Archeological evidence of large northern bluefin tuna, *Thunnus thynnus*, in coastal waters of British Columbia and northern Washington

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Abstract.—This study presents archeological evidence for the presence of adult bluefin tuna, *Thunnus thynnus*, in waters off the west coast of British Columbia and northern Washington State for the past 5,000 years. Skeletal remains of large bluefin tuna have been recovered from 13 archeological sites between the southern Queen Charlotte Islands, British Columbia, and Cape Flattery, Washington, the majority found on the west coast of Vancouver Island.

Vertebrae from at least 45 fish from 8 sites were analyzed. Regression analysis (based on the measurement and analysis of modern skeletal specimens) was used to estimate fork lengths of the fish when alive; corresponding weight and age estimates were derived from published sources. Results indicate that bluefin tuna between at least 120 and 240 cm total length (TL) (45–290 kg) were successfully harvested by aboriginal hunters: 83% of these were 160 cm TL or longer. Archeological evidence is augmented by the oral accounts of native aboriginal elders who have described strategies used until the late 19th century for hunting bluefin tuna.

Despite this information, there are no 20th-century records of adult bluefin tuna in the northeastern Pacific. Archeological evidence suggests that either perturbations in the distribution of Pacific bluefin have occurred relatively recently or the specific environmental conditions favoring the movement of large tuna into northeastern Pacific waters have not occurred in this century.

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Evidence is presented here for the occurrence of adult bluefin tuna, *Thunnus thynnus*, in waters of the northeastern Pacific, off the coast of British Columbia and northern Washington, for the past 5,000 years. The physical evidence consists of archeological remains of large bluefin tuna harvested by aboriginal hunters. Aboriginal North Americans of this area (part of the so-called "Northwest Coast" culture region) were accomplished seamen and skilled hunters of marine mammals (Mitchell and Donald, 1988). Coastal archeological sites throughout this region often contain abundant skeletal remains of the many fish and marine mammal species that sustained human populations over thousands of years (Calvert, 1980; Huelsbeck, 1983; Mitchell, 1988).

Skeletal remains of large bluefin tuna have been recovered from 13 archeological sites. The archeological deposits containing tuna date from at least 5,000 years ago until the early 20th century. The existence of bluefin tuna remains from this region have been previously reported (McMillan, 1979), but none were systematically analyzed until now.

For this study, 78 intact vertebrae from 8 archeological sites were measured and the data compared with those from vertebrae of modern specimens (specimens from the remaining 5 sites could not be examined, owing largely to difficulties in retrieving archived specimens but, in one case, because all skeletal material had been discarded by museum staff). Tentative estimates of the size of the archeological specimens were made by comparing the size of vertebrae from modern specimens of known length with the size of vertebrae collected from archeological deposits. The resulting length estimates were then used to calculate weight and age estimates by using length–weight algorithms derived from recent data. Data are presented in a manner that should facilitate the analysis of any additional archeological specimens recovered.

In addition to the results of the analysis of the archeological material, anecdotal evidence is presented from ethnographic accounts of tuna-fishing methods related by native elders of the Mowachaht tribe who live on the west coast of Vancouver Island. These recent oral accounts substantiate and augment the physical evidence: they describe bluefin tuna ethology, pinpoint the time of year that bluefin tuna were present and confirm that large bluefin tuna were being harvested in the northeastern Pacific until the late 19th century. The historic evidence for bluefin tuna occurrence in this area, although sparse, is also presented.

The archeological evidence and ethnohistoric accounts are significant because of the absence of modern records for adult bluefin tuna in the northeastern Pacific. Consequently, the distribution of northern bluefin tuna of all age classes in the Pacific and all modern records for adults in the eastern Pacific are reviewed. The addition of historical information presented here to our present state of knowledge of modern bluefin tuna distributions has important implications for our understanding of changing environmental conditions over time and perhaps also for determining the impact of 20th-century fisheries on Pacific bluefin tuna populations.

Distribution of Pacific bluefin tuna

The distribution of northern bluefin tuna in the Pacific is somewhat enigmatic, especially that of the adult portion of the population (Foreman and Ishizuka, 1990; Bayliff, 1994; Smith et al., 1994). Sexual maturity in Pacific northern bluefin is reached at about 5 years, and most spawning is reported between April and July in waters off Japan and the Philippine Islands, and in August in the Sea of Japan (Bayliff, 1994). Northern bluefin tuna are transoceanic migrators in both the Atlantic and Pacific; the movements of these fish are largely deduced by tagging experiments and catches of various age classes at specific times and locations (Nakamura, 1969; Rivas, 1978; Bayliff, 1994).

Some of the population of Pacific bluefin tuna migrate from the western to the eastern Pacific Ocean during their first or second year. The proportion of the population that undertakes this migration appears to vary from year to year (Bayliff et al., 1991). These migrating fish spend a period of one to six years in the eastern Pacific, a sojourn which may or may not be interrupted by visits to the central or western Pacific before the survivors return to spawn in the west (Bayliff, 1994). Adult fish in the Pacific appear to follow a general pattern of being distributed farther to the west during the spring (when spawning occurs) and farther to the east in the fall (Bayliff, 1993).

It is not known if all fish return to spawn every year after sexual maturity is reached. Tagging experiments indicate that although the journey from west to east may take 7 months or less, the journey from east to west takes nearly 2 years; therefore there does not appear to be enough time for mature adult fish migrating from the eastern Pacific to spawn in the west every year. In addition, because a few adult fish have been captured in the eastern Pacific either just before or after the spawning season, some adults probably do not return to the western Pacific every year but rather spend variable lengths of time in the eastern Pacific (Bayliff, 1994).

Most harvested adult bluefin tuna are caught in the western Pacific, where they are known to range as far north as the Sea of Okhotsk at about 50°N (Bayliff, 1980). Catch records of large bluefin tuna are noted at feeding areas off northeastern Honshu, Japan (ca. 40°N), off eastern Taiwan (about 25°N), and in the central Pacific near the Emperor Seamount (40°N, 175°E) (Nakamura, 1969).

Adult bluefin tuna are considered rare everywhere in the eastern Pacific; sporadic records have come from southern California and northern Mexico only. Although small bluefin tuna (less than 120 cm total length [TL] and 5–45 kg) are caught regularly off California and Mexico and somewhat larger fish (120–160 cm TL and 45–80 kg) occasionally, adults over 160 cm TL (80 kg) are seldom encountered (Foreman and Ishizuka, 1990; Bayliff, 1994).

