A review of Southern Hemisphere humpback whaling by period and catch location

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ABSTRACT

Comprehensive Assessments of the seven Southern Hemisphere humpback whale (*Megaptera novaeangliae*) breeding stocks require an understanding of their respective catch histories. A lack of information on humpback whale catches from American, British and French open-boat (or pre-modern) pelagic and land-based whaling from 1760 to the late 1920s from some fleets precludes detailed estimations of catch histories from this era. We therefore provide a review of the whaling of the species across the Southern Hemisphere by modern whaling period, during which some 215,928 humpback whales are estimated to have been taken between 1903 and 1973, comprising land-based, moored floating factory, and both regulated and unregulated illegal pelagic whaling. Between 1904 and 1914, humpback whales were the main catch at South Georgia and the South Shetland Islands, while, at further Southern Ocean land stations, catch efforts were carried out from the South Orkney, the South Sandwich and Kerguelen Archipelagos, with more limited success. Off the coasts of South America, humpback whales were taken off the west coast and from the Brazilian coast between 1905 and 1963. Southern African catch records show extensive humpback catches from whaling stations across the coast from Madagascar to Gabon from 1908 to 1963, as do catch records from Australia and New Zealand across the same period. A rapid growth in pelagic whaling across the Southern Ocean from 1923 onwards resulted in extensive humpback catches until 1963, despite significant temporal and spatial restrictions. Although humpback whales were totally protected across the Southern Hemisphere by the International Whaling Commission from October 1963, the Soviet Union fleets violated catch and reporting regulations from 1947 to 1973, resulting in significant illegal catches. Additional unregulated catches were made by the *Olympic Challenger* fleet between 1950 and 1955 in the Antarctic and off the west coast of South America. The information compiled in this review is critical to the evaluation of the whaling impact on each breeding stock, and for future status assessments of the species, and can provide evidence of the historical distributions of the species in breeding and feeding grounds.

KEYWORDS: CONSERVATION, DISTRIBUTION, WHALING – HISTORICAL, WHALING – MODERN, WHALING – REVISED CATCHES, WHALING MANAGEMENT

INTRODUCTION

Humpback whales (*Megaptera novaeangliae*) generally undertake annual migrations from summer high-latitude feeding grounds to winter breeding grounds in mid to low-latitude coastal waters in both the Northern and Southern Hemispheres (Matthews, 1938; Mackintosh, 1942; Chittleborough, 1965; Dawbin, 1966). Coastal waters

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can also be part of the species' migratory corridors between such grounds (e.g., Félix *et al*., 2014; Rosenbaum *et al*., 2014; Fossete *et al*., 2016; Andrews-Goff *et al*., 2018). Within the Southern Hemisphere, this migratory preference, as well as the proximity of breeding grounds to continental coasts, and the southwestern Atlantic feeding grounds to both the Scotia Arc islands and Antarctic Peninsula, resulted in the species becoming extremely susceptible to early modern whaling from 1904 onwards (Findlay, 2001).

Migration links between the whaling centres of the southwest Atlantic Ocean and the west coast of Africa were suggested from whaling catches by Mörch (1911), while Kellogg (1929) linked summer feeding grounds to winter breeding grounds occurring off the east and west coasts of South America, South Africa (including the southern and eastern coasts of Madagascar) and Australia, and in the Pacific Islands to the north of New Zealand. Thereafter, Hjort *et al*. (1932; 1933a; 1933b; 1934; 1935; 1937; 1938; all in Mackintosh, 1942) and Bergersen *et al*. (1939; in Mackintosh, 1942) sub-divided the Southern Ocean whaling grounds into five longitudinally distinct feeding regions based on Antarctic catch data for humpback whales, blue whales (*Balaenoptera musculus*) and fin whales (*Balaenoptera physalus*). These regions were designated as follows: (1) Area I – from 170°W and 60°W, with the waters around the South Shetland Islands in the western Antarctic Peninsula at the western board; (2) Area II – from 60°W to 0°, including the coastal waters of the Scotia Arc Islands; (3) Area III – from 0° to 70°E, off the coast of Queen Maud Land; (4) Area IV – from 70°E to 130°E, south of the west coast of Western Australia; and (5) Area V – from 130°E to 170°W, south of New Zealand and including the Ross Sea. Each Area was presumed to comprise a distinct whale stock designated as Group I–V respectively. Mackintosh (1942) further found that humpback whales aggregated in five summer feeding regions, in the Bellinghausen Sea, the southwest Atlantic Ocean, to the south of South Africa, to the southwest of Western Australia, and to the south of New Zealand, and noted the similarity of these regions to the established Areas I to V. Mackintosh (1965) extended the Groups from five to six (with Area I between 60°W and 120°W, Area II between 0° and 60 W°, Area III between 0° and 70°E, Area IV between 70°E and 130°E, Area V between 130°E and 170°W and Area VI between 170°W and 120°W; Fig. 1) based on fin and blue whale catches and following a review of mark data from the Discovery Investigations[7] (Rayner, 1940), while the distribution of humpback whale catches in waters south of 40°S by pelagic whaling identified by Omura (1973) only overlapped with Areas III, IV and V. With more information obtained on the distribution of illegal Soviet catches (described later in this review), some of these areas were divided longitudinally (Areas IIIW = 0–35°E and IIIE = 35°E–70°E; Areas IVW = 70°E–100°E and IVE = 100°E–130°E; Areas VW = 130°E–150°E and VE = 150°E–170°E; and Areas VIW = 170°W–155°W and VIE = 155°W–120°W) (IWC, 1998; Fig. 1). Such Soviet lower latitude catches in the southeastern Atlantic Ocean between 1947 and 1973 also identified Area IIE and Area IIIW as additional important summer habitat of humpback whales, albeit at slightly lower latitudes than the common feeding areas for the species.

