex 43-068 were not exposed during detailed mapping in 2009. Since that time, sediments shifted and remains of three Winged Heart trap enclosures have been recorded at Complex 43-068; these are not illustrated in Figure 7.

Winged Chevron trap features were recorded only at complex 43-065 (Figure 7). Radiocarbon dates of 530 B.P. and 380 B.P. were obtained from features interpreted as enclosure and wing components, respectively, and a single date recovered from a 130 m long linear feature interpreted as multiple leaders yielded an estimate of 510 B.P. One or more of these linear alignments may be temporally and functionally associated with similarly aligned Winged Chevron trap features recorded during survey (not mapped in detail) at features 43-156, 43-154 and 43-153 (Figure 7, upper right). In the same orientation of features, feature 43-158 is a complex of Winged Heart traps that was superseded by the Winged Chevron traps at this location.

Complexes 43-120, 43-121 and 43-122

Approximately 200 m south of the 064-068 series (cf. Figure 4a), 457 stakes were recorded and a detailed map was produced that illustrates three Winged Chevron trap complexes (Figure 9), hereafter termed the 120-series. These appear to be connected by leaders and arranged sequentially along a central line across depths similar to serially linked traps described previously in the 064-068 series. Six stakes selected for radiocarbon dating suggest three traps were built between 180–140 B.P. (median dates 180–180–180–180–140 B.P. at complexes 43-122, 43-121, 43-120), and a second trap was constructed about 130 B.P. (complex 43-120). Of particular interest, detail of complex 43-121 (Figure 9a) clearly illustrates a narrow space of 0.27 m between two stakes situated at the apex of the trap's V-shaped wings. This space is interpreted as the entrance into the trap's terminal enclosure. The 120-series would have extended at least 190 m seaward from the shore (Figure 9b), and three additional Winged Chevron trap features (features 43-263, 43-262 and 43-260) recorded during survey but not mapped in detail (Figure 9b, upper right) may further extend the trap series seaward. If traps in these features are contemporaneous with traps in the 120-series, the overall structure (comprising six complexes) may have been about 320 m in length. A six meter long alignment (a probable portion of a leader) at the apex of feature 43-120-2 (Figure 9) reinforces the possibility of an extended trap system.

Immediately south of the 120-series (see Figure 9b), a second linked Winged Heart trap system comprising four complexes (43-264, 43-266, 43-267 and 43-259) was also recorded but not mapped in detail, and an additional five Winged Heart and nine serially linked Winged Chevron trap systems were recorded elsewhere along the southwestern shore. A map illustrating their distribution is presented in Greene (2015).

Complexes 43-004, 43-009, 43-034 and 43-085

The central area of the tidal flats, defined as the area situated between

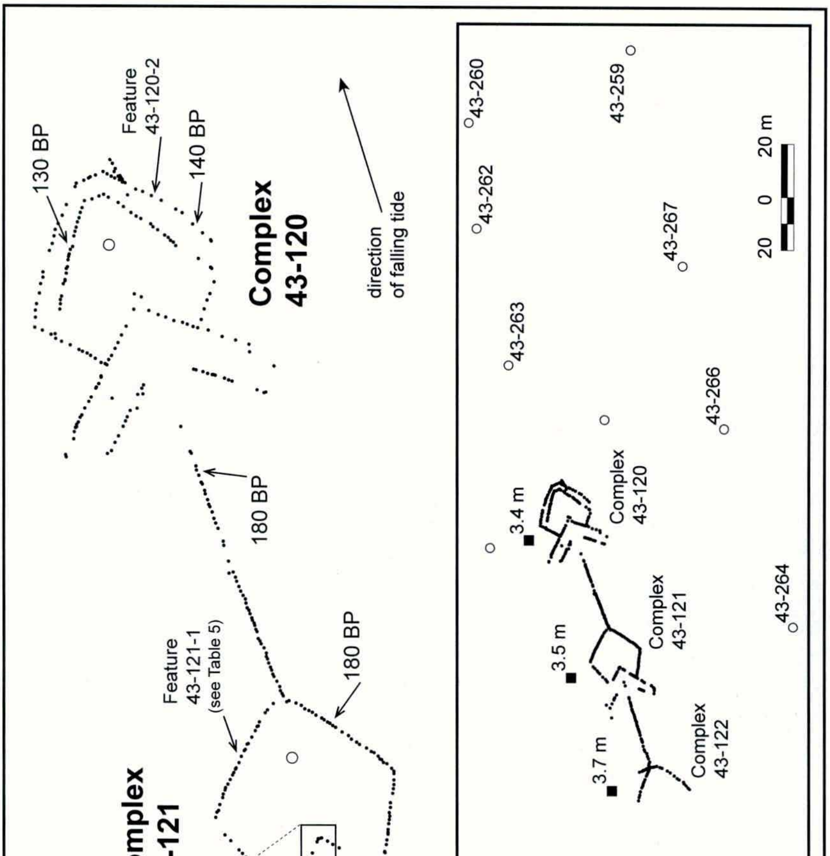

FIGURE 9. Detailed map illustrating the distribution and ages of linked Winged Chevron trap features at complexes 43-122, 43-121 and 43-120. Stake n=457. Figure 9a illustrates the inferred entrance into the enclosure at complex 43-121, and Figure 9b shows the orientation of the trap system to the shore and other features (small circles) not mapped in detail. Mean tide is 3.3 m.

the approximately +1.3 and +2.0 m tide levels, is submerged below tidal waters about 85 to 95 percent of the year (John Harper, personal communication 2006). Here, 27 stake feature locations were recorded during survey and, of these, seven complexes (43-004, 43-009, 43-011, 43-012, 43-034, 43-085 and 43-130) were mapped in detail (Figure 4b; also Greene 2015). Mapping conducted at complexes 43-004, 43-034, 43-085 (Figure 10) illustrates the intensive use of Winged Chevron traps in the lower intertidal zone and trap consistency in form and orientation to the direction of the falling tide. A schematic (Figure 11) derived from complex 43-085 illustrates structural and functional attribute values that characterize the bilaterally symmetrical form and complex design elements of the trap type. Thirty-eight Winged Chevron traps were identified among the seven stake feature locations mapped in detail. If we include the number of traps recorded during survey (n=28), a total of 66 Winged Chevron traps were recorded in the central area (Table 3).

In contrast, only one Winged Heart trap has been identified conclusively in the area (Figure 12; also Figure 13), and two additional features appear to exhibit attributes characteristic of the trap type. The large Winged Heart trap recorded at complex 43-009 has a fish impounding area of about 1,200 m^2 and an entrance approximately 7 m (estimated) in width leading into the trap's enclosure. Despite concerted effort during mapping, no stakes associated with wings were located for this feature, possibly due to differential preservation or poor exposure, or perhaps this trap functioned without wings. Four superimposed Winged Chevron traps are also illustrated in Figure 12, and two of these (features 43-009-1 and 43-009-4) exhibit narrow entrances 1.1 m and 1.0 m in width, respectively, leading into terminal enclosures.

Fourteen stakes were selected for radiocarbon dating in the central area of archaeological site DkSf–43. Results indicate Winged Chevron traps were built between approximately 600 B.P. (complex 43-269) and 120 B.P. (complex 43-004), and the Winged Heart trap at complex 43-009 was constructed about 980 B.P. Two of these stakes, one each selected from an enclosure and a wing of a Winged Chevron trap (Feature 43-009-1 illustrated at Figure 12), yielded statistically indistinguishable median dates of 190 cal B.P. (Beta-191582) and 180 cal B.P. (Beta-191583) (Table 1), respectively, and we conclude that the enclosure and wing components of the trap were probably constructed contemporaneously.