In the northern portion of the eastern Pacific, few modern records exist for bluefin tuna. Neave (1959) mentioned three occurrences in British Columbia waters during August 1957 and 1958, but no sizes or numbers were given. These reports came from an area approximately 200–400 miles off the west coast of Vancouver Island (49°N, 134°24'W; 48°N, 131°06'W; 51°N, 130°W). A 7.5-kg bluefin tuna was caught in a salmon seine in July 1958, near Kodiak, Alaska, and on 1 October 1957, bluefin tuna were sighted 80–100 miles off Cape Flattery, Washington (Radovich, 1961). Sea-surface temperatures off the British Columbia coast were reported as being warmer than usual during both years.

I presume (because no sizes are mentioned in the reports) that these recent northern records are for relatively small fish of 5–45 kg because this size range is the most common in the eastern Pacific. Bluefin tuna larger than 45 kg in the eastern Pacific are rare enough that they are noteworthy when encountered. Although the earliest modern record of a very large bluefin tuna in southern California appears to be that of 1899 (Holder, 1913), sporadic occurrences of bluefin tuna over 50 kg have been reported since then (Dotson and Graves, 1984; Foreman and Ishizuka, 1990).

The largest reported catch of giant bluefin tuna in the eastern Pacific was made in 1988 (Foreman and Ishizuka, 1990). Seiners caught an estimated 987 adult bluefin tuna between November and early January off southern California, including many over 100 kg and some more than 250 kg, including one that broke California records at 458 kg and 271.2 cm TL. Seiner operators involved in this fishery reported that large bluefin tuna travelled in small schools of less than 10 similar-size individuals, often less than 5 for very large fish.

Analysis of stomach contents of some of these fish indicated that they had been feeding at the surface on chub mackerel, *Scomber japonicus,* and the opalescent inshore squid, *Loligo opalescens,* a strongly phototactic species (Recksiek and Frey, 1978). Bluefin tuna are also reported to be phototactic (Bayliff, 1980). When water temperatures were recorded for these 1988 catches, they indicated lower than average sea-surface temperatures (mean 14.1°C) for southern California waters in the eastern Pacific. Bluefin tuna are generally found associated with water temperatures of 17–23°C (Bell, 1963).

The commercial catch of such high numbers of large fish in 1988 has raised the possibility that adult bluefin tuna may occur regularly off California but are only occasionally recognized or observed. Foreman and Ishizuka (1990) have suggested that small schools of adult bluefin tuna may go unrecognized if mistaken for pods of marine mammals or go undetected if travelling or feeding at depth. If so, it may be that the conditions that govern their infrequent movement into inshore feeding areas are very specific and thus rarely occur.

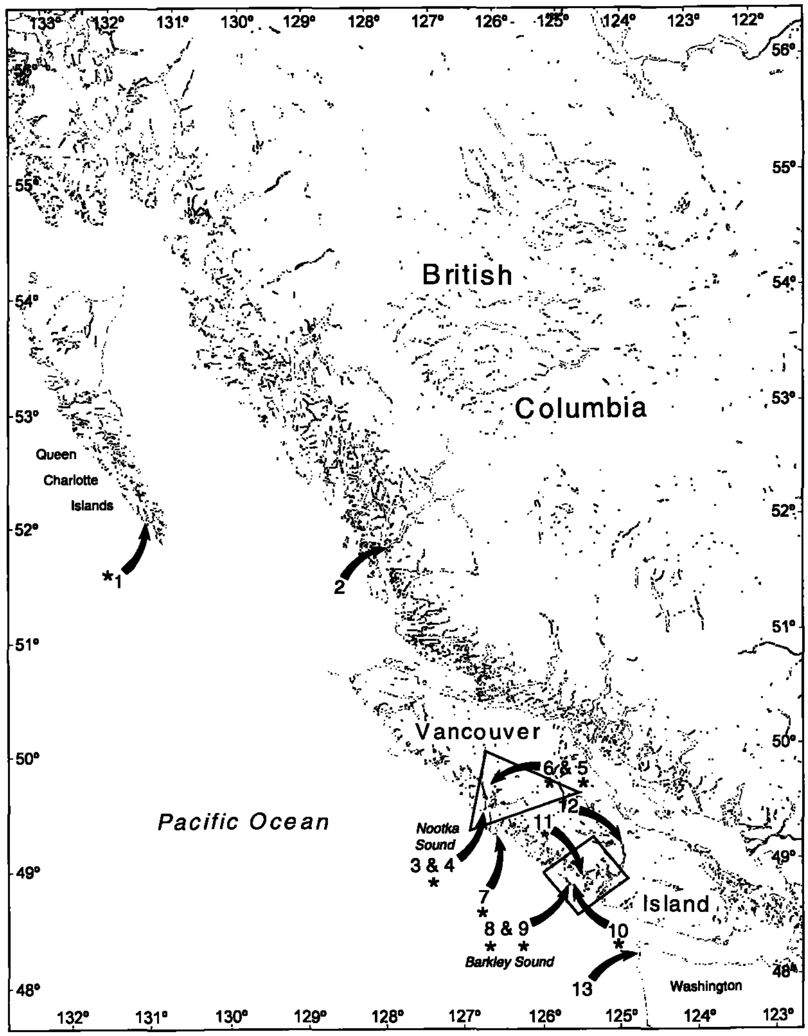

Figure 1

Map of the Pacific northwest coast of North America, showing the location of archeological sites from which bluefin tuna, *Thunnus thynnus,* remains have been recovered. *indicates samples examined in this study. *1 = FaTt 9 Louscoone Point; 2 = ElSx 1 Namu; 3 = DjSp 1 Yuquot village; *4 = DjSp 3 Yuquot midden; *5 = DkSp 1 Kupti; *6 = DkSp 3 Tahsis midden; *7 = DiSo 1 Hesquiat; 8 = DfSi 4 Macoah; * 9 = DfSi 5 Ch'uumat'a; *10 = DfSj 23A T'ukw'aa village; *11 = DfSj 23B T'ukw'aa defensive site; 12 = DhSe 2 Shoemaker Bay; 13 = 45CA24 Ozette village.

Analyses and results

The archeological sample

Vertebrae were examined from 8 of the 13 sites from which remains of bluefin tuna were found. As is typical for faunal remains recovered from archeological sites, chronological dates for tuna specimens are estimated in relation to the ^{14}C-dated strata from which they were recovered: none of the bluefin tuna remains have yet been dated directly.