Southern Hemisphere humpback whales are currently recognised to be distributed in discrete breeding stocks across seven winter low-latitude breeding grounds in warm temperate, subtropical and even tropical shallow coastal waters off continents or archipelagos (IWC, 1998; 2011). Such grounds are found off Brazil in the southwestern Atlantic Ocean (Breeding Stock A); off the West African coast between Angola and Equatorial Guinea in the southeastern Atlantic Ocean (Breeding Stock B); across the southwestern Indian Ocean (Breeding Stock C); off Western Australia in the southeastern Indian Ocean (Breeding Stock D); in the southwestern Pacific Ocean (Breeding Stock E); in the Central South Pacific Ocean (Breeding Stock F); and on the east coast of South America off Colombia and Ecuador (Breeding Stock G). Breeding Stock B was further divided into breeding sub-stock B1 found off Gabon and Equatorial Guinea and sub-stock B2 found off the west coast of South Africa. This area occupied by sub-stock B2 is not a breeding ground *per se*, but a migratory corridor and a summer feeding area within the southern Benguela upwelling system, with sub-stock B2 designation based on genetic differences between animals in this area and those found in sub-stock B1 (IWC, 2007; Kershaw *et al*., 2017). Other breeding sub-stocks have been recognised over time, namely Breeding Stock C divided into the coastal waters of Mozambique (C1), the Mozambique Channel (C2), Madagascar (C3) and the Mascarene Archipelago (C4), while Breeding Stock E is divided into Eastern Australia (E1), New Caledonia (E2) and Tonga (E3), and Breeding Stock F into the Cook Islands (F1) and French Polynesia (F2) (Fleming & Jackson, 2011) (Fig. 1).

[7] A series of scientific surveys aimed to collect information on the biology and ecology of whales and their prey to provide a basis for whaling regulations.

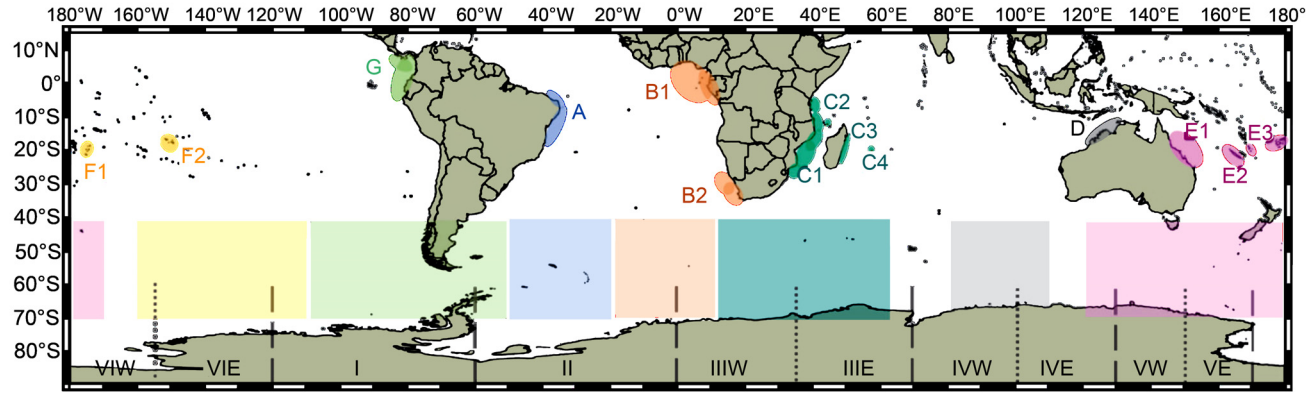

Figure 1. Distribution of the core breeding and primary feeding grounds of the Southern Hemisphere humpback whale breeding stocks A–G, and Southern Ocean Management Areas I–VI and sub-areas (Donovan, 1991; IWC, 1998; 2006). The same colours are used to indicate the breeding and feeding grounds used by each stock. Dashed lines indicate the limit of the main Management Areas, whereas dotted lines mark the limits of sub-areas (W = west and E = east). Source: Seyboth *et al*. (2023).