Feature and Artifact Characterization

Trap Feature Types

The Winged Heart and Winged Chevron traps (Figures 2a and 2b) are large-scale, structurally complex, similarly configured composite structures built with three components arranged along a central line. The leader (component 1) of each type is oriented more or less perpendicular to the nearest shore and is, thus, generally aligned with the direction of the falling tide. This linear alignment bisects a pair of bilaterally positioned wing structures (component 2) that form a wide-angle V-shaped funnel entry, open toward the shore, which terminates seaward at the entrance into a single fish impounding enclosure (component 3). The leader does not appear to penetrate the entrance into the terminal enclosure of either trap type. Both trap designs dis-

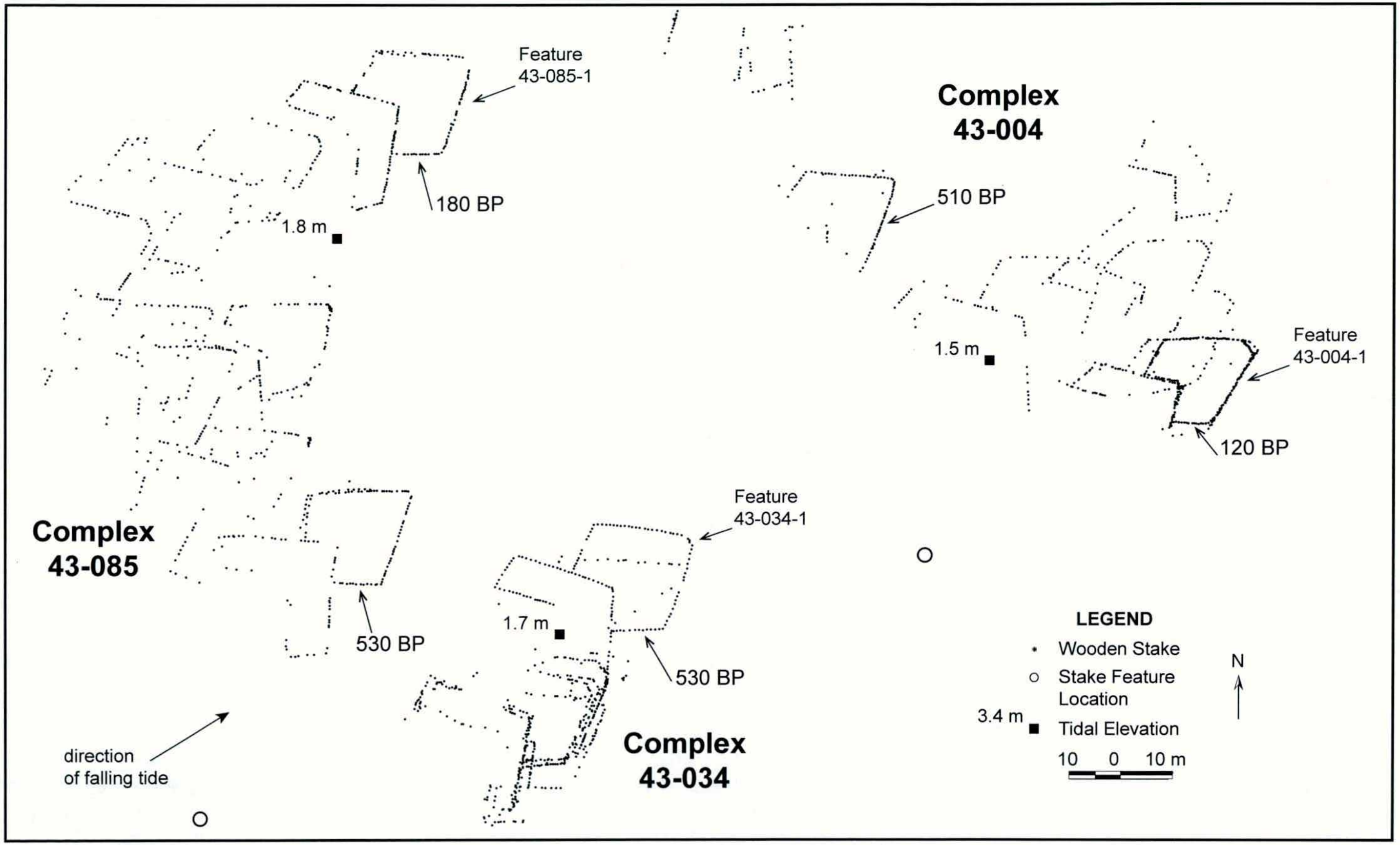

FIGURE 10. Detailed map illustrating the distribution, ages and consistency in form and orientation of Winged Chevron trap features located in the central area of the tidal flats (cf. Figure 4b). Stake n = 2,041. A small circle represents a Winged Chevron trap feature not mapped in detail.

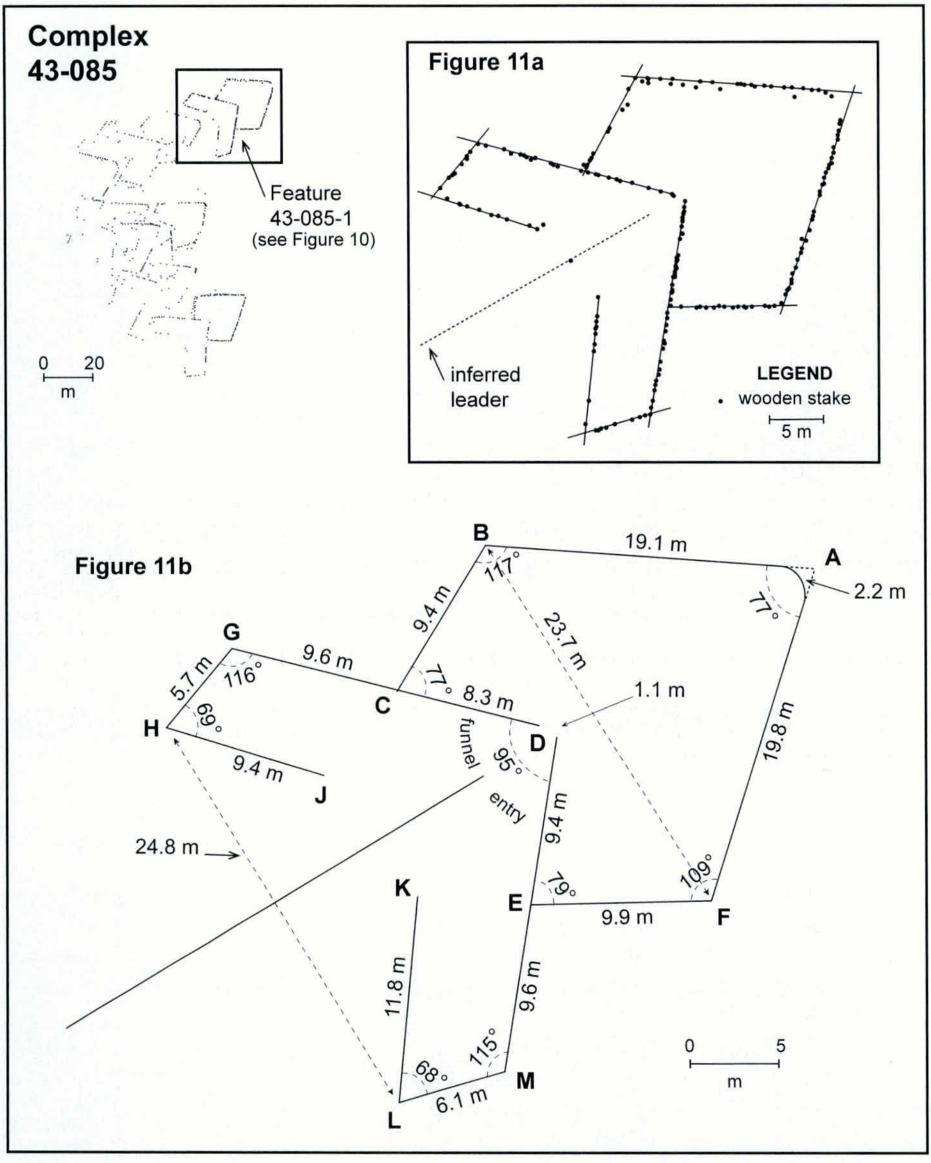

FIGURE 11. Detailed map and schematic diagram of Winged Chevron trap feature 43-085-1 illustrating the bilateral symmetry that characterizes the trap type.