The northernmost archeological evidence for the occurrence of bluefin tuna is from the southern Queen Charlotte Islands (Fig. 1), whereas Namu on the central British Columbia mainland is the oldest known deposit yielding bluefin tuna remains (dated at 4050–3050 BC). Bluefin tuna have also been recovered from sites at Hesquiat Harbour and Shoemaker Bay on the west coast of Vancouver Island and from the Ozette site near Cape Flattery, Washington (see Table 1 for more details). Vertebrae are the only traces of bluefin tuna recovered from the above sites, and only specimens from the Hesquiat Harbour and Queen Charlotte Islands were available for analysis.

Archeological excavations at four sites each in both Nootka and Barkley Sounds on the west coast of Vancouver Island also yielded bluefin tuna remains and, in contrast to other area sites, both vertebral and nonvertebral skeletal remains are represented. Neither scales nor otoliths, however, were found. Tuna were reported from all strata of the 1966 excavation at the village of Yuquot on Nootka Sound

Table 1

Archeological sites from which bluefin tuna, *Thunnus thynnus*, remains have been recovered, with excavation information, dates, references and numbers of remains reported that could not be analyzed in this study.

Area and site no.	Description of site and excavated remains
Queen Charlotte Islands and the North Coast, British Columbia	
1 (FaTt 9)	Louscoone Point village, Kunghit Haida territory; 52°08'N, 131°14'W; small test excavation 1985 (Wigen[1]:Acheson[2]); from deposits dated ca. AD 800–ca.1800.
2 (ElSx 1)	Namu village, Bella Bella territory; 51°52'N, 127°52'W; major excavation 1969–71; from deposits dated 4050–3050 BC (Cannon, 1991); 1 vertebra reported.
Vancouver Island, British Columbia	
Nookta Sound area sites, Mowachat territory; ca. 49°40'N, 126°37'W	
3 (DjSp 1)	Yuquot village; major 1966 excavation; from all deposits 2300 BC– AD 1880 (McMillan, 1979); 87 vertebral and nonvertebral specimens reported.
4 (DjSp 3)	Yuquot fishing station; from surface collection 1968;no dates (Marshall[3]).
5 (DkSp 1)	Kupti village; small 1968 excavation; from deposits ca. AD 1260–1460 (Marshall[3]).
6 (DkSp 3)	Tahsis Inlet midden; from 1990 shovel test; no dates (Marshall[3]).
7 (DiSo 1)	Hesquiat village, Hesquiat territory; 49°24'N, 126°28'W; major 1973–75 excavation; from deposits dated AD 1230–1430 (Calvert, 1980).
Barkley Sound area sites, Toquat territory; ca. 49°N, 125°20'W; 1991–93 excavations (McMillan and St. Claire[4])	
8 (DfSi 4)	Macoah village; bluefin from upper levels of deposits dated 2460 BC–ca.AD 1880.
9 (DfSi 5)	Ch'uumat'a village; bluefin from deposits dated ca. AD 1370.
10 (DfSj 23A)	T'ukw'aa village; bluefin tuna from deposits dated AD 760–1310.
11 (DfSj 23B)	T'ukw'aa defensive site; bluefin tuna from deposits dated AD 1175–1880 .
12 (DhSe 2)	Shoemaker Bay, Tseshaht territory; 49°15'N, 124°49'W; major 1973/74 excavation; from deposits dated AD 500–820 (Calvert and Crockford, 1982); 17 vertebrae reported.
Olympic Peninsula, Washington State	
13 (45CA24)	Ozette village, Cape Alava; Makah (Nuu-chah-nulth subdivision) territory; 48°10'N; 124°44'W; major 1971–80 excavation; from house floor deposits dated AD 1510 (Huelsbeck, 1983); 2 vertebrae reported (one modified).

[1] Wigen, R. J. 1990. Identification and analysis of vertebrae fauna from eighteen archaeological sites on the southern Queen Charlotte Islands. British Columbia Heritage Trust, 800 Johnson St. Victoria, British Columbia, Canada V8W 1N3. Unpubl. rep., 79 p.
[2] Acheson, S. 1992. Archaeology Branch, British Columbia Ministry of Small Business, Tourism, and Culture, 800 Johnson St., Victoria, British Columbia, Canada V8W 1N3. Personal commun.
[3] Marshall, Y. M. 1990. The Mowachaht archaeology project, phase 1, 1989. Archaeology Branch, British Columbia Ministry of Small Business, Tourism, and Culture, 800 Johnson St., Victoria, B.C., Canada V8W 1N3.
[4] See Footnote 3 in the main text of this paper.

(dated from about 2300 BC to ca. AD 1880), making this the longest continuous record of *Thunnus* occurrence in the region (McMillan, 1979; Marshall, 1993). Unfortunately, these specimens are archived in Ottawa and could not be retrieved easily for analysis: three other small excavations undertaken during 1968 and 1990 at sites along Nootka Sound, however, recovered remains of bluefin tuna and these specimens were available for inclusion in this analysis.

It is pertinent to mention that all fish remains from the 1966 excavation of the village at Yuquot were identified to genus level only (McMillan, 1979), perhaps giving the impression that the tuna remains might be albacore (*T. alalunga*), a species that occurs regularly in the eastern Pacific (Hart, 1973). However, crew working on the excavation of Yuquot reported that remains of some very large fish were recovered (Dewhirst[1]). According to the literature (and in my own twenty years experience analyzing faunal remains from this area), albacore have never been reported from any archeological site in British Columbia. Moreover, albacore rarely, if ever, exceed 50 kg; it therefore seems unlikely that *Thunnus* remains from Yuquot are albacore rather than bluefin tuna.

[1] Dewhirst, J. 1992. Archeo Tech Associates, 1114 Langley St., Victoria, British Columbia, Canada V8W 1W1. Personal commun.

Table 2

Calculated fork lengths (cm) and estimated weights (kg) of comparative specimens—USNM catalog numbers 269001, 269004, 268964, 269002 (Nankai collection numbers 1, 2, 3, 6) National Museum of Natural History (NMNH), Smithsonian Institution.

	Nankai 1 269001	Nankai 2 269004	Nankai 3 268964	Nankai 6 269002
Skull length (cm)	26.2	25.3	23.5	28.5
Total of vertebral lengths (1–39 cm)[1]	148.1	124.1	121.2	146.9
Total skeletal length (SL) (cm)	174.3	149.4	144.7	175.4
Estimate of intervertebral cartilage—40 spaces	20.0	20.0	20.0	20.0
Estimate of snout and tail flesh (cm)	10.0	10.0	10.0	10.0
Estimated fork length (cm)	204.3	179.4	174.7	205.4
Estimated weight (kg)[2]	184	130	121	187

[1] All measurements available from the author or NMNH, Smithsonian Institution.
[2] Foreman and Ishizuka, 1990; 184.