Much of what is known about the migrations performed by the stocks and sub-stocks arises from: (1) the seasonality of historic whaling catches (e.g., Findlay, 2001; Rocha *et al*., 2015) and more recent survey sightings (e.g., Branch & Butterworth, 2001); (2) the returns of natural or tag marks through, for example, natural marking photo-identification (Kaufman *et al*., 1990; Gill & Burton, 1995; Rock *et al*., 2006; Franklin *et al*., 2008) or marked during the Discovery Investigations (Rayner, 1940; Mackintosh, 1942; Chittleborough, 1965; Dawbin, 1959; 1964; 1966), respectively; (3) the incidence of cold water diatoms (e.g., *Benetella ceticola*) colouring the skins of animals recently arrived on the breeding grounds (e.g., Nemoto *et al*., 1980); and (4) satellite tagging studies (e.g., Zerbini *et al*., 2006; Andrews-Goff *et al*., 2018; Bestley *et al*., 2019; Reisinger *et al*., 2021). Distributions of breeding stocks across the summer feeding grounds appear to show broader longitudinal ranges and a greater degree of mixing than those found on the breeding grounds where distributions tend to be within areas of warm (> 21°C) and shallow (less than 200 m water depth) waters (Rasmussen *et al*., 2007) that are somewhat longitudinally restricted by north-south orientation of coasts separated by deep open ocean basins. Non-migration or annual residency is a characteristic of the small humpback whale population of the Arabian Sea where the population appears to have adapted to the prevailing warm winter and cool productive summer conditions (utilised on migrations elsewhere) induced by shifts in seasonal monsoon patterns (Minton *et al*., 2010).

Trans-equatorial movement of Southern Hemisphere migrations has been recorded, both in the eastern tropical Pacific Ocean (e.g., Stone *et al*., 1990; Rasmussen *et al*., 2007) and in the eastern Atlantic Ocean (e.g., Valsecchi *et al*., 1997) where cooler ocean conditions (induced by the eastern boundary Humboldt/Peru Current and Benguela Current Systems on the west coasts of both South America and Southern Africa respectively) result in more northerly distributions of the Southern Hemisphere breeding grounds (Findlay *et al*., 2017). However, the difference in the timing of seasons between the Northern and Southern Hemispheres results in the migrations being six months out of phase, so that trans-equatorial mixing is assumed to be minimal at a global scale (Chittleborough, 1958; Clapham, 1996).

Knowledge of Southern Hemisphere humpback whale population characteristics, life histories, seasonal distributions and migratory behaviour arises from the whaling history on this species divided into two main forms, namely (1) research carried out contemporary to the whaling activities (e.g., the Discovery Investigations – see Mackintosh, 1942; Mackintosh & Wheeler, 1929); and (2) retrospective analyses on catch information, including seasonal and spatial distributions (e.g., Findlay, 2001; Smith *et al*., 2012). A major challenge in the IWC Scientific Committee's recent Comprehensive Assessments of these seven humpback whale breeding stocks arises from the broad longitudinal dispersal of animals as they migrate from their breeding grounds to their summer polar feeding grounds (Jackson *et al*., 2015). Breeding stock assessments require an understanding of their respective catch histories, including the assignment of catches to stocks from outside the breeding grounds, and the extent of longitudinal dispersal and mixing of animals from discrete breeding stocks within and across the feeding areas. The assignment of high-latitude catches to low-latitude breeding stocks often remains speculative. Aiming to contribute to further understanding, this paper provides a comprehensive review of humpback whaling catch history across the Southern Hemisphere by location and whaling era.

METHODS AND MATERIALS

A thorough review of the history of Southern Hemisphere modern whaling catch operations, including net (e.g., Whangamumu, New Zealand), land-based (e.g., Durban, South Africa), small boat (e.g., the Perano operation in Tory Channel, New Zealand), moored floating factory (e.g., Ambra or Mangoro), low-latitude pelagic (e.g., Uniwaleco) and high-latitude pelagic legal (e.g., the *Balaena* fleet) or illegal (e.g., the *Olympic Challenger* fleet) operations across the Southern Hemisphere was conducted to account as far as possible for operational effort by location between 1890 and 1973 (apart from the catches from Tonga which continued to 1978). This review included operations both within and outside regulation.

In addition, the IWC Catch Database (version 5.5) (Allison, 2013a; 2013b) was accessed. It is composed of a summary dataset (Allison, 2013a), which describes annual catches of the species by location or expedition and season or year and a comprehensive dataset (Allison, 2013b) with known and estimated catch positions for all catches for which such information is available. Although estimates of the catch positions are identified for these (to the nearest one degree of latitude and longitude), there are some differences in the confidence of these estimated locations, based on operational or logistic factors and the original catch return data provided by that operation (e.g., location, vessel expedition or station). All Southern Hemisphere humpback whale catches were assigned to as precise positions as possible.