play bilateral axial symmetry and a high degree of consistency in form.

Specifically, Winged Heart trap enclosures are heart-shaped structures built with a truncated backwall and two long, symmetrically curvilinear sidewalls that terminate shoreward as tightly recurved elements on either side of a funnel-shaped entrance (Figure 2a). Detailed measurements of these traps based on

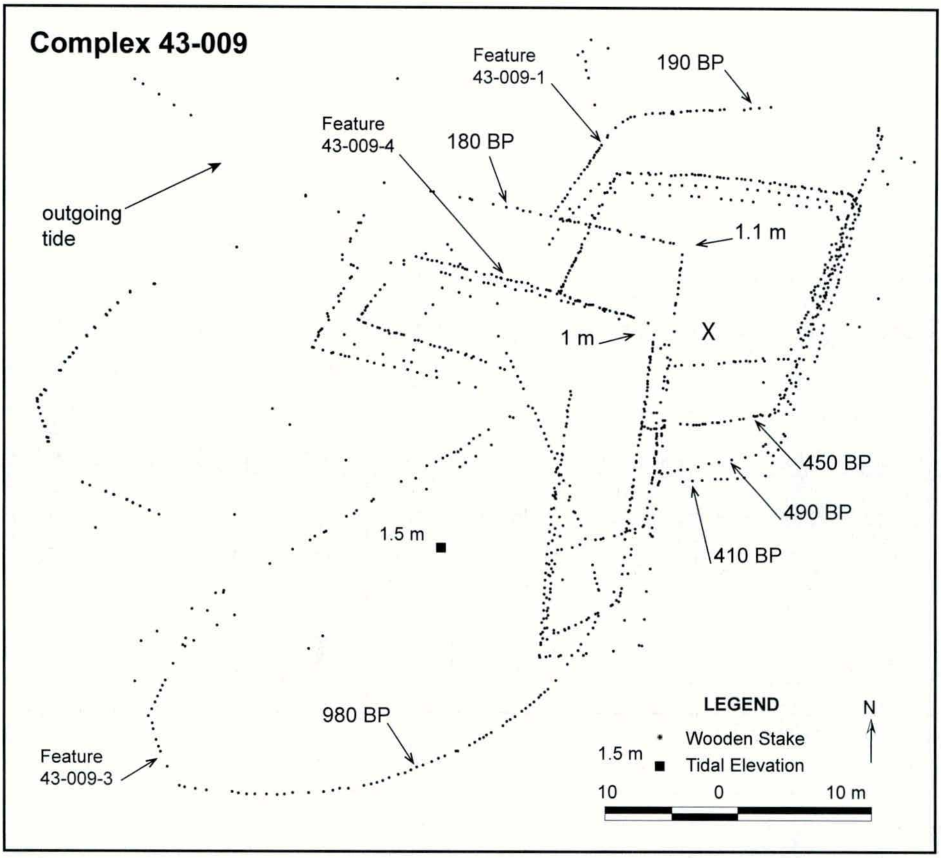

FIGURE 12. Detailed map showing the distribution and ages (cal B.P.) of one Winged Heart trap and four Winged Chevron trap features at Complex 43-009. Features 43-009-1 and 43-009-4 show inferred entrances 1.1 m and 1 m in width, respectively, leading into Winged Chevron trap enclosures. The person in the photo at Figure 13 is standing at X.

seven partial traps are presented in Table 4. Attribute values include large enclosure areas of approximately 700–900 m^2 (one trap appears to have utilized a fish catching area of about 1,200 m^2) and large entrances approximately 5 m (and perhaps as great as 7 m) in width leading into terminal enclosures. Enclosure walls are single lines of stem stakes, however, different parts of an enclosure may have been built using different stake sizes and spacing. Stakes forming backwall and sidewall elements of one feature are 6–13 cm in diameter (mean of 9.3, n = 133) and spaced about 50–75 cm apart, whereas stakes in recurved elements at the enclosure's entrance are less robust (5–9 cm in diameter, mean of 7.7, n = 16) and spaced at intervals of about 30–50 cm. Wing components of the feature are built with relatively small stems (3–8 cm in diameter) spaced about 15–30 cm apart in single, or possibly double lines, while the leader appears to be a single line of relatively small, closely spaced stem stakes. These data may sug-

FIGURE 13. Photo of patterns of overlapping alignments at complex 43-009. The view is toward the north shore of the estuary and the location of K'ómoks First Nation (IR 1).

TABLE 4. Summary of structural and functional attribute values inferred from seven partial Winged Heart trap features.[1, 2, 3]

Feature Number	Trap Enclosure			Trap Entrance			Wing Length	Leader Length	Overall Trap Length	Reference Figure
				Width						
	Width x Length	Backwall Length	Area	Between Wing Tips	Into Enclosure	Funnel Entry Angle				
43-003-1	34 x 34	21	900*	–	–	–	–	–	–	6
43-003-4	30 x 30	18	730*	–	–	–	–	–	–	6
43-009-3	43* x 36	34*	1,200*	–	7*	–	–	–	–	12
43-064-1	27* x 28	17	–	–	–	–	–	–	–	7
43-066-4	30 x 31	23	760	–	5*	80	16	51	76	7
43-067-2	30* x 32	23	800	34*	5	77	17	52	78	7
43-068-1	–	–	–	–	–	–	16	–	–	7

[1] Reference Figure 2a for trap element terminology used in this table.
[2] Attribute values: length and width (m), area (m^2) and angles (degrees of arc) were evaluated in a GIS. An asterisk indicates an approximated value.
[3] Gaps in data are due to variations in visibility and/or differential preservation of features.

gest differing structural strengths in different parts of the trap's framework.

Winged Chevron traps have a high degree of consistency in form. A schematic diagram derived from one well-preserved feature (43-085-1) illustrates the bilateral symmetry that characterizes the trap type (Figure 11b). Detailed measurements of structural and functional attributes of trap feature 43-085-1 and

11 other partial traps are presented in Table 5. Attribute values include trap enclosures that encompass areas of approximately 200–300 m^2 and widths of entrances leading into terminal enclosures that vary between about 0.26 and 1.1 m. Trap enclosure and wing wall elements are linear single lines of stem stakes and leaders appear to be single lines of closely spaced small split stakes with small stems at intervals. Diameters of stems forming the wall of one well-preserved enclosure are in the range of 4–12 cm (mean of 7.8, n = 128) and spaces between stakes vary between 33 and 175 cm with a mean of 65. Wing wall elements are typically poorly preserved and attributes were generally not evaluated.

