

ELECTRONIC APPENDIX

This is the Electronic Appendix to the article
Killer Whales and Whaling: The Scavenging Hypothesis

by

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Supplementary material for:

Killer Whales and Whaling: The Scavenging Hypothesis

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Trends in abundance of living whales and floating carcasses during 20th Century: methods

From estimates in the literature, and our own extrapolations, we estimated global populations of each whale species group at three points in the 20th Century: 1900, 1945, 2000 (Table 2 of supplementary material). We filled in population and biomass trajectories from 1900-1945 and 1945-2000, by finding maximum rates of increase, r , such that the following recurrence relationship of a logistic population model fitted the population estimates at both endpoints:

$$n(t) = n(t-1) \cdot [1+r \cdot (n(1900) - n(t-1)) / n(1900)] - c(t-1)$$

where $n(t)$ is the population size at the start of year t , and $c(t)$ is the catch in year t (see below for origin of catch data). Estimates of r using this method ranged between 0.025-0.039, not unreasonable given what we know of the large whales (Wade 2002). These trajectories (Fig. 1 of paper) give an idea of trends in the availability of live whales during the 20th Century.

The reported catches of the worldwide whaling industry indicate the availability of carcasses from this cause. These were obtained from the data of the Bureau of International Whaling Statistics (as reported and amended by Gambell 1999 and <http://luna.pos.to/whale/sta.html>). As with the availability of live whales, we plot (in Fig. 1 of paper) trend lines for carcass availability including and excluding minke.

The natural mortality of non-*Balaenoptera* baleen whales and sperm whales (classes C and D) potentially provides carcasses which could be used by scavenging killer whales. During the 20th Century most of these will have been sperm whales. The natural mortality rate of sperm whales is not known but it is probably between 1-5% per year (Whitehead In press). By the 20th Century, following substantial sperm whaling in the 19th Century, it would probably have been lower than in pre-whaling times, because of density-dependent factors as well as a reduced number of old animals. Thus we estimate approximate confidence intervals for the availability of carcasses resulting from natural mortality during the 20th Century by multiplying mortality rates of 1% (lower limit) and 3.5% (upper limit) by the estimated population size of sperm whales (Whitehead 2002) plus an estimate of the numbers of non-*Balaenoptera* baleen whales (class C) linearly interpolated between the estimates for 1900, 1945 and 2000.

In Fig. 2 of the paper, the curves of Fig. 1 are translated into whale biomass, using the mean adult masses of the species (Whitehead & Mann 2000). The biomass of the carcasses produced by the whaling industry in each year was calculated by multiplying the mean biomass of those carcasses where species was recorded by the total number of carcasses, including those where species was not recorded. As catch by species was not available from 1900-1909, the

mean carcass biomass for 1910 (38.5t) was used for these years. Estimates of r for biomass trajectories, calculated using the same methods as for numbers, ranged between 0.037-0.051.

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Table 1. Some references in the whaling literature to scavenging by killer whales (also called “orcas”).

Date	Region	Description	Source
1700s	North Atlantic	“These Killers are of such invincible Strength, that when several Boats together have been towing a dead Whale, one of them has come and fastened his Teeth in her, and carried her away down to the Bottom in an Instant. And sometimes again, they have bit out a Piece of Blubber of about two Foot square, which is of that Toughness that an Iron...will hold it till it draws the Boat under Water.... The Carcasses, or Bodies of dead Whales in the Sea, serve for Food for Gulls, and other Sea-Fowl, as well as Sharks, for they are not very nice.”	Dudley 1725:265
1810s-20s	S Africa, S Atlantic or Indian Ocean	"Capt. Dring lost two fish [right whales], after being killed, by being carried off by the Killers... These animals attacked the dead whales, it is said for the sake of its tongue, which alone they eat, and often carry them off from the fishers against every security and precaution—the boats towing them being obliged to cut them adrift to prevent their being carried down along with them. The Americans state that they have carried whales away from alongside a ship and broken even hawsers with which they were secured!"	Scoresby in Stamp & Stamp 1983:127-8
1840s-1930	SW Pacific	Killer whales routinely assisting whalers to find and kill baleen whales and then scavenging on the carcasses, especially the tongues.	Dakin 1934; 146-158; Wellings 1964
19 th C	NE Pacific	"Instances have been known ... where a band of Orcas laid siege to whales that had been killed by whalers, and which were being towed to the ship, in so determined a manner, that, although they were frequently lanced and cut with boat-spades, they took the dead animals from their human captors, and hauled them under water, out of sight."	Scammon 1874:90
Ca. 1900	Newfoundland, NW Atlantic	Reports of killer whales (and sharks) tearing at carcasses fastened to catcher boats	Millais 1907:193
1912	Korea, NW Pacific	Reports of killer whales routinely scavenging tongues from gray whales killed by modern shore whalers. In one instance after a whale had been killed, a school of killers came “from a long distance away ... at full speed straight for the ship.” They “circled about the vessel and one of them forced open the mouth of the dead whale to get at the tongue,” at which point the whalers drove the killers away with rifle fire.	Andrews 1916:199