Catch data were extracted from the comprehensive dataset by annual expeditions and operations and were compared with information identified in the literature review of operational processes and factors. Catch locations were classed according to the confidence of such location estimates as: (1) individual location known; (2) confined within a small area (10 degrees of latitude by 10 degrees of longitude, e.g., catches identified to the South Shetland Islands or South Georgia); (3) confined to a broader area (20° by 20° or broader, e.g., catches estimated to Western Australia); (4) by station or moored floating factory position (e.g., Durban or Grytviken); or (5) within an ocean basin (e.g., South Pacific). Remaining catches of unknown locations were randomly assigned within a spatial polygon to the smallest area identified within the dataset (Fig. 2).

After classifying the catch locations to the smallest area possible (based on the best available information), the catches were separated by the type of whaling operation, namely land-based, moored floating factory, both legal and illegal pelagic, and recent whaling (i.e., catches assigned to Tonga between 1961 and 1978) to facilitate comparison of the catches and catch operations across the IWC Catch Database and the literature review.

Catches within the IWC Catch Database with defined catch locations were assigned to these catch locations regardless of their location confidence. Catches without detailed catch location information were randomly assigned to the smallest areas as identified within the referred dataset. For example, catches known only to arise from Western Australia were assigned randomly within a spatial polygon restricted to the marine

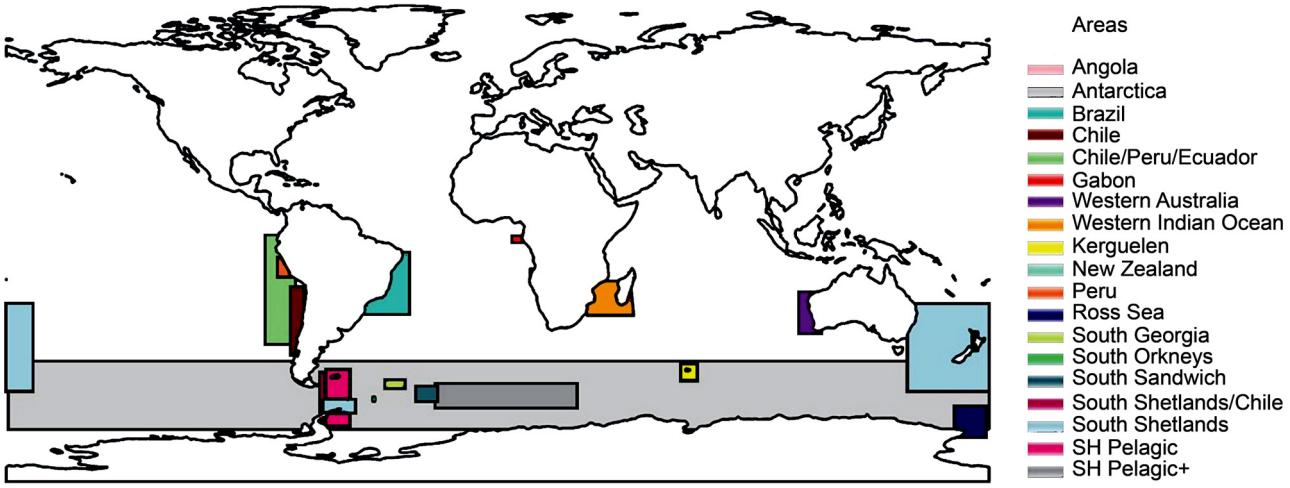

Figure 2. Marine polygons based on reference catch areas from the IWC Catch Database. The limits of each area were indicated in IWC documents and catches with unknown locations were randomly assigned to a coordinate within its respective area.

environment of the Western Australian region. Such areas (in which catches lack detailed locations) and their respective polygons of assignment are presented in Figure 2. Random assignments were conducted using the library 'sf' of the software R (version 4.3.1) (R Core Team, 2017) through RStudio IDE environment (RStudio Team, 2020) and the 'st_sample' command with the completely random strategy. In the case of the Soviet illegal catches, similar assignments were made to polygons based on areas visited by each fleet during their operations (Figs. 3–6), using information from the catch locations and vessel tracks described by Zemsky *et al*. (1995). So-called sanctuary areas, where humpback whale catches were prohibited during specific periods over the whaling era, and the adherence or non-adherence to these were accounted for in the random assignment of legal and illegal catches respectively.

Catches were then allocated (based on their actual, estimated or assigned locations) to broad area grids of 10° of latitude by 10° of longitude for the visualisation of data under a spatial location scale compatible with the level of confidence within the dataset. This allowed an association of the catches in the regions north of 40°S to the different breeding stocks.