Stake Characterization

Most of the original upright wooden poles pounded into the estuarine sediments to build trap frameworks have broken off or eroded to near the surface of the tidal flats. Remains of these are 3 to 13 cm diameter stems (small tree trunks or saplings) or small split stakes (probable Western redcedar) which average 2 cm x 3 cm in cross section. Of the 57 stem stakes recovered for ^{14}C dating, most are cleanly prepared with side branches and bark removed, some display bright colours of the cambium layer and 35 stems (selected from features of both trap types) were cut from Douglas fir trees (see Table 1). Stakes excavated with sharpened distal ends display fac-

TABLE 5. Summary of structural and functional attribute values inferred from 12 partial Winged Chevron trap features.[1, 2, 3]

	Trap Enclosure														Trap Entrance					
	Wall Element Length[4]						Interior Angle[4]								Width[5]					
Feature Number	A–B	A–F	B–C	E–F	C–D	D–E	∠ABC	∠AFE	∠BCD	∠DEF	Apical ∠BAF	Apical Wall Length	Width B–F	Area	Between Wing Tips	Into Enclosure	Funnel Entry ∠CDE	Leader Length	Overall Trap Length	Reference Figure[6]
43-004-1	19.3	19.1	7.6	7.7	8*	8*	120	120	74	76	59*	3.7	18.6	210	–	–	90	–	–	10
43-009-1	20.6*	21*	9.2	9.1*	10	9.1*	130	116*	67	79	66*	–	22*	290*	–	1.1	95	–	–	12
43-009-4	18.2	17.4	10.3	10	7.8	7.7	112	119*	80	81	77*	–	22*	290*	–	1	98	44*	64*	12
43-012-2	21.1	20.6	10.2	10.6	9.8	9.8	117	117	73	73	69	1.5	23.3	320	–	0.26	89	–	–	4b
43-034-1	20	19.2	10.5	10.3	8.5	8.4	109	110	85	85	77	2.7	24.5	320	–	0.37	105	–	–	10
43-048-1	16.3	17*	10.2	–	–	–	119	116*	–	–	76	1.4	–	–	23	–	–	–	–	4b
43-048-3	16	15.8	8.6	8.3	8.9	8.5	121	128	73	67	70	1.1	19	210	–	1	100	–	–	4b
43-085-1	**19.1**	**19.8**	**9.4**	**9.9**	**8.3**	**9.4**	**117**	**109**	**77**	**79**	**77**	**2.2***	**23.7**	**290**	**24.8**	**1.1**	**95**	–	–	**11b**
43-120-2	18.2	17.8*	9.2	8.6*	6.8	6.9	100	102	88	87	76	3.1	22*	230*	–	–	100	42*	58	9
43-121-1	15.4	14.8	11.4*	11.4	7.4	7.5	109	116	69*	66	85	1.6*	20	230	17*	0.27	88	37*	54	9
43-130-1	19*	20*	10.1	9.9	9.9	9.9	113	109	75	75	76*	–	23.8	290*	–	0.28	85	–	–	4b
43-230-1	18*	19*	9.1	7.4	10.1	10.2	111	112	80	81	80*	–	23.6	260*	–	0.29	100	–	–	4a

[1] Reference Figures 2b and 11b for terminology used in this table.

[2] Attribute values: length and width (m), area (m^2) and angles (degrees of arc) were evaluated in a GIS. An asterisk indicates an approximated value.

[3] Gaps in data are due to variations in visibility and/or differential preservation of features.

[4] Columns presenting trap enclosure wall element length and interior angle data are arranged to illustrate similar values of corresponding elements, e.g., A-B ≈ A-F and ∠ABC ≈ ∠AFE.

[5] The width of an inferred entrance leading into a trap's enclosure is evaluated only if the entrance is clearly defined and not obscurred by superimposed features.

[6] Large-scale maps illustrating features 43-012-2, 43-048-1, 43-048-3, 43-130-1 and 43-230-1 are presented in Greene (2015).

eted conical points A number of stems (n=16) also display distinct grooves (surface modifications) that spiral around the stem, and some grooves appear to spiral in opposite directions (Z- and S-twist patterns). These modifications, observed on remains of stakes recovered from both trap types, are interpreted as use-wear patterns produced by abrasion resulting from lashing removeable lattice panels (using cordage) to the original poles. One 119 cm long stake sample with a sharpened distal point displays a similar pattern on the proximal 53 cm portion of the stake and no grooves on the distal 66 cm portion of the sample. If the surface modifications on the proximal portion represent use-wear marks, the 66 cm distal portion of the sample may represent the approximate depth to which the original pole was pounded into the tidal flats. In addition, three long stems (266 cm, 289 cm and 299 cm in length) recovered as surface finds also display surface modifications that appear to spiral along their lengths. These stakes may represent the original lengths of poles used to construct some traps at Comox Harbour.

Other Cultural Materials Identified During Survey

A small number of related cultural items were also recovered within the intertidal zone. Among these, a large fragment of basketry, probably from a large burden or pack basket made with distinctive open wrapping weave technique (Croes 2014), was recovered in a salvage excavation. Analysis suggests the basketry was constructed (most likely) with Western redcedar elements (*Thuja plicata*) and spruce root (*Picea*) wrapping (Croes 2014; also Table 1), and a specimen for AMS ^{14}C dating yielded an estimate of 230±40 B.P. (Beta-191586; Table 1). This basket may have been used for fish collection. Several long (~200 cm x 3.5 m x 0.8 cm), finely split pieces of (probable) Western redcedar also recovered as intertidal surface finds exhibit spaced surface modifications (possible use-wear marks). We tentatively interpret these as remains of latticework panel elements. The basketry, split cedar pieces and other materials recovered in the intertidal zone (cordage, a wooden wedge with attached grommet, a bone chisel, fragments of spatulate tools and stone net weights) are reported in Greene (2015).

Discussion

The identification of 196 wood-stake features situated within the intertidal zone at Comox Harbour demonstrates the presence of a vast archaeological resource that was little understood archaeologically prior to this study. To our knowledge, no other Northwest Coast intertidal fishing site has recorded the density of vertical stakes, conservatively estimated to be between 150,000–200,000, or the number, large sizes, distinct forms and technological complexity of traps. Only the southeast Alaska double-lead-and-enclosure wood-stake-and-stone traps recorded by Mobley and McCallum (2001) are "similar … in their overall configuration" (Moss and Cannon 2011:4; also Moss 2013).

Ethnographic Accounts of Northwest Coast Wood-Stake Tidal Fishing Structures

Among the few accounts of stationary wood-stake tidal fishing structures, Barnett reports that permanent stake enclosures ("fish mazes") built on tidal flats near the mouth of Puntledge [Courtenay] River were "used for salmon and worked at high tide" (Barnett 1935–

1936; also Barnett 1939:229, 1975:82). One enclosure was described as "a labyrinth with a small entrance and no exit" (Barnett 1939:279). K'ómoks elder Mary Everson recalls her grandmother telling her that the "sticks" [remains of fish traps] located along the shore [near *q'ʷúmuʔxʷs*] were used to catch salmon. Mary also notes that different families owned the different weirs and were tasked with maintaining them (Mary Everson, interview February 1, 2005) (also Thornton 2003:45).

