

Supplement 1

Text S1. Isotopic corrections of billfish data from California archaeological sites.

To make our bulk collagen data from archaeological billfish (Table S3 in Supplement 2) comparable with previously published works (Acosta-Pachón et al. 2020) (Table S4 in Supplement 2) required correcting for isotope effects due to temporal baseline shifts (Clark et al. 2021) and sample preparation differences (Wilson & Szpak 2022). Modern swordfish anal spines analyzed by Acosta-Pachón et al. (2020) were not demineralized or lipid-extracted (Table S4). It was thus necessary to first estimate a correction factor between purified billfish bone collagen and whole bone, as Wilson and Spzak (2022) found differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of these tissue types (Table S5 in Supplement 2). Using data from Wilson and Spzak (2022) (Table S5) we computed the mean difference in bulk $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of paired samples, finding bulk tissue lipid-extracted collagen samples were on average higher by +0.5 ‰ ($\delta^{13}\text{C}$) and +0.2 ‰ ($\delta^{15}\text{N}$) than untreated whole bone samples. We applied these correction factors to archaeological billfish isotope data (see Rcode, Supplement 3).

Next, we adjusted for anthropogenically-driven isotope changes in atmospheric $\delta^{13}\text{C}$ and ^{13}C discrimination by phytoplankton as a result of increasing atmospheric and oceanic [CO₂] and increasing water temperatures (Clark et al. 2021). Expanding from the methods of Vokhshoori and colleagues (2019) we applied a correction of 0.05 ‰ per decade between 1860 to 1960 (Francey et al. 1999), 0.16 ‰ per decade from 1960 to 1990 (Quay et al. 2003), and 0.20 ‰ per decade from 1990 to 2014 (Quay et al. 2017), for a total correction of 1.46 ‰. Clark et al. (2021) recommend correcting all modern data to pre-industrial (i.e., ca. 1850) values to allow direct comparisons across studies. However, due to the lack of available raw data from Acosta-Pachón (2020), we corrected archaeological billfish data to an AD 2014 value to compare modern and ancient billfish ecology and habitat; corrected data for archaeological California billfish are presented in Table S1. After the above corrections were applied, our isotopic dataset marginally failed assumptions of univariate normality [function *shapiro.test()* in Program R]. We thus used unpaired Mann-Whitney tests to evaluate differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values among swordfish from mainland vs. island sites (Figures 1, 2; Supplement 3).

Table S1. Measured and corrected isotope values of archaeological billfish from California.