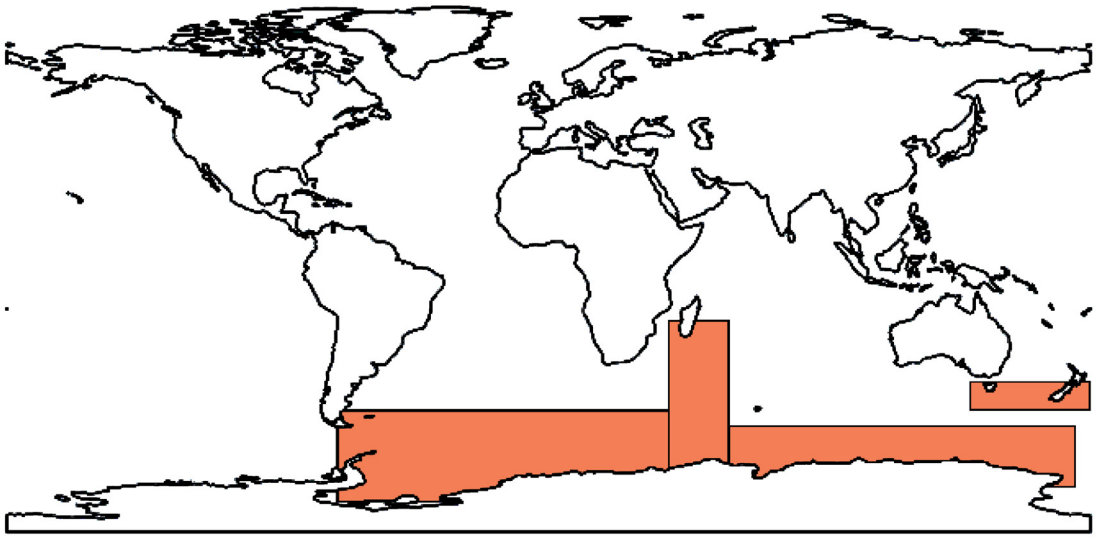

Figure 3. Marine polygons based on areas of operation of the *Slava* Soviet whaling fleet to which catches with an unknown location were randomly assigned. Such polygons have been derived from overall fleet tracks and catches across species.

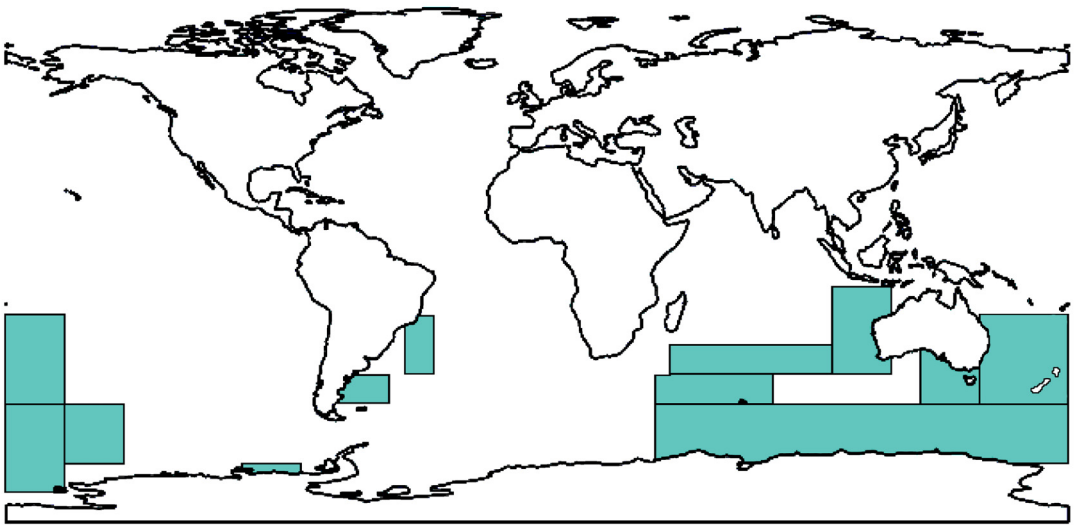

Figure 4. Marine polygons based on areas of operation of the *Sovetskaya Rossiya* Soviet whaling fleet to which catches with an unknown location were randomly assigned. Such polygons have been derived from the overall fleet tracks and catches across species.