Elsewhere, Curtis (1970a:50) describes a Coast Salish salmon trap comprising "two long, converging lines of upright poles which led the fish into a *cul de sac*" on a falling tide, and Drucker (1951:16; also Stewart 1977) describes a rectangular Nuu-chah-nulth salmon trap framework about 4 m or more long by 2 m wide covered top and sides with rigid lattice panels. The shoreward-facing long side of the trap incorporated two narrow entrances situated between two fence-like arms (wings) which formed a V-shaped funnel, typically bisected by a third fence (leader), open toward the shore. Salmon would swim over or around the trap and fish caught between the wings on a falling tide were funneled into the trap and stranded as the water receded.

Accounts of wood-stake tidal structures used to capture herring are equally rare. The Twana, a Coast Salish group of western Washington, built a trap formed by two "roughly converging" fences closed on the seaward end with lattice or brush on a falling tide, another configured with two converging fences that terminated offshore "in a narrow aperture within a large circular end pocket...." (Elmendorf 1992:76), and Swan (1857:27) describes "traps or weirs, rudely constructed of twigs and brush" at Willapa Bay on Washington's Pacific coast. Elsewhere, Coast Salish built lattice-work fences set across river mouths or the necks of small embayments. When "used specifically to catch herring, the sticks [in the weir] were placed approximately ¼ inch [6 mm] apart, and when used specifically to catch salmon, they were placed two inches [5 cm] apart" (Kennedy and Bouchard 1974:21; see also Byram 1998:210; Tveskov and Erlandson 2003:1025).

Fish Behaviour and Modern Large-Scale Stationary Fish Trap Design

While ethnographic and archaeological records of Northwest Coast wood-stake intertidal fishing structures provide relatively poor analogues for the Comox Harbour traps, highly similar large-scale North American commercial stationary traps designed with knowledge of fish behaviour allow a detailed interpretation of Winged Heart and Winged Chevron trap design, function and fish species harvested. A brief overview of fish behaviour and design of modern large-scale inshore trap fishing gear follows.

Wood-stake heart-shaped traps designed to target a variety of pelagic schooling fish (e.g., herring, bluefish, mackerel, capelin and shad) were used along the east coasts of Canada and the United States during the historical and contemporary periods (Doucet and Wilbur 2000; Earll 1887a, 1887b; True 1887), and another type of trap-fishing gear designed to specifically target salmon was used historically along the coasts of southeast Alaska (Cobb 1911; Heckman 1908; Hipkins 1968; Moser 1899; Scudder 1970), British Columbia (Sloan 1940), Washington State (Rathbun 1899:295–305; Rounsefell 1938) and northeast United States (Atkins 1887; Smith 1898). Classified as passive "fishing gear into which the fish is guided" (von Brandt 1984:156; also He and Inoue 2010), these untended traps functioned automatically with the tides, day and night (Fridman 1973:376).

The success of these fisheries is predicated on detailed knowledge of fish behaviour (Cobb 1911; Fridman 1973; He and Inoue 2010; Heckman 1908; Nomura 1980) and the resolution of "two conflicting goals: (1) allow fish to enter [a trap] easily and (2) prevent fish from escaping once they have been trapped" (He and Inoue 2010:171). To accomplish these goals a trap's leader, set to intercept the swim path of fish, is typically oriented perpendicular to the shore (Nomura 1980:454). Set in this manner, fish can encounter the leader from either side, i.e., "during either flood or ebb tide" (Earll 1887a:501) and, sensing danger, swim toward deeper water (a behavioural tendency) and the trap (He and Inoue 2010:171; von Brandt 1984:161). Importantly, the leader also must be set "in a strictly linear direction" since bends in the leader may encourage fish to deviate from their path and swim around the trap (Fridman 1973:377). These traps may also incorporate wing-like structures [some traps function without wings (Mark Simonitsch, personal communication 2012)] to redirect, concentrate and funnel fish toward, and eventually through, an entrance leading into the trap's terminal fish impounding enclosure. To allow easy entry, the size of this entrance must reflect the tolerance level of fish to the trap (Mark Simonitsch, personal communication 2012; cf. He and Inoue 2010).

Modern heart-shaped traps designed to capture relatively timid schooling fish are reported to use large entrances approximately 3 to 7 m in width (M. Simonitsch, personal communication 2012) leading into terminal enclosures. Nova Scotia herring weir fisherman Stanley Stanton reports that large entrances are not seen as an obstacle to herring and "they go in as a school" whereas "if it looks like there's not enough room to get in, most bank up against the mouth and go around the outside ... but you'll always get a few" (S. Stanton, personal communication 2012). Once inside, the enclosure must also incorporate design elements that discourage schooling fish from returning to the opening and escaping impoundment. These elements comprise a funnel entrance formed by recurved walls (termed a non-return device) that redirect fish away from the opening to swim in circular patterns inside the enclosure (von Brandt 1984:169), and a large enclosure area to allow strong schooling fish to continue swimming and maintain school cohesion: "the more timid the fish [e.g., herring], the larger must be the [enclosure]" (Fridman 1973:384). Such modern heart-shaped traps may encompass fish catching areas of about 700–1,500 m^2 (Kurt Martin, personal communication 2005; Waring et al. 2013:316).

In contrast, salmon are more tolerant of risk (Pingguo He, personal communication 2012) and capable of swimming through narrow openings where "there is just space for a salmon to pass" (Curtis 1970b:28; also Stewart 1977:99). For example, highly successful historical Alaskan and northeastern United States salmon traps are reported to have used narrow slit-like entrances (0.2–1 m in width) leading into terminal enclosures (Atkins 1887:680; Hipkins 1968:7; Moser 1899:170; Sloan 1940: exhibit 5; Smith 1898:117–119). Having passed through such a narrow opening (also termed a non-return device), there is "little chance of the fish returning the same way" (von Brandt 1984:169). Salmon "are more skillful at getting out of traps than other types of fish" (Pingguo He, personal communication 2012) and a narrow entrance is essential to prevent escape. The wide entrance of a precursor to narrow-entranced northeastern United States salmon traps proved to be "much inferior as a great many salmon escaped by the entrance" (Atkins 1887:683).

Comox Harbour Trap Design and Function

The Winged Heart and Winged Chevron traps were large-scale, complex structures that incorporated design characteristics closely analogous to highly successful modern and historical passive trap fishing gear designed with knowledge of fish behaviour to guide fish into, and retain those fish within, a trap's terminal impounding enclosure. Design characteristics common to both Winged Heart and Winged Chevron traps include: bilateral axial symmetry and a high degree of consistency in form that suggests the traps were precisely constructed using ethnographically known standardized units of measurement (Boas 1909:410; Drucker 1951:81); a leader set in a linear direction more or less perpendicular to the shore so that fish approaching the leader turn and are guided toward deeper water and the trap; a leader that bisects the trap's entrance to allow fish to enter the enclosure from either side of the fence (i.e., on a rising or a falling tide); a pair of bilaterally-positioned wings that form a V-shaped funnel entry to concentrate and redirect fish toward the trap enclosure's entrance; and an entrance which incorporates species specific design characteristics (i.e., the width of the entrance and non-return devices) to only allow certain types of schooling fish to easily enter the enclosure and, once inside, prevent their escape. Both trap types would have operated automatically with the tides, day and night. At low tide, fish captured in traps set near shore would be stranded on the surface of the tidal flats to be removed by hand, and fish captured in traps set low in the intertidal profile would at times remain in water to be netted or speared.