Museum	Catalog Number	Location	Site Age	Site	Element	Species [^]	$\delta^{13}\text{C}$	${}^{\circ}\delta^{13}\text{Cc}$	$\delta^{15}\text{N}$	$\Delta\delta^{15}\text{N}_C$	C (wt%)	N (wt%)	${}^{\circ}\text{C:N}_{\text{atomic}}$
USNM	26380a	Santa Barbara Mainland	late Holocene ^x	Unknown	Centrum	<i>Xiphias gladius</i>	-14.9	-16.9	13.2	13.0	44.7	14.7	3.5
USNM	26380b	Santa Barbara Mainland	late Holocene ^x	Unknown	Centrum	<i>Xiphias gladius</i>	-11.7	-13.7	6.5	6.3	42.2	15.7	3.1
USNM	62661a	Santa Barbara Mainland	pre-CE 1800	CA-SBA-46	Centrum	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	45.1	11.6	4.5
USNM	62661b	Santa Barbara Mainland	pre-CE 1800	CA-SBA-46	Centrum	<i>Xiphias gladius</i>	-14.8	-16.8	10.3	10.1	40.0	14.1	3.3
USNM	62661c	Santa Barbara Mainland	pre-CE 1800	CA-SBA-46	Centrum	<i>Xiphias gladius</i>	-16.4	-18.4	8.1	7.9	37.8	12.3	3.6
USNM	62661d	Santa Barbara Mainland	pre-CE 1800	CA-SBA-46	Centrum	<i>Xiphias gladius</i>	-13.3	-15.3	13.5	13.3	43.3	14.6	3.5
USNM	23690	Santa Rosa Island	late Holocene ^x	Unknown	Rostrum	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	42.8	13.2	3.8
USNM	26325	Santa Cruz Island	late Holocene ^x	Unknown	Rostrum	<i>Xiphias gladius</i>	-11.5	-13.5	6.7	6.5	43.1	15.2	3.3
USNM	26233a	Santa Cruz Island	late Holocene ^x	Unknown	Finray spine	<i>Xiphias gladius</i>	-11.6	-13.6	12.7	12.5	40.6	15.3	3.1
USNM	26233b	Santa Cruz Island	late Holocene ^x	Unknown	Finray spine	<i>Xiphias gladius</i>	-12.3	-14.3	11.1	10.9	42.2	15.2	3.2
SBMNH	SCRI-496-35	Santa Cruz Island	~1500-150 cal BP	CA-SCRI-496	Rostrum	<i>Kajikia audax</i>	-11	-13.0	13.9	13.7	42.1	15.8	3.1
SBMNH	CHIS-12522	Santa Cruz Island	~1500-150 cal BP	CA-SCRI-504	Centrum	<i>Xiphias gladius</i>	-13.3	-15.3	10.3	10.1	43.0	14.2	3.5
SBMNH	CHIS-12122	Santa Cruz Island	~1500-150 cal BP	CA-SCRI-423	Rostrum	<i>Xiphias gladius</i>	-10.6	-12.6	12.0	11.8	38.4	14.6	3.1
SBMNH	SCRI-496-32	Santa Cruz Island	~1500-150 cal BP	CA-SCRI-496	Rostrum	<i>Xiphias gladius</i>	-10.8	-12.8	13.5	13.3	37.3	13.9	3.1
SBMNH	CHIS-12500	Santa Cruz Island	~1500-150 cal BP	CA-SCRI-504	Finray spine	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	43.0	12.8	3.9
SBMNH	CHIS-12124	Santa Cruz Island	~1500-150 cal BP	CA-SCRI-423	Centrum	<i>Xiphias gladius</i>	-11.6	-13.6	14.2	14.0	38.8	14.5	3.1
USNM	29664	San Miguel Island	late Holocene ^x	Unknown	Finray spine	<i>Xiphias gladius</i>	-12.2	-14.2	11.7	11.5	41.7	15.3	3.2
SBMNH	31769	San Miguel Island	~1200 cal BP	CA-SMI-481	Centrum	<i>Xiphias gladius</i>	-11.5	-13.5	13.7	13.5	32.4	12.2	3.1
SBMNH	19617	San Miguel Island	3000-2500 cal BP	CA-SMI-87	Centrum	<i>Xiphias gladius</i>	-10.9	-12.9	13.6	13.4	36.9	13.9	3.1
SBMNH	NA-CA-VEN11-844°	Ventura County Mainland	n/a	CA-VEN-11	Rostrum	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SBMNH	38461°	Santa Rosa Island	n/a	CA-SRI-2	Finray spine	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Museum	Catalog Number	Location	Site Age	Site	Element	Species [^]	$\delta^{13}\text{C}$	${}^*\delta^{13}\text{Cc}$	$\delta^{15}\text{N}$	$\blacklozenge\delta^{15}\text{N}_\text{C}$	C (wt%)	N (wt%)	${}^0\text{C:N}_{\text{atomic}}$
SBMNH	38465°	Santa Rosa Island	n/a	CA-SRI-2	Finray spine	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SBMNH	37792°	Santa Rosa Island	n/a	CA-SRI-2	Finray spine	<i>Xiphias gladius</i>	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[^] From Rick et al. (2019).

* $\delta^{13}\text{Cc} = \delta^{13}\text{C}$ Corrected: -0.5 ‰ (tissue) and -1.46 ‰ (Suess/Laws Effect); see Methods for details.