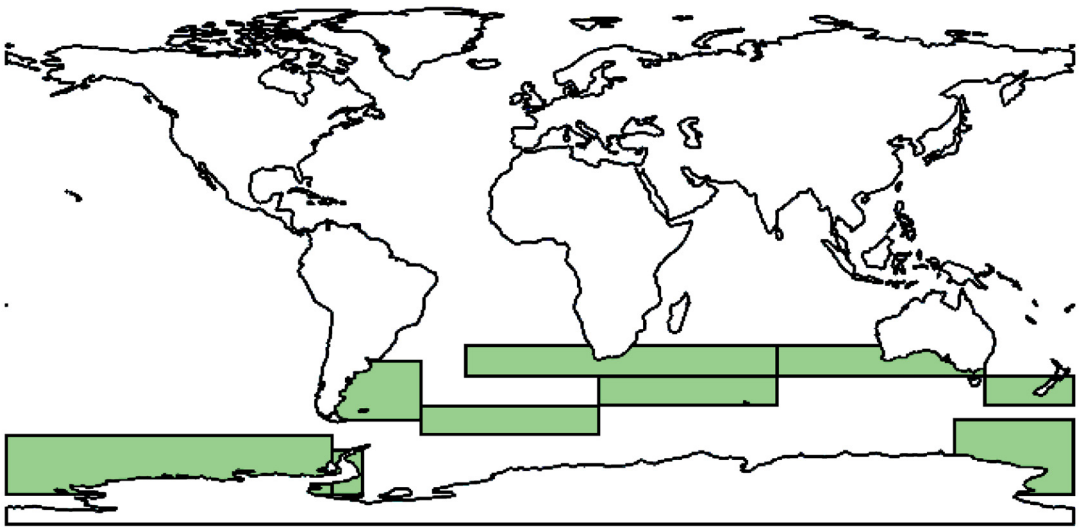

Figure 5. Marine polygons based on areas of operation of the *Sovetskaya Ukraina* Soviet whaling fleet to which catches with an unknown location were randomly assigned. Such polygons were derived from the overall fleet tracks and catches across species.

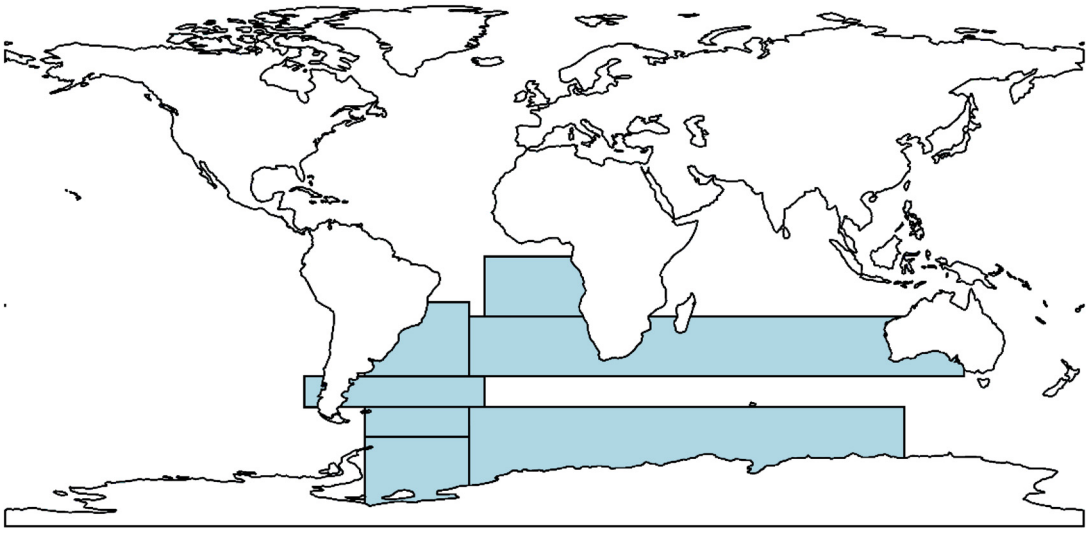

Figure 6. Marine polygons based on areas of operation of the *Yury Dolgoruky* Soviet whaling fleet to which catches with an unknown location were randomly assigned. Such polygons have been derived from the overall fleet tracks and catches across species.

RESULTS

Overview of Southern Hemisphere whaling history

Southern Hemisphere whaling can be categorised into several sectoral types, including (1) net whaling; (2) pre-modern open-boat whaling (pelagic and land-based), between 1760 and the 1920s (although periods vary by region); and (3) modern whaling (pelagic, moored floating factory and land-based), between 1904 and 1973. All types, to some extent, targeted humpback whales, despite the species being protected across the Southern Hemisphere from October 1963 (IWC, 1963; Tønnesen & Johnsen, 1982). Pre-modern open-boat whaling is defined as whaling from rowed catcher boats using hand-thrown harpoons, while modern whaling describes catching whales from motorised catchers using cannon-fired harpoons. Humpback whales were heavily targeted across the modern whaling era (Kellogg, 1929; Matthews, 1938; Mackintosh, 1942; Chittleborough, 1965; Findlay, 2001). Information about whaling of Southern Hemisphere humpback whales has been reviewed across these main whaling periods, together with the only limited information available from the

open-boat whaling era. Net whaling carried out in Whangamumu, New Zealand, is discussed under modern whaling. No humpback whales are believed to have been caught by the illegal Sierra/Run fleets operating of the southwestern coasts of Africa (Best, 1996). Limited commercial and aboriginal catches of humpback whales from Pagalu in the Gulf of Guinea described by Aguilar (1985) were considered insignificant to be further investigated here.