Trap Fishing Strategies

The nearly continuous distribution of calibrated ^{14}C dates (Figure 5) indicates multiple traps may have operated at particular times in different areas of the estuary. For example, clusters of dates suggest the Winged Heart trap at complex 43-009, located in the central area of the tidal flats, and Winged Heart traps set nearshore at complexes 43-003 and 064-068 were fishing between 1050 and 950 B.P. (Figures 4a and 4b). Winged Chevron traps situated at different tidal elevations also appear to have been fishing contemporaneously. A cluster of six dates between 550 and 500 years B.P., derived from two complexes situated nearshore (43-003 and 43-065) and three complexes located low in the intertidal profile (43-004, 43-034 and 43-085), suggest a minimum of five Winged Chevron traps (and probably more) were operating at that time. Similarly, a cluster of 14 dates obtained from ten different Winged Chevron features, situated both low and high in the intertidal profile, comprise median calibrated ^{14}C ages between 200 and 100 years B.P. At least ten traps were likely fishing contemporaneously during this period. Such contemporaneous, large-scale fishing activity at multiple locations in the intertidal profile could have resulted in the capture of enormous quantities of fish.

The most technologically sophisticated trap fishing strategy used at Comox Harbour, however, is represented by a series of linked traps built contemporaneously along a central line. Termed a mass harvest fishing system, this linear arrangement of traps was aligned with the falling tide and often comprised three or four traps (or possibly more) located at progressively lower tidal elevations. Similar arrangements of traps, termed "double or triple headers," were set historically along the United States Atlantic seaboard to maximize harvest of schooling fish (Mark Simonitsch, personal communication 2012; also Atkins 1887:683; Earll 1887b:549). Earll reports that such arrangements were particularly successful in "localities where the bottom is level or slopes very gradually" (Earll 1887b:549). To date, we have identified linked trap systems only within the low gradient upper intertidal zone along the southwestern shore at Comox Harbour.

Detailed mapping and ^{14}C dating demonstrate that these serially linked systems were built and rebuilt repeatedly over time in essentially the same footprint. A complex of multiple episodes of construction of four linked Winged Heart traps (complex 064-068) is illustrated in Figure 7. When set to fish, this system would have presented a significant linear obstruction (extending about 300 m from the shore—the length of three football fields) to redirect the movement of fish towards the traps. In a later period of trap construction, a series of probably six Winged Chevron traps (features 43-122, 43-121, 43-120, 43-263, 43-262 and 43-260) may have presented a similar obstruction about 320 m in length (Figure 9b).

Such mass harvest fishing systems, set perpendicularly to the shore across a range of decreasing tidal elevations, were likely designed to work with Comox Harbour's semidiurnal (twice daily), unequal height, high tides (Morris et al. 1979). All traps in a linked trap fishing system (e.g., the Winged Heart trap 064-068 series) set between present-day mean high tide (4.7 m) and mean water (3.3 m) levels (Figure 7) would have been submerged and capable of fishing on a full tide. As the tide slowly receded, potentially large numbers of fish would have been guided sequentially into each of the four traps and stranded as the tide fell below the mean water level. This trap fishing strategy would have operated automatically with the tides to ensure fish capture over a broad range of twice daily unequal high tides. Built with individual enclosed fishing areas of approximately 750 m^2, the four traps of the 064-068 series (submerged at high tide) would have presented a total fish catching area of about 3,000 m^2.

Analysis of detailed mapping and ^{14}C dating also suggests that stand-alone traps were built and rebuilt repeatedly at the same locations over hundreds of years, with Winged Chevron traps succeeding Winged Heart traps in the same footprint. Examples include a complex of six (primarily Winged Heart) traps, situated near shore at complex 43-003 (Figure 7) with median calibrated radiocarbon dates of 1290, 1040, 1040, 880, 520 and 120 B.P., and a sequence of five (predominantly Winged Chevron traps) at complex 43-009, located low in the intertidal profile with median calibrated radiocarbon ages of 980, 490, 450, 410 and 190/180 B.P. (Figure 12). The possibility that some traps identified as stand-alone traps may be associated with, as of yet, unidentified serially linked trap systems cannot be excluded. These large-scale stand-alone traps appear to have no equal when compared to the fish catching capacity of other Northwest Coast intertidal trap features. For example, based on current evidence, "enclosed fishing areas" (Langdon 2006:46) of the Winged Heart traps were approximately 700–1200 m^2 (Table 3), whereas enclosure dimensions of southeast Alaska heart-shaped features suggest substantially smaller fish catching areas (Mobley and McCallum 2001:31).

To date, a total of 323 individual traps, including 72 Winged Heart traps and 169 Winged Chevron traps have been conclusively identified at Comox Harbour (Table 3). Of these, 66 Winged Chevron traps and three Winged Heart traps were recorded in the central area of the tidal flats. The overall predominance of Winged Chevron traps, more than twice the number of Winged Heart traps, suggests a significant intensification in fishing activity in the estuary after about 700 B.P., particularly low in the intertidal zone. Traps set in the central area of the tidal flats would be submerged and capable of fishing about 85 to 95 percent of the year.

A Hiatus in Trap Construction ca. 700 B.P.
Current radiocarbon estimates indicate Winged Heart traps were constructed from approximately 1300 B.P. to 800 B.P. and Winged Chevron traps were built between about 600 B.P. and 100 B.P. (Figure 5). Based on this evidence, the change in trap type appears to be one of abrupt replacement rather than gradual transition and a hiatus in trap construction may be present. However, given the large numbers of trap features present in the estuary (Table 3), the sampling fraction of stakes is quite low and there is a reasonable possibility that some of the undated features may clarify the nature of the transition in trap type and narrow (or eliminate) the inferred temporal gap.

New Trap Type… New Fish?
The replacement of Winged Heart traps by Winged Chevron traps may be due to a variety of factors, including economic, sociopolitical and environmental factors. However, we propose that the dominant force driving the change in form was a climate-induced shift in ecological conditions that altered the productivity and availability of fish populations at the beginning of the Little Ice Age. The relationship between a changing climate and fish productivity is complex (e.g., Beamish et al. 2009; Finney et al. 2002, 2010; Mantua et al. 1997; Zebdi and Collie 1995), however, high resolution paleontological records of fish remains may provide a long-term proxy relationship between Holocene northeastern Pacific Ocean fish populations and ocean conditions (Finney et al. 2010) to evaluate fish abundances during the periods of Comox Harbour trap use.

Evidence from sediment cores retrieved from an undisturbed ~10,000-year record of annual deposition in the Saanich Inlet basin suggests herring particularly (but also Pacific hake, dogfish and skate) were abundant in southeastern Vancouver Island waters between about [illegible]

using Saanich core

date on +/- herring

nicliffe et al. [illegible] 2010), whereas "abundances in the last 1,000 years were lower than the rest of the record" (Tunnicliffe et al. 2001:197). High abundance prior to 1000 B.P. corresponds to ages of Winged Heart traps at Comox Harbour, and the inferred decline in herring in southern British Columbia after 1000 B.P. may have been a factor contributing to the change in trap form ca. 700 B.P.

Salmon have been present in Strait of Georgia waters since ca. 12,000 RCYBP (Harrington et al. 2004). Salmon are poorly represented in the Saanich Inlet record (Tunnicliffe et al. 2001), however, results of multi-proxy paleoecological reconstructions of sockeye salmon abundance at Kodiak Island, Alaska nursery lakes infer a multi-centennial decline in northeastern Pacific Ocean sockeye salmon between about 2050 B.P. and 1150 B.P., increasing numbers of salmon after 1150 B.P. and consistent abundance beginning ca. 700 B.P. (Finney et al. 2002, 2010) coeval with glacier advance in southern Alaska (Calkin et al. 2001 in Finney et al. 2010) and the southern British Columbia Coast Mountains (Koch and Clague 2011). If this inferred shift to consistently higher salmon abundance occurred in southern British Columbia, greater salmon availability at Comox Harbour may also have been a factor contributing to the change in trap form ca. 700 B.P.