Recent excavations at four locations along Toquart Bay in Barkley Sound on the west coast of Vancouver Island have recovered relatively large numbers of both vertebral and nonvertebral bluefin tuna skeletal remains. Full analysis of this material is still in progress: only a few of the nonvertebral remains have been examined thus far. All vertebrae, however, are included in this study.

Modern skeletal samples

In order to estimate the size of fish represented by isolated vertebrae from archeological samples, it was necessary to determine the size relationship between individual vertebrae and the corresponding fork length in modern samples of the fish. Measurements taken from the vertebrae of modern skeletal specimens of known-size fish of comparable size were used for this purpose (Casteel, 1976; Wheeler and Jones, 1989).

Recent skeletal specimens of large (160 cm TL and over) Pacific bluefin tuna were found to be extremely rare, and the only known specimens had, unfortunately, no corresponding size data (length or weight); therefore fork lengths (snout to fork of the tail) had to be estimated for these specimens as well. Fortunately, these four recent specimens of bluefin tuna (loaned by B. Collette, Museum of Natural History, Smithsonian Institution, Washington, D.C.) have skulls that are still articulated, and it was possible to determine a "skeletal length" for these specimens (Table 2). The skeletal length is defined as the basal length of the skull plus the combined lengths of all 39 vertebrae. The vertebral column of the comparative specimens had been sawed into sections during skeletal preparation, sometimes by cutting through a centrum. Vertebra no. 30, either by itself or with portions of no. 29 and no. 31 attached, was apparently removed from the specimens at some point and not returned. Estimates of the length measurements of all three of these vertebrae were used in the regression equations. These four fish appear to be the only disarticulated skeletal specimens of large Pacific bluefin tuna available for analysis (however, several museums have reconstructed skeletal specimens of large individuals on display). All raw data for these specimens are available on request from the author and are also on file at the National Museum of Natural History, Smithsonian Institution.

In order to estimate a fork length from the skeletal length for these comparative specimens, I assigned a value of 0.5 cm to the intervertebral cartilage (40 spaces, 20 cm total) and an additional 5 cm each for flesh on the snout and the tail. These values consistently added 30 cm to the measured skeletal length and yielded an estimated fork length. This method was chosen so that if a more accurate determination of the "soft tissue" component of the fork length of bluefin tuna is subsequently developed, the estimates given in this report can be easily adjusted.

The vertebral centrum length and breadth measurements from the four comparative specimens (Fig. 2) were used in single (least-squares) regression equations for each of the 39 vertebrae in the spinal column by using logarithmic transformations of vertebral and skeletal length measurements to determine their linear relationship. Because the size and shape of vertebrae change (sometimes quite dramatically) over the length of the fish, it was necessary to calculate a separate algorithm for each vertebra in the spinal column.

Table 3 presents the resulting values for the relationship between the greatest centrum length, GL, and greatest proximal centrum breadth, GB(p), to the skeletal length, SL, for the recent specimens as calculated by regression analysis. In this table, some values are missing or are based on only 3 specimens owing to the original preparation of the comparative skeletons. Standard deviations and confidence limits are not given but are available on request.

Size determination of archeological specimens

The standard formula used to estimate the size of fish represented by the archeological specimens is given by Casteel (1976, p. 96) as: log (*fork length*) = $a + b \times \log$ (*GL* or *GB*). The constant (a) and the slope—or x coefficient —(b) are taken from Table 3 (i.e. the values derived from the comparative specimens), and the logarithm of the greatest length, *GL*, or proximal breadth, *GB*(p), from each archeological specimen (Table 4).

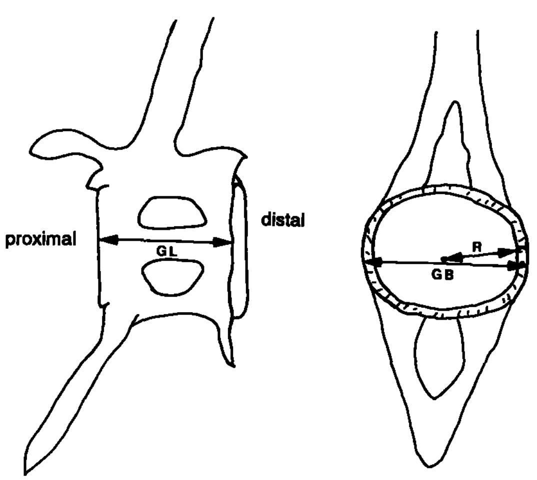

Figure 2

Definitions of vertebral measurements taken from both comparative and archeological specimens of bluefin tuna. Greatest length (GL): maximum length of the centrum, taken at the lateral midpoint with digital calipers and measured to the nearest mm. Greatest breadth (GB) = maximum breadth of the centrum, taken at the lateral midpoint of the proximal face, GB(p), and distal face, GB(d), taken with digital calipers and measured to the nearest mm. Radius (R) = the maximum distance from the center of the cone to the edge, of the proximal face, R(p), and distal face, R(d), taken at the lateral midpoint. This measurement was taken with a plastic ruler cut diagonally to fit into the cone of the centrum; in this way the amount of growth from the center of the cone to the sharp raised ridge at the lip of the centrum was measured to the nearest 0.5 mm.

Casteel (1976) noted that although the regression method is the most accurate way to estimate fish length from bone size, these length estimates always vary somewhat between vertebrae from the same individual, even when the predictive value (r) of the equation is high. When both length and breadth measurements were available for an archeological specimen, the measurement that produced the length estimate with the highest correlation coefficient (r) value for that individual was used to represent that fish. Alternatively, an average of all available measurements could have been made, although this method allowed both comparative and archeological specimens to be treated similarly.

The method used in the present study required that vertebral specimens be identified to exact column position. This can be problematic for archeological specimens because several of the centra in the vertebral column are almost identical and because archeological specimens may often lack diagnostic neural or haemal arches and spines. However, an archeological specimen can almost always be defined to a small range within the column (e.g. vertebrae numbers 14–16). Vertebrae not identified to exact position were found to be so similar in size and proportion to adjacent vertebrae that they could be treated as interchangeable for the purpose of the estimations attempted here. Where the exact position of an archeological specimen was uncertain (which occurred for less than one third of the specimens examined), the number of the vertebra used to calculate the size estimates is given in parentheses, e.g. (15).