Pelagic open-boat whaling

From 1760 to 1805, American, British and French open-boat whalers expanded voyages to the Southern Hemisphere (Wray & Martin, 1983; Richards & Du Pasquier, 1989; Smith *et al*., 2012). In this broad area, Smith *et al*. (2006) suggested that pre-modern open-boat whalers took humpback whales in all ocean basins apart from the Antarctic. Wray and Martin (1983) describe humpback whaling around Madagascar, the Mozambique Channel and south of Durban, South Africa, during the austral winter months as early as 1785. In the austral summer, humpback whales were caught off the Crozet Islands and Kerguelen in the southern Indian Ocean (Smith *et al*., 2012). The exploitation of the South Atlantic off Southern Africa expanded (Wray & Martin, 1983; Richards & Du Pasquier, 1989) with whaling at Walvis Bay, Namibia, spanning the period 1788–1803, and whales caught along the east coast of South Africa from the Cape to Delagoa Bay, Mozambique mainly from ca. 1790–1798 (Richards & Du Pasquier, 1989). Delagoa Bay sustained whaling well into the 1840s, although by 1850 catches were scarce (Wray & Martin, 1983). In a 1796 journal entry, a whaler noted the absence of whales in Walvis Bay, the same area that had been lucrative only three years earlier (Smith *et al*., 2012). Whaling greatly diminished on the African coast with catches being too poor by 1805 for activities to be sustained in the area (Richards & Du Pasquier, 1989; Smith *et al*., 2012), although limited whaling continued at Delagoa Bay until 1823 (Richard & Du Pasquier, 1989). Hostilities between Britain and France between 1793–1799 resulted in a reduction of whaling activities in the area, while the inshore coasts of South America were considered too dangerous from 1796 as Spain and England were at war. These restrictions, combined with exhausted whaling grounds, provided incentives to explore new grounds, such as eastern Australia and northern New Zealand (Richards & Du Pasquier, 1989).

American pelagic open-boat whaling

American whaling refers to activities performed by the USA. Its pelagic open-boat component arose out of the eastern seaboard, including New York and Massachusetts, with Nantucket and New Bedford becoming marked centres. In the latter half of the 18th Century, American whalers began voyaging to the Southern Atlantic (Smith *et al*., 2012), reaching the coast of Guinea by 1763 (Best & Ross, 1989; Richard & Du Pasquier, 1989). From 1772, American whalers began arriving at the Falkland Islands (Richards & Du Pasquier, 1989). Whalers likely reached Southern Africa in 1785 (Richards & Du Pasquier, 1989), with many Nantucket captains choosing to winter in the Cape, South Africa (Booth, 1964). Despite Dutch proclamations prohibiting foreign vessels from whaling and fishing in South African bays, American whalers continued whaling in this region well into the 1860s (Booth, 1964; Best & Ross, 1989; Richards & Du Pasquier, 1989). Maury (1852, in Smith *et al*., 2012) and Townsend (1935) mapped catch positions of species identified in logbooks and journals arising from American open-boat whaling voyages from 1780 to 1820, although only the noon positions of whale ships on days when one or more humpback whales were taken are mapped. Collated and digitised by Smith *et al*. (2012), the geographic distribution indicates that American fleets in the Southern Hemisphere whaled across the entire Pacific Ocean, as well as north of 40°S in the Atlantic Ocean, reaching southward along the South American coast, and across the Indian Ocean between 20°S and 45°S, with the highest catches occurring between 1840 and 1890 (Smith *et al*., 2012).

The distribution of humpback whales in these records are observed predominantly in low-latitude breeding and calving grounds in the austral winter and spring months (June to November) as the fleets made few excursions into the inclement waters south of 50°S, where summer distributions on feeding grounds would be expected (Smith *et al*., 2012). As noted by Findlay *et al*. (2011), the records in certain areas presented by Townsend (1935), such as the coast of Mozambique, show catch distribution of humpback whales centred in small areas rather than across the entire coasts (for contradictory information see Wray & Martin, 1983). Some

14,000 American open-boat pelagic whaling voyages in the western Indian Ocean are estimated to have been undertaken between 1800 and 1888, but not all of these would have been to the Southern Hemisphere (Wray & Martin, 1983). The number of voyages began to decline from 1875, thus following a pattern of expansion and contraction as each area became exhausted (Smith *et al*., 2012). By the 1880s, almost no American whaler was active in the Indian Ocean, although the area was occasionally frequented until the early 20th Century with the last American whaler/sealer noted in 1916/17 (Wray & Martin, 1983; Smith *et al*., 2012). Although mainly right and sperm (*Physeter macrocephalus*) whales were caught, humpback whales were targeted on their winter breeding grounds and recorded catches of this species are likely to be underestimated (Wray & Martin, 1983; Smith *et al*., 2012). Best (1987) estimated that some 14,000 to 18,000 humpback whales were taken by the American pelagic fleet in the 19th Century. Acknowledging the assumptions made by Best (1987) in the estimation of global humpback catches, Smith *et al*. (2012) suggested that American pelagic catches from each of the Southern Hemisphere populations ranged from zero to over 4,000, with the highest catches off western Africa, western South America and Tonga. However, such catch histories do not incorporate the British and French fleet catches, land-based open-boat catches, or take into consideration struck and lost rates, the completeness of the American records or accuracy of oil returns (on which catch numbers are estimated), which are expected to fluctuate widely during the winter migrations.