1940s-1950s	Antarctic	First-hand description of killers scavenging offal discarded from a factory ship, and of a killer shot and killed by the whalers during the scavenging. Also, the following is attributed to one of the crew: "He hates killer whales with a loathing quite out of proportion to the damage they do to him and his bonus, though they do tear out the tongues and the best part of the oil from half the whales we catch."	Robertson 1954: 159
1950	Newfoundland, NW Atlantic	Film sequence of pod of killer whales scavenging a whaler-killed fin whale	Sergeant & Fisher 1957; Mitchell & Reeves 1988
1951	Labrador, NW Atlantic	Several inflated flagged whales lost due to killer whales; one fin whale delivered to whaling station "had all skin and blubber removed from one side, from head to tail, as neat and clean as any flensing ship could do it."	Whaling inspector's report in Mitchell & Reeves 1988:164, 166
1950s	Labrador, NW Atlantic	... a solitary, large killer whale used to follow catcher boats into Hawke Harbour, taking bites from towed whales. The whalers finally killed this individual, apparently using dynamite concealed in meat.	Mitchell & Reeves 1988:166
1950s-60s	Antarctic	"When killers come up to a factory they are attracted by the tongues of the whales lying aft; as these are full of oil we are not pleased to see them being eaten under our noses, and home-made hand grenades are sometimes used to scare the killers off. I have seen a pair of killers accompanying a catcher which was towing a fin whale alongside at 8 knots: they were coming in turns to tear off pieces of the tongue which had almost all gone by the time we heaved the whale up."	Ash 1964:56
1950s-1960s	General	"Killers often go for the carcasses while they are being towed alongside the catchers back to the whaling station, tearing lumps out of the tongue as it lolls from the open mouth."	Ommanney 1971:48
1960s	General	"Killer whales ... feed on the carcasses of large whales and are considered a pest by the whalers." Photograph: "A fin whale carcass is cast free with a marker flag, radar reflector and radio beacon. A killer whale porpoises behind it..."	Burton 1973:58, plate 10 facing p. 97
1960s	Antarctic	"Killers frequently attack the corpses of rorquals tied at the sterns of factory ships in the Southern Ocean, and in some areas near the South Shetland Islands the density of killers on the whaling grounds is so high that rorquals left 'in flag' for 24 hours have the blubber almost stripped away by the time they are finally towed to the factory ships." Also shows photograph of two killer whales scavenging tongues of rorquals tied to stern of factory ship	Gaskin 1972:120

20 th C	Antarctic	“... the killers constantly follow the whaleships, feeding off the offals and tearing out the tongues of the whales as they lie moored at the stern... Large masses of blubber and tongue are torn away from the cadavers, and the killers make off. But they will be back if they dare. Rifles are always kept at the stern to fight them off.”	McLaughlin 1962:130
20 th C	Antarctic	"... killer whales regularly tore out the tongues of dead and air-filled whales with mouths wide open... bold enough to tear out the tongues of killed whales tied to the board of a whale boat towing them to the base. Often the killer whales almost wholly consumed the tongues of whale carcasses stocked as feed for the whale base. Attempts to drive away the killer whales by throwing various objects at them from the whale boat or even by opening fire were almost of no avail... killer whales quite often cause serious losses to whale hunters by snatching away the valuable tongues." Also shows photograph of several killer whales "tearing out the tongues of dead [whaler-killed] whales."	Heptner et al. 1996:689-90

Table 2. Approximate global population estimates and mass (Whitehead & Mann 2000) of large whales (and minke whales) during the 20th Century.

Species	Mass (t)	Approximate population in:			Sources of population data
		1900	1945	2000	
Blue	105	220,000	40,000	15,000	Chapman 1974; Klinowska 1991; Reeves et al. 2003, with an approximate correction for pygmy blue whales (<i>Balaenoptera musculus brevicauda</i>)
Fin	50	550,000	400,000	112,000	Chapman 1974; Klinowska 1991; http://www.natureserve.org/explorer/servlet/NatureServe?searchName=Balaenoptera+physalus
Sei	19	170,000	170,00	40,000	Chapman 1974; Klinowska 1991;
Bryde's	12	100,000	100,000	100,000	Very, very approximate; see Klinowska 1991
Humpback	35	140,000	3,000	30,000	Clapham et al. 1999; Branch & Butterworth 2001
Bowhead	90	2,000	2,000	10,000	Punt & Butterworth 2000; Fig. 3, assuming few animals outside Bering-Chukchi-Beaufort stock
Gray	31.5	1,000	3,000	23,000	Buckland & Breiwick 2002, Fig. 19, assuming very few animals in western Pacific
Right: 3 species	54.5	500	500	8,000	Baker & Clapham 2004 for southern right whales, adding a few hundred for northern right whales
Sperm	20	800,000	850,000	360,000	Whitehead 2002
Minke	6.6	1,000,000	1,000,000	1,000,000	http://www.iwcoffice.org/conservation/estimate.htm ; assuming populations changed little over 20th Century

The National Electronic Sectional Appendix (NESA) contains detailed information useful to operators about network capability, as well as a considerable amount of other data. NESA is an electronic data source with significant advantages over a hard copy publication. These include: search tools for locations, routes and keywords. Electronic Appendix. This thesis includes a CD-ROM containing 70 interferograms we made of the potentially active volcanoes and calderas in the central Andes, but does not include all of the interferograms we have made. The interferograms are linked to HTML tables of the volcanoes (volc.html) and calderas (calderas.html). A Electronic appendix for Helliwell, Barington-Leigh, Harris and Huang, "International Evidence on the Social Context of Well-Being". Table 5: Inter-regional differences in coefficients. Interaction terms between region dummies and individual variables are included in order to identify differences in coefficients, using region 1 as a baseline.