Fish Species Targeted

The overall configuration and design characteristics of the Winged Heart trap type are very similar to modern North American stationary heart-shaped tidal traps designed to harvest immense numbers of schooling fish. These modern traps incorporate large entrances (as great as 7 m in width) that allow relatively timid fish with strong schooling tendencies to enter easily and be retained in large terminal enclosures. Similarly, Winged Heart traps were designed with large entrances (about 5 to 7 m in width) leading into very large enclosures. Based on the high degree of similarity in the overall configuration, sizes and entrance design characteristics of the Winged Heart traps to modern, large-scale, heart-shaped traps; high proportions of herring bones in Comox Harbour midden deposits (directly associated with trap features); and high herring productivity in southern British Columbia ca. 2000–1000 B.P., declining thereafter (Tunnicliffe et al. 2001), we propose that the Winged Heart traps were built to target herring between ca. 1300 and 800 B.P.

While the Winged Heart traps were likely designed to ensure herring capture, other fish also may have been captured. For example, the inferred increase in Kodiak Island lake sockeye salmon abundance after ca. 1150 cal B.P. (Finney et al. 2002, 2010) and an "increase in the relative abundance of salmon remains in [Haida Gwaii] village middens after 1200 cal B.P." (Orchard 2011:120; also Maschner 1997; Orchard and Clark 2014) suggest some salmon may have been available (and captured) at Comox Harbour. In contrast to herring, however, salmon would not have been as efficiently retained in a Winged Heart trap's terminal enclosure due to their behavioural tendency to escape from enclosures built with wide entrances (Atkins 1887). Other fish also captured in these traps may have included rockfish, dogfish and flatfish (Simonsen 1991:20). K'ómoks elder Stewart Hardy (personal communication 2005) recalls (as a child) large numbers of "black rockfish" entering the harbour. Black rockfish (*Sebastes melanops*) is a common, wide-ranging, often-schooling fish along the Pacific Coast of North America (Eschmeyer and Herald 1983:143).

The Winged Chevron trap type appears highly similar in overall configuration and inferred species-specific design characteristics to traps used in the highly successful North American (particularly Alaskan) historical salmon trap fisheries. These modern traps were built with narrow slit-like entrances (i.e., non-return devices) approximately 0.2–1 m in width to ensure salmon capture (Atkins 1887; Hipkins 1968; Moser 1899; Sloan 1940; Smith 1898) and Winged Chevron traps appear to have utilized similarly narrow entrances (0.26 to 1.1 m in width) leading into terminal enclosures. Based on the high degree of technological similarity of Winged Chevron trap design characteristics to historical salmon traps and the presence of salmon rivers at Comox Harbour, we propose that the Winged Chevron traps were designed to target salmon in a specialized fishery.

While the shift to the Winged Chevron trap form about 700 B.P. is broadly contemporaneous with an inferred decline in southern British Columbia herring abundance after ca. 1000 B.P. (Tunnicliffe 2001), the shift is closely contemporaneous with inferred consistently high northeastern Pacific Ocean sockeye salmon abundance (Finney et al. 2002, 2010) and a more concentrated focus on salmon at Barkley Sound (on the west coast of Vancouver Island) after ca. 800 B.P. (Frederick 2012; McKechnie 2012; McMillan et al. 2008; Monks 2006); Haida Gwaii after ca. 800 B.P. (Orchard and Clark 2005; Orchard 2011); Tebenkof Bay (on the southeast Alaska coast) between 800–600 B.P. (Maschner 1997); and in Alaska's Kodiak Archipelago beginning ca. 650 B.P. (Partlow 2000:225). The increased importance of salmon at these broadly spatial outer coast locations suggests ecological conditions supportive of high salmon productivity were widespread by about 800 B.P. The shift from Winged Heart traps to the Winged Chevron trap form would have ensured maximum salmon capture about this time. While some herring probably would have also gotten into the Winged Chevron traps (Pingguo He, personal communication 2012), herring's timidity and strong behavioural tendency to school would have likely resulted in their viewing this trap's narrow slit-like entrance as an obstacle and caused most to escape around the trap (Mark Simonitsch, personal communication 2010), effectively limiting mass capture of herring in favour of salmon.

On-shore Evidence for Salmon Fishing

A salmon-focused trap fishing economy at Comox Harbour should be associated with high proportions of salmon bones in midden deposits. However, terrestrial midden deposits associated with fish traps are characterized by low proportions of salmon bones. The possibility that Pentlatch Peoples living at Comox Harbour disposed of unused parts of salmon butchering in water, as practiced "in at least some contexts" by numerous Northwest Coast groups (Donald 1997:180; also Barnett 1935–36; 1939, 1975; Boas 1921:245–247; Hoffman et al. 2000; Jenness n.d.:15; Suttles 1974:174), may be inferred from the example of differential deposition of salmon bones in contemporaneous terrestrial and waterlogged midden deposits at the Little Qualicum River site (DiSc–1) (Bernick 1983, 2013; also Bernick and Wigen 1990), a Pentlatch (Kennedy and Bouchard 1990:443) fishing camp located south of Comox Harbour. At the Little Qualicum River site, salmon bones predominate (96 percent of all specimens) in the waterlogged portion of the site, in contrast to terrestrial non-waterlogged midden deposits where herring remains predominate (Bernick and Wigen 1990:156).

Placing the Site within the Broader Coastal British Columbia Geomorphological and Ecological Context

Comox Harbour is situated along the margin of a relatively narrow coastal plain (the Nanaimo Lowland) underlain by abundant unconsolidated Quaternary sediments (Clague and Bornhold 1980). Riverine and tidal processes acting on these sediments have developed "some of the most interesting and dynamic littoral features" on the otherwise rugged British Columbia coast (Clague and Bornhold 1980:363). The mid-Vancouver Island portion of the coastal plain, which includes Comox Harbour, particularly consists of beaches (uninterrupted by rocky headlands), deltas and spits. Here, the northern Salish Sea (Strait of Georgia) relative sea level has remained largely unchanged for at least 1,300 years (and probably longer) permitting the large, relatively well-sheltered delta at Comox Harbour to function as a long-term stable platform for large-scale mass harvest trap fishing systems (cf. Elder et al. 2014:60). The harbour is advantageously located within the most utilized herring spawning area on the British Columbia coast (DFO 2014) and the watershed historically contained some of the most diverse and productive salmon spawning habitat along east coast Vancouver Island for (possibly) all salmon species (DFO 1958:12; Hamilton et al. 2008:8; Hancock and Marshall 1985:85; Hourston 1962:3; also Barnett 1935–1936; Frank 1962). In comparison, salmon habitat at similarly large east coast Vancouver Island watersheds may have been less productive for some salmon species, particularly pink (Riddell and Beamish 2003:6), chinook (Hourston 1962:3) and sockeye salmon (Marshall et al. 1976:40, 1977:14). Considering the relatively stable shoreline and intertidal zone, and the wealth of marine resources available to Aboriginal Peoples at Comox, the harbour "may have been at the center of prehistoric cultural activity" in the northern Salish Sea for at least 1,300 years (cf. Simonsen 1990a:3).