Table 4 presents all archeological vertebrae measured (by vertebra number) and the length estimates derived from them. Where eroded edges prevented accurate measurement, an estimate was taken if it was likely to be accurate to within 1 mm. A total of 78 vertebrae were measured, representing at least 45 individuals. Several vertebrae were found attached (occasionally in articulated position) or could potentially have belonged to the same individual by virtue of similar size and proximity within the archeological deposit (this is a standard assumption for determining the minimum number of individuals represented by skeletal remains recovered from archeological contexts). Radius measurements of these specimens were also taken (because this dimension is preferred by some researchers for ageing purposes) but are not reported or used in the calculations. All measurements are available on request from the author.

The fork-length estimates for the archeological sample listed in Table 4, as for the comparative skeletons, are derived by adding 30 cm to the estimated skeletal length to yield a fork length (to account for

Table 3

Regression analysis values: log of vertebral lengths, *GL*, and proximal breadth, *GB(p)*, vs. log of skeletal length, *SL*, of 4 modern bluefin specimens (USNM 269001, 269004, 268964, 269002). NA = not applicable. Number of observations=4 (*=3); Degrees of freedom=2 (*=1).

Vertebra no.	Constant *GL*	X Coefficient *GL*	*r* value *GL*	Constant *GB(p)*	*X* Coefficient *GB(p)*	*r* value *GB(p)*
1	4.8553	0.7814	0.903	NA	NA	NA
2	4.6692	0.8328	0.881	3.8396	0.9154	0.892
3	4.4210	0.9155	0.917	4.0180	0.8634	0.945
4	4.6286	0.8486	0.901	4.4710	0.7433	0.965
5	5.2932	0.6351	0.908	4.5377	0.7295	0.997
6	4.9966	0.7257	0.933	4.6478	0.7096	0.981
7	4.2052	0.9593	0.992	4.3649	0.8043	0.970
8	4.1994	0.9492	0.932	4.0022	0.9111	0.970
9	4.6598	0.8064	0.955	3.9509	0.9272	0.985
10	4.7950	0.7543	0.928	3.9373	0.9300	0.994
11	3.9914	0.9810	0.993	3.8234	0.9561	0.996
12	5.3210	0.5964	0.908	4.2293	0.8463	0.985
13	4.6473	0.7785	0.971	4.3599	0.8081	0.994
14	4.4486	0.8287	0.983	4.0404	0.8918	0.992
15	4.5968	0.7815	0.954	4.4404	0.7807	0.988
16	4.6118	0.7746	0.991	4.4515	0.7768	0.986
17	4.2226	0.8808	0.972	4.3918	0.7903	0.989
18	3.5879	1.0526	0.962	4.3059*	0.8088*	1.000
19	4.3551	0.8328	0.997	4.2695	0.8175	0.988
20	4.3449	0.8360	0.994	4.4124	0.7797	0.983
21	4.1621	0.8809	0.985	4.3422	0.7963	0.987
22	4.2308	0.8604	0.987	4.2783	0.8129	0.991
23	5.1630*	0.5922*	0.705	NA	NA	NA
24	4.3756	0.8189	0.987	4.4521	0.7663	0.989
25	4.2320	0.8561	0.989	4.1347	0.8494	0.988
26	4.0288	0.9085	0.997	4.2699	0.8127	0.975
27	3.8883	0.9387	0.995	4.4668	0.7626	0.984
28	3.8464	0.9475	0.996	3.9946	0.8854	0.993
29	3.4217	1.0551	0.976	4.1875	0.8305	0.979
30	4.0737	0.8741	0.937	4.1472	0.8386	0.999
31	3.6730	0.9715	0.886	NA	NA	NA
32	4.0061	0.8852	0.876	NA	NA	NA
33	4.5576	0.7398	0.859	3.7206	0.9430	0.995
34	5.1867	0.5850	0.598	3.9220	0.9076	0.998
35	5.6621	0.4777	0.595	4.3345	0.8317	0.976
36	5.3978	0.5952	0.942	5.8817*	0.4347*	0.713
37	5.7937	0.6068	0.921	3.5138	1.1630	0.990
38	6.2246	0.5138	0.862	3.1768	1.3458	0.988
39	3.7247	0.9270	0.901	4.5084	0.9313	1.000

intervertebral cartilage [20 cm] and flesh on the snout and tail [10 cm]). Weight estimates have been calculated from the formula derived by Foreman and Ishizuka (1990) for large Pacific bluefin and are presented in Table 5.

Age estimations included in Tables 5 and 6 are compiled from data presented by Bayliff (1994) that was based on fork-length estimates. However, Hales and Reitz (1992) cautioned that age data determined from modern population samples may differ from prehistoric populations. They report a distinct change in growth rates over time for Atlantic croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae), from Florida, a change determined from the analysis of otolith growth increments from prehistoric samples. Compared with modern populations, croakers from populations of several centuries ago grew more slowly and lived much longer.

Although the results of the croaker study suggest that modern data relating size to age may not accurately predict the age of prehistoric fish specimens, no data are currently available to address this phenomenon for any population of bluefin tuna. Should bluefin tuna be shown to exhibit the same pattern as croaker, the archeological specimens of bluefin tuna reported here would actually represent fish older than those predicted by this analysis. However, length measurements were converted to age and weight estimates in this study primarily so that comparisons could be made with modern tuna distribution data, which are often reported by age class or weight. The critical point was to establish whether adult, rather than juvenile, tuna were more abundant in the archeological sample, because these age classes display distinctive behaviors and, more importantly, have different ecological requirements.

Size of bluefin tuna represented by the archeological sample

Table 5 presents the final length, weight, and age estimates of bluefin tuna by geographic area. By far the majority of fish within the total sample (83%) were at least 6 years or older, ranging between 160

Table 4

Archaeological bluefin tuna vertebrae measurements and fork length estimates, by vertebrae number. All specimens. Measurements are defined in Figure 2.

Vertebra no.	Centrum GL (mm)	Centrum GB(p) (mm)	Estimated FL (cm)	Vertebra no.	Centrum GL (mm)	Centrum GB(p) (mm)	Estimated FL (cm)
01	27.0	44.4	198.7	21	38.3	45.1	189.6
02	26.3	48.2	191.5	22	39.2	44.8	189.6
04	22.5	39.6	164.7	22	39.2	46.5	188.6
04	31.6	65.1	224.9	24	39.4	47.5	193.5
05	27.1	58.7	212.4	24	45.1		195.3
06	30.8	58.9	218.2	25	40.8	48.3	209.8
09	25.6	34.4	168.2	26	40.1	47.6	194.8
(09)		48.7	220.8	(28)	30.2	35.9	190.7
(09)	22.3	30.5	153.6	29	33.7	36.3	159.3
(10)	33.4	45.0	206.7	29	45.3	49.5	155.3
11	24.4	34.6	165.5	29	50.3	58.2	201.1
(11)	31.0	37.8	177.5	30	28.1	32.0	221.1
(12)	35.0		200.5	30	36.7		138.5
(12)	36.7	46.5	206.9	30	38.3	44.0	167.1
(12)	34.9	41.9	192.0	30	46.7		172.3
14	33.5		187.0	30	47.3	50.0	199.2
(14)	33.9	40.9	185.4	30	47.5	51.2	201.1
(14)	34.1	42.0	189.3	31	48.6	52.8	201.7
(14)	32.5	42.1	189.7	31	52.7	53.8	201.3
(14)	27.7	32.8	157.8	32	41.7	45.6	215.3
15	35.4	42.5	188.4	32	43.7		179.3
(15)	31.4	42.5	188.4	32	49.7	54.4	185.6
16	35.9	45.6	191.2	33	26.6	27.0	204.4
16	36.1	42.9	191.9	33	43.8	44.8	122.4
(16)	31.3	35.4	175.0	33	44.5	47.2	178.9
(16)	33.8	40.9	183.9	33	44.7	45.6	186.5
(16)	40.2	47.2	206.0	33	47.9	53.9	181.4
(16)	41.2	51.8	209.4	33	52.2	53.7	207.3
17	36.0	42.8	187.3	33	53.7	55.2	206.7
17	37.5	47.3	200.2	34	48.1		211.3
(17)	37.0	43.9	190.4	34	48.2		202.4
(17)	38.2	44.2	191.3	35	41.2	42.0	202.6
18	37.2	46.5	195.4	36	30.5		200.8
(18)	26.8	32.4	153.5	38	11.9	28.2	198.9
19	39.4	47.2	196.0	38	16.5	31.8	210.3
(19)	27.2	32.7	151.9	39		23.0	243.2
20	35.5	44.5	182.4	39		19.5	198.3
(20)	38.0	45.0	191.3				
(20)	44.3	54.0	213.4				

Table 5

Archeological bluefin tuna length and age estimates, per individual represented, listed by geographic area. The length estimate associated with the highest correlation coefficient (*r*) for individuals represented by several elements is used here. See Figure 1 for locations.

Specimen no.	Site no.	Vertebra no.	Estimated fork length[1] (cm)	Estimated weight[2] (kg)	Estimated age class[3] (yr)
Barkley Sound, Vancouver Island, *n* = 36					
52	DfSi5	33	122.4	47	4
84	DfSj23a	30	138.5	65	5
51	DfSi5	(19)	151.9	83	5–6
54	DfSj23a	(18)	153.5	86	5–6
59	DfSj23a	29	155.3	88	5–6
30	DfSj23a	(14)	157.8	92	5–6
58	DfSj23a	11	165.5	105	6
25	DfSi5	30	167.1	107	6
55	DfSj23a	09	168.2	109	6
85	DfSj23a	30	172.3	117	6–7
83	DfSj23a	(16)	175.0	122	6–7
49	DfSi4	33	178.9	129	6–7
56	DfSj23a	33	181.4	134	7
48	DfSj23a	(16)	183.9	139	7
61	DfSj23a	33	186.5	144	7
39E	DfSi4	17	187.3	146	7
36C	DfSi4	22	188.6	149	7
47	DfSi4	(14)	189.3	150	7
60	DfSj23a	(14)	189.7	151	7
69F	DfSj23b	26	190.7	153	7
86	DfSi4	(20)	191.3	154	7
87	DfSj23a	02	191.5	155	7
57	DfSi5	01	198.7	171	7–8
26	DfSj23b	(12)	200.5	175	7–8
32	DfSi4	30	201.1	176	7–8
24	DfSj23a	(16)	206.0	188	8
44	DfSj23a	33	206.7	190	8
31	DfSj23a	(12)	206.9	190	8
68	DfSj23a	(16)	209.4	197	8
45A	DfSi4	24	209.8	198	8
64	DfSj23a	05	212.4	204	8
67	DfSj23b	31	215.3	212	8
63	DfSi4	06	218.2	219	8
72	DfSi4	(09)	220.8	226	8–9
66	DfSi4	29	221.1	227	8–9
80	DfSj23a	38	243.2	293	9–10
Hesquiat Harbour, Vancouver Island, *n* = 2					
21	DiSo1	32	186.0	143	7
20	DiSo1	(20)	213.4	207	8
Nootka Sound, Vancouver Island, *n* = 6					
NA	DkSp1	(28)	159.0	94	5–6
NA	DkSp1	(11)	177.0	125	6–7
1	DjSp3	39	198.3	170	7–8
3E	DkSp1	36	198.9	171	7–8
4	DkSp1	(10)	206.7	190	8
2	DkSp1	38	210.3	199	8
Queen Charlotte Islands, *n* = 1					
15E	FaTt9	19	196.0	165	7–8

[1] All raw data and calculations available from the author.
[2] Log (weight, kg) = (–9.02408) + 2.6767 × log (length, cm) (Foreman and Ishizuka, 1990).
[3] After Bayliff 1994a: 246.

Table 6

Distribution of estimated age and size classes of bluefin tuna harvested within the Barkley Sound area only, based on archeological remains from Barkley Sound area sites.

Estimated fork length (cm)	Number of individuals	Estimated age class (yr)[1]
120–129	1	4
130–159	5	5–6
160–179	8	6–7
180–199	11	7–8
200–219	8	8
220–239	2	8–9
240–260	1	9–10
	Total = 36	

[1] After Bayliff, 1994a: 246 (data for vertebrae only).

and 240 cm TL and between approximately 96 to 293 kg in weight. The youngest fish was estimated at 4 years (120 cm TL) and the oldest between 9 and 10 years (240 cm TL). Of the total sample of 45 individuals, 36 were recovered from the Barkley Sound area on the southwest coast of Vancouver Island, and the range of sizes from that area is summarized in Table 6. The relative size range of the bluefin tuna vertebrae harvested from Barkley Sound is shown pictorally in Figure 3.

Ethnographic and historic information

Information from ethnographic sources substantiates and augments archeological evidence indicating that large bluefin tuna were present and harvested by Nuu-chah-nulth people of Vancouver Island well into the 19th century. Elders of the Mowachaht group from Nootka Sound on Vancouver Island have contributed invaluable details about tuna hunting strategies employed by their elders, some through interviews with Richard Inglis of the Royal British Columbia Museum, Victoria, British Columbia during 1991 and 1992 (Inglis[2]). These accounts represent the only ethnographic description of aboriginal tuna hunting on the northwest coast (McMillan, 1979). Pertinent details that substantiate the occurrence of adult bluefin tuna during the historic period are presented here.

The month of August is said to have been the time when tuna could be found feeding at the surface in inshore waters (sea-surface temperatures during August usually average about 14°C [Sharp, 1978]). The occurrences of large tuna were apparently preceded and accompanied by recognizable changes in water and weather conditions and by a unique set of associated fauna. Tuna traveled well inside Nootka Sound into protected inlets and were harpooned at night as

[2] Inglis, R. 1993. British Columbia Ministry of Aboriginal Affairs, #100-1810 Blanchard St., Victoria, British Columbia, Canada V8V 1X4. Personal commun.

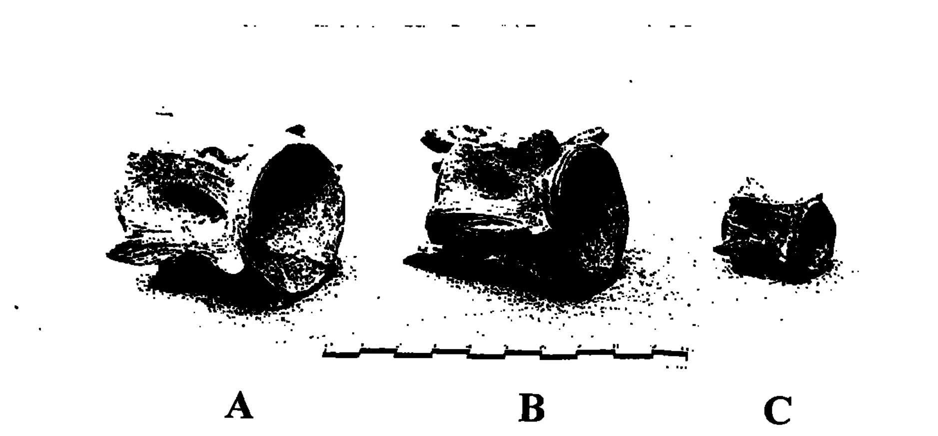

Figure 3

Selected vertebrae from Barkley Sound archeological deposits. See Figure 1 for locations. (**A**) Specimen no. 44, vertebra no. 33; site DfSj 23a; length ca. 210 cm; (**B**) Specimen no. 61, vertebra no. 33; site DfSj 23a; length ca. 190 cm; and (**C**) Specimen no. 52, vertebra no. 33; site DfSi 5; length ca. 120 cm.

they fed at the surface in shallow inshore waters (located by spotters positioned on nearby cliffs). Bioluminescent plankton present in the water made the big fish especially visible at night, even from a distance.

A fire was sometimes built in the bow of the hunter's canoe to attract the fish to within spearing distance, a strategy called "pit-lamping." Another method was to paddle the canoe quickly away from an area where tuna were spotted: the canoe created a path of light as it moved through the bioluminescence. The tuna would follow the light, right up to and under the canoe, and were harpooned as they emerged at the bow. The word for tuna ("silthkwa") means "like the bow wave made by a boat," and undoubtedly reflects their surface-feeding behavior. These tuna were always referred to as "big fish, 6 to 8 feet (ca. 180–244 cm TL) long."

George Louis of the Ahousat Band was about 80 years old when interviewed in 1992. He said that his father told a story about the tuna hunting he observed as a small boy (perhaps when about 10 years old) sometime between 1880 and 1890. No official records or unofficial accounts have been found which indicate that large tuna have been observed in British Columbia waters since that time. Large bluefin tuna were captured, however, by sport anglers during the 1890's in southern California (Holder, 1913).

The only written reference to tuna found to date in the historic record is a footnote in the account of a meeting between George Vancouver and Bodega y Quadra at Nootka Sound in 1792. Mention is made of a porpoise and tuna stew ("large Tunny and a Porpus") being served during a feast given in their honor by Nuu-chah-nulth chief Maquinna on 4 September 1792 (Lamb, 1984, p. 304). There is, of course, no way of knowing if the "tuna" was bluefin tuna, some other tuna species, or some other taxon altogether. The capture of porpoise, however, would have required similar hunting skills and equipment as those described above for bluefin, and both could have been caught during a single hunting expedition. "Porpoise" remains are reported from a number of coastal shell middens (Mitchell, 1988) and are most likely to be either harbour porpoise, *Phocoena phocoena*, white-sided dolphin, *Lagenorhyncus obliquidens*, or Dall's porpoise, *Phocoenoides dalli* (Leatherwood et al., 1988). Moreover, bluefin tuna (even very large ones) would have been quite familiar to the Europeans exploring the coastal waters of British Columbia because the similar Atlantic subspecies occurs in European coastal waters. In marked contrast to the many unknown species regularly encountered by explorers in the north Pacific, large bluefin tuna might have been so familiar that they did not warrant special comment.

Discussion

Archeological evidence and potential sampling bias

The archeological remains described above represent a size class of bluefin tuna previously unknown in the northern portion of the eastern Pacific and constitute a small but valuable biological sample of the ancient population. However, some of the cultural and taphonomic (postdepositional) influences that affected the sample must be considered before ecological or zoogeographic interpretations can be made.

The archeological shell middens from which the bluefin tuna specimens have been recovered are essentially garbage dumps created over many centuries by the disposal of food and other household waste. The calcium carbonate leaching from abundant shellfish remains in these midden deposits effectively neutralizes acids in the soils that would otherwise rapidly destroy bone. Preservation of vertebrate skeletal remains is often excellent under these conditions, even after several thousand years.