British pelagic open-boat whaling

British open-boat pelagic whaling operated in the Southern Hemisphere from 1775 to 1859, primarily targeting whales in the South Atlantic but extending into the Indian and Pacific Oceans by the late 1780s and reaching the coast of Brazil by 1775, Patagonia by 1778 and thereafter off west Africa (Richards & Du Pasquier, 1989). In addition, catches were recorded in Delagoa Bay and the Mozambique Channel from 1800 by British vessels returning from Australia (Wray & Martin, 1983; Smith *et al*., 2012), while convict transports to Tasmania engaged in opportunistic whaling from 1803 (Colwell, 1969).

French pelagic open-boat whaling

The French Government, encouraging a revival of whaling through incentives, secured a substantial whaling fleet after 1783, using the experience of skilled American whalers (Richards & Du Pasquier, 1989). In 1786, Nantucket whalers established operations at Dunkirk, France (Booth, 1964; Richards & Du Pasquier, 1989), and, by 1789, these fleets were whaling off Brazil, Walvis Bay, Namibia and other areas of the South Atlantic, predominantly targeting sperm and southern right whales (*Eubalaena australis*). Operations extended into the Pacific by 1790 but ceased abruptly in 1793. However, many Nantucket whalers resorted to taking out duplicate registrations under aliases, switching from French to American registry from 1802 to 1804, thus complicating future compilations of catches by nationality for statistical tables (Richards & Du Pasquier, 1989).

Land-based open-boat whaling

The arrival of pelagic open-boat whaling fleets in the Southern Hemisphere colonies resulted to some extent in the commencement of land-based open-boat whaling. In some cases, such as in South Africa, land-based whaling had been unsuccessfully attempted prior to this, with operations limited to coastal waters and concentrating to some extent on winter distributions of southern right whales (Best & Ross, 1989). The requirement for suitable boats and equipment meant that land-based open-boat whaling in South Africa did not commence until 1792 (Tønnesen & Johnsen, 1982; Best & Ross, 1989) and expanded after the second British occupation in 1908 (Best & Ross, 1989). Humpback whales, sighted in abundance, were considered 'furious and active' and thus avoided by the whalers (Best & Ross, 1989), with only 18 individuals caught in South African waters between the months of June to October from 1892 to 1905 (Best & Ross, 1989). In Australia, land-based open-boat whaling commenced in 1790, as restrictions brought on by the Anglo-French war (June 1778–September 1783) encouraged whalers to explore new grounds (Colwell, 1969; Richard & Du Pasquier, 1989). Although efforts by convict transport ships to pursue sperm whales near Tasmania were at first unsuccessful (Colwell, 1969), foreign whalers soon arrived (Richard & Du Pasquier, 1989), with the first of five shore stations built on the island by 1804 (Tønnesen & Johnsen, 1982) where British, American and French whalers focused on sperm and southern

right whales. Likewise, land-based open-boat whaling in South Australia from 1837, on Australia's east coast in Twofold Bay from 1841 to 1844, and again after 1849, concentrated on southern right and sperm whales until the 1850s (Colwell, 1969). Open-boat humpback whale catches off Brazil between 1904 and 1924 were estimated to be between 2,300 to 4,750 individuals (Zerbini *et al*., 2019), with whalers operating mainly in the northeastern region of Caravelas, Bahia (Morais *et al*., 2017).

Overall, the incompleteness of records, and the available information on struck and lost or varying oil yield rates, all point to marked assumptions that need to be estimated to identify the pre-modern open-boat catch histories, and, in many cases, the available data preclude such estimations.

Modern whaling

The first Southern Hemisphere humpback whale to be taken in the period of modern whaling was from the Strait of Magellan on New Year's Eve, 1903 (Tønnesen & Johnsen, 1982). Subsequently, between 1904 and 1985, more than 1,500,000 whales of all species were killed in the Southern Hemisphere (Clapham & Baker, 2009; Allison 2013a), with nearly 220,000 humpback whales taken during this period (Findlay, 2001). Modern whaling of humpback whales can be divided into several regional eras, which are detailed below.

High-latitude Antarctic land-station catches

The commencement of modern whaling in the Antarctic Peninsula and Scotia Arc Islands can be linked to early Antarctic voyages by Carl Anton Larsen. Captaining expeditions of the *Jason* (1892–1894) and the *Antarctic* (1901–1903), Larsen identified a lack of southern right whales but an abundance of blue, fin and humpback whales in the waters of the Antarctic Peninsula, Weddell Sea and Scotia Sea (Mörch, 1911; Tønnesen & Johnsen, 1982; Hart, 2006; Burnett, 2012). The *Antarctic* was lost in the Weddell Sea in February 1903, but, after being rescued, Larsen sought Argentinian backing for Antarctic rorqual whaling in Bueno Aires in December 1903 (Tønnesen & Johnsen, 1982; Hart, 2006). The resultant Compañia Argentina de Pesca S.A. was formed in February 1904 and initiated whaling at Grytviken, South Georgia, in November of the same year (Mörch, 1911; Tønnesen & Johnsen, 1982; Burnett, 2012). Modern whaling in the South Shetland Islands commenced in 1