Conclusions

The east coast of Vancouver Island is characterized by a variety of littoral features (e.g., extensive beaches, large river deltas, spits and bars) relatively rare on the otherwise generally rugged British Columbia coast. Here, the Comox Harbour estuary provided a relatively large, well-sheltered and stable platform for the development of complex large-scale, mass harvest trap fishing systems. About 1,300 years ago (and probably earlier), people began constructing frameworks for these traps consisting of upright wooden poles embedded in the tidal sediments of the estuary. When set to fish, removeable lattice panels likely were lashed to the frameworks as evidenced by use-wear marks on remains of the poles. An estimated 150,000 to 200,000 stakes represent the remains of more than 300 fish traps located near productive salmon streams and well-utilized herring spawning habitat. These temporally and morphologically distinct traps were of two types, termed Winged Heart and Winged Chevron traps. The trap designs consisted of fixed, standardized elements that indicate the people who constructed these traps were already familiar with these elements. Designed to capture fish at all stages of a tidal cycle (i.e., on either a rising or a falling tide), these passive fishing structures interrupted the movements of fish and guided them into a trap's terminal impounding enclosure. Remarkably, both trap types are most analogous to sophisticated, historical and contemporary North American commercial fishing traps designed with detailed knowledge of fish behaviour.

A series of 57 radiocarbon dates demonstrates continuous use of Winged Heart traps between about 1300 and 800 B.P. and the Winged Chevron trap type between approximately 600 and 100 B.P. The shift in trap type ca. 700 B.P. appears abrupt rather than transitional, and the dominant force driving the shift was likely a change in environmental conditions that altered northeastern Pacific Ocean fish productivity and availability at the beginning of the Little Ice Age. Both trap types functioned as stand-alone traps distributed extensively across the estuary's intertidal profile and as components of serially linked traps (i.e., mass harvest fishing systems) set nearshore to catch fish over a range of descending tidal levels. Many specific locations were used repeatedly over time (some for as long as 400 to 1,000 years) with rebuilding of the serially linked trap systems perhaps about every 40–110 years. Data also suggest numerous traps operated contemporaneously at various locations in the estuary and approximately twice as many Winged Chevron traps as Winged Heart traps were constructed over time.

The large sizes and numbers of traps, the concurrent use of multiple traps at particular times in different areas of the estuary, and the capability of the linked trap systems to fish for extended periods of time (i.e., across a range of tidal elevations) during a tidal cycle suggest significant intensification of fish production at Comox Harbour (cf. Langdon 2006:45) over hundreds of years, particularly after ca. 700 B.P. Such large-scale trap systems would have required skilled fishermen to design, construct and maintain the traps, and a high population density and organization of labour to efficiently process the fish for long-term storage (Moss et al. 1990; Moss and Cannon 2011) and probably trade (Kennedy and Bouchard 1990).

Herring remains dominate faunal assesmblages at Comox Harbour shell middens associated with trap features and we propose the Winged Heart trap type was designed to ensure mass capture of herring between ca. 1300–800 B.P. However, other fish (e.g., salmon, dogfish, rockfish, flatfish) may also have been captured in the traps. Salmon were increasingly available at outer-coast village sites after ca. 1200 B.P. (Orchard and Clark 2014) and may also have become more common at Comox Harbour about this time. If so, salmon, in contrast to herring, would not have been efficiently captured in the wide-entranced Wing Heart traps. Winged Chevron traps, however, would have maximized capture of the increasing numbers of salmon after about 700 B.P. This shift to the Winged Chevron trap type is closely contemporaneous with inferred consistent sockeye salmon abundance in the northeastern Pacific Ocean (Finney et al. 2002, 2010) and a more concentrated focus on salmon at outer-coast British Columbia and southern Alaska village sites after ca. 800 B.P. (e.g., McMillan et al. 2008; Maschner 1997). These traps appear very similar in form to historical, North American large-scale salmon traps and we propose the Winged Chevron trap features infer direct archaeological evidence for a specialized mass harvest salmon fishery at Comox Harbour after ca. 700 B.P. Low proportions of salmon remains at Comox Harbour midden sites (directly associated with trap features) are inconsistent with a salmon-focused economy and are probably the result of differential processing and disposal practices.

McKechnie et al. (2014) have recently highlighted the significance and high percentages of herring remains in archaeological sites on the Northwest Coast. They conclude that herring remains are found in consistently high percentages in prehistoric contexts and that a decline in herring significance is probably related to early industrial fishing over the past 50–100 years. At Comox Harbour, the shift from a trap form designed to maximize herring capture (Winged Heart traps) to one designed to maximize salmon capture (Winged Chevron traps) occurred earlier, about 700 years ago. This suggests that people at Comox Harbour were shifting their dependence from herring, and a perhaps more generalized economy, to a more concentrated focus on salmon (cf. Orchard and Clark 2014). Ames (2003:20) suggests Northwest Coast salmon abundance "was subject to enormous variations in time and space" and "household economies had to take full advantage of salmon abundance when it occurred." A Winged Chevron trap salmon-focused fishery between ca. 700–100 B.P. is consistent with ethnographic accounts that suggest "fish mazes" built on tidal flats at Comox Harbour were used for salmon (Barnett 1935–1936), while herring rakes were used to obtain large quantities of herring (Curtis 1970b:19).

There has been an increasing awareness of the degree to which Northwest Coast intertidal zones were modified in the past (e.g., Caldwell et al. 2012; Harper et al. 1995; Langdon 2006; Lepofsky and Caldwell 2013). The construction of multiple, frequently simultaneously used fish traps at Comox Harbour is an indication of the extent to which the estuary was enhanced and modified by Aboriginal peoples to provide increased returns. The Winged Heart traps enabled capture of herring in numbers that likely exceeded or enhanced other techniques such as netting or herring rakes, and, similarly, Winged Chevron traps likely permitted harvesting salmon in larger numbers and earlier in the salmon spawning cycle.

The technologically sophisticated Comox Harbour traps should be viewed as part of the development of trap/weir fishing technology that may derive from earlier forms. The mass harvest fishing systems suggest that they are the result of a period of long term intensification and development of intertidal fishing technology and should be viewed as part of the Developed Northwest Coast Pattern (Matson and Coupland 1995) along with social complexity, permanent villages, large multifamily households and numerous other characteristics.

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Notes

1. Two stakes (43-003-1 and 43-003-4) selected from two Winged Heart trap features at Complex 43-003 (Figure 6) returned statistically indistinguishable radiocarbon estimates. These two features are superimposed one above the other. As such, we believe that the mean calibrated dates of these features (1040 B.P. and 1040 B.P., respectively) should be spaced slightly farther apart. Considering the probability range of these dates at 2σ (Table 1), both traps were constructed between 1178 and 930 B.P., however, it is not possible to suggest the order of trap construction during this 248 year period.
2. Two stakes (064-1 and 064-2) selected from Complex 43-064 (Figure 7) returned statistically indistinguishable ^{14}C dates with median calibrated dates of 1150 and 1140 B.P., respectively (Table 1), and two stakes (43-068-4 and 43-068-5) selected from Complex 43-068 (Figure 7) similarly returned statistically indistinguishable ^{14}C dates with median calibrated dates of 1240 B.P. and 1240 B.P. On review of the mapping data, we conclude that the dates selected from complex 43-064 were probably obtained from the same trap enclosure, and the dates from complex 43-068 were likely selected from the same wing element.
3. The Little Qualicum River wet/dry midden site (DiSc–1) is located near an intertidal wood-stake fish trap complex (Bernick 1983; also Simonsen 1976; Stewart 1977). Greene and McGee visited the site in 2009 and it is our opinion that trap features display attributes consistent with the Comox Harbour Winged Chevron trap type.

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