The bones of animals recovered during archeological excavation of a shell midden represent a very small portion of the animals harvested by aboriginal people. Many processes operate on the carcass of a harvested animal to reduce the number of bones that might eventually be discarded into a midden (Davis, 1987; Lyman, 1994). These include butchering methods, distribution of edible parts (sharing), cooking procedures, and consumption of the edible portions. Some bones may have been set aside for tool or ornament manufacture (only one piece of altered bluefin tuna has been recovered: a vertebra fashioned into a spool, from the Ozette Village site in Washington). Moreover, scavengers, especially dogs and birds, may have removed or destroyed parts of a carcass so that in the end only a few bones from any given animal are represented in the midden. Finally, only small portions of most large midden deposits are actually excavated by archeologists, further reducing the sample of harvested animals available for archeozoological analysis (Ringrose, 1993, for detailed discussions of these issues; Lyman, 1994). For example, the remains of the 36 individual bluefin tuna recovered from Barkley Sound (Table 6) represent an empirically undeterminable fraction of what was actually harvested and consumed by the aboriginal people in that area. In addition, the number of fish successfully landed constituted a very small proportion of the available population of bluefin tuna. Presumably only a few bluefin tuna would have been actively pursued and some of these would invariably have been lost during the hunt. Thus, even if only one giant bluefin tuna was successful harvested every few seasons by native hunters, this could still constitute evidence of a significant population of tuna available as a local resource.

Unfortunately, the time interval between catches of bluefin is not precisely determinable from the dated archeological deposits; it is impossible at this time to determine if catches were made annually, every 10 years, or every 100 years. Although expensive, the use of accelerator ^{14}C-dating methods on small samples of bluefin tuna remains is the only way to determine a more precise time frame. The remains of bluefin tuna recovered from Barkley Sound during several recent field seasons are perhaps the best candidates for future analysis because there are many vertebral and nonvertebral skeletal elements and the remains appear to represent less than 2,000 years of harvesting activities (McMillan and St. Claire[3]).

Geographic range of prehistoric bluefin tuna remains

As discussed at greater length previously (Crockford, 1994), it appears probable that the ability to hunt large Pacific bluefin tuna was strongly correlated with native groups who were capable of active whaling. This possible correlation with active whaling rather than with the use of so-called "drift" whales (which die naturally and are fortuitously encountered at sea or as beached carcasses) is important. No other archeological sites in western North America or northeastern Asia appear to contain remains of large bluefin tuna. No large bluefin tuna have been reported from sites in southern California where adult tuna are occasionally taken today, although the remains of other large fish, such as marlin, have been identified and large marine mammals, such as sea lions, were clearly taken (Moratto, 1984; Raab[4]). We cannot assume, however, that large bluefin tuna were not present in southern California waters during prehistoric times because a lack of whaling technology may have prevented aboriginal Californians from harvesting such a resource.

In northern Japan, active whaling is not clearly indicated by the archeological record although hunting of sea lions and other large marine mammals was practiced. Large bluefin tuna remains have not been reported from archeological sites bordering the Sea of Okhotsk and the Sea of Japan where large bluefin tuna occur today (Niimi, 1994; Otaishi, 1994), but it appears that not many large sites in these areas have been excavated. As in the case for California, it would be inappropriate, given the absence of evidence for an active whaling technology, to suggest that adult bluefin tuna were absent in Japanese waters during prehistoric times.

In contrast, the recovery of large bluefin tuna among dated archeological deposits that span almost 5,000 years is evidence that the occurrence of adult bluefin tuna off the British Columbia coast was longstanding. Clearly, large bluefin tuna were a resource consistently (if sporadically) available to aboriginal people on the central northwest coast until relatively recently. The Nuu-chah-nulth people, in particular, were especially adept at using this resource, and their material culture included large seagoing canoes, detachable harpoon heads, braided ropes, and floats required for the successful hunting of both whales and large tuna (Huelsbeck, 1983; Mitchell and Donald, 1988). Archeological remains are, by inference, invaluable indicators that the environmental conditions that favored the presence (i.e. the inshore surface-feeding behavior) of bluefin tuna must have existed off the coast of British Columbia as a recurring pattern for at least 5,000 years.

Implications

The lack of reports of adult bluefin tuna off the British Columbia coast since the late 19th century may be due to several factors, including the impact of 20th-century fisheries in both the eastern and western Pacific, the association of large bluefin in northern waters of the eastern Pacific with very specific environmental conditions that have not recurred since the late 19th century, and the misidentification of small schools of large bluefin tuna as marine mammals.

Although relative abundance records over the past 100–150 years are not available for Pacific bluefin tuna, it has been shown for other species that when abundance decreases, the range of a species often contracts (Kawasaki, 1991). In order to investigate how 20th-century fisheries may have impacted abundance and thus the distribution of bluefin tuna, a comprehensive record of the history of the bluefin tuna fishery as conducted by all nations throughout the north Pacific would be needed. This is especially true for Japanese waters because of the use there of large-scale harvesting methods.

It is also possible, however, that short- or long-term (or both) changes in environmental conditions may be affecting bluefin tuna distributions in the east-

[3] McMillan, A. D., and D. E. St. Claire. 1992. The Toquart archaeology project: report on the 1992 excavations. Archaeology Branch, British Columbia Ministry of Small Business, Tourism and Culture, 800 Johnson St. Victoria, British Columbia, Canada V8W 1N3: permit 1991–46. Unpubl. rep., 100 p.

[4] Raab, M. 1994. Anthropology Department, California State University, Northridge, CA 91330. Personal commun.

ern Pacific (Rothschild, 1991). Hubbs (1948) partially addressed this issue in his presentation of evidence that mean water temperatures in southern California were warmer in the mid-to-late 1800's (1850–80). Such water temperatures appeared to be associated with distinctly tropical fauna that no longer occur so far north. This period corresponds roughly to that mentioned in the northwest coast ethnographic accounts as the last time when large tuna were hunted and may reflect a recurring pattern of occasional warm periods along the whole coast of North America.

Because the surface-feeding behavior of large bluefin tuna makes them very conspicuous in inshore waters, it would be extremely unlikely for adult tuna to go totally unnoticed for the last 100 years in British Columbia waters (even if they could not be caught or were indeed mistaken for marine mammals in deeper waters). It seems reasonable to assume under the circumstances that modern records are correct: large adult bluefin tuna have not frequented the northern waters of the eastern Pacific during the last 100 years. The reasons for their absence, however, remain to be determined.

Clearly, more investigation into the history of the distribution and harvesting of all age classes of bluefin tuna within the entire north Pacific will be necessary before we really understand the implications of the archeological remains reported in this study. Complex interactions of changes in ecological conditions and harvesting pressures on various age classes over the last 100 years probably have affected and may have had unexpected repercussions on the population structure of Pacific bluefin tuna. A better understanding of the distribution of adult tuna in the north Pacific through inclusion of archeological records may help document perturbations in the modern fishery.

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