♦ $\delta^{15}\text{N}_\text{C} = \delta^{15}\text{N}$ Corrected: -0.2 ‰ (tissue); see Methods for details.

◊ Samples with C:N ratios > 3.6 not included in analyses; see Methods for details.

○ Samples did not yield sufficient material for stable isotope analysis.

✗ Based on other swordfish specimens from similar archaeological collections we suspect these date to the late Holocene.

Table S2. Bulk tissue $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of archaeological billfish from Maine (Newsom et al. 2022).

Sample Number	Site Name	Location	Provenience	Species	Element	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N _{atomic}
NV 1	Nevin	Blue Hill, ME	n/a	<i>Xiphias gladius</i>	Vertebrae	-11.9	10	3.3
TF 2-1	Turner Farm	North Haven Island, ME	W25 S100, Brown	<i>Xiphias gladius</i>	Vertebrae	-12.2	9.2	3.3
TF 2-2	Turner Farm	North Haven Island, ME	W25 S100, Brown	<i>Xiphias gladius</i>	Vertebrae	-11.6	10.5	3.3
WS 4-1	Waterside	Sorrento, ME	Col 2, Lvl 12, 250cm BD	<i>Xiphias gladius</i>	Rib	-10.7	9.8	3.2
WS 4-2	Waterside	Sorrento, ME	Col 2, Lvl 12, 250cm BD	<i>Xiphias gladius</i>	Rib	-10.9	9.8	3.2
WS 5-1	Waterside	Sorrento, ME	Area 3	<i>Xiphias gladius</i>	Rostrum	-11.7	10.5	3.3

References

- Acosta-Pachón TA, Ortega-García S, Graham B (2020) Assessing residency and movement dynamics of swordfish *Xiphias gladius* in the Eastern North Pacific Ocean using stable isotope analysis. *Marine Ecology Progress Series* 645:171–185
- Clark CT, Cape MR, Shapley MD, Mueter FJ, Finney BP, Misarti N (2021) SuessR: Regional corrections for the effects of anthropogenic CO₂ on $\delta^{13}\text{C}$ data from marine organisms. *Methods in Ecology and Evolution*
- Francey RJ, Allison CE, Etheridge DM, Trudinger CM, Enting IG, Leuenberger M, Langenfelds RL, Michel E, Steele LP (1999) A 1000-year high precision record of $\delta^{13}\text{C}$ in atmospheric CO₂. *Tellus B: Chemical and Physical Meteorology* 51:170–193
- Newsom BD, Heller AS, Spiess A, Allen K (2022) Exploring the Marine Reservoir Effect on Archaeological Swordfish Remains: A Case Study from Maine, USA. *Proceedings of the Canadian Archaeological Association*. Edmonton, Canada.
- Quay P, Sonnerup R, Munro D, Sweeney C (2017) Anthropogenic CO₂ accumulation and uptake rates in the Pacific Ocean based on changes in the 13C/12C of dissolved inorganic carbon. *Global Biogeochemical Cycles* 31:59–80
- Quay P, Sonnerup R, Westby T, Stutsman J, McNichol A (2003) Changes in the 13C/12C of dissolved inorganic carbon in the ocean as a tracer of anthropogenic CO₂ uptake. *Global Biogeochemical Cycles* 17:4-1-4-20
- Rick T, Harvey VL, Buckley M (2019) Collagen fingerprinting and the chumash billfish fishery, Santa Barbara Channel, California, USA. *Archaeological and Anthropological Sciences* 11:6639–6648
- Vokhshoori NL, McCarthy MD, Collins PW, Etnier MA, Rick T, Eda M, Beck J, Newsome SD (2019) Broader foraging range of ancient short-tailed albatross populations into California coastal waters based on bulk tissue and amino acid isotope analysis. *Marine Ecology Progress Series* 610:1–13
- Wilson T, Szpak P (2022) Acidification does not alter the stable isotope composition of bone collagen. *PeerJ* 10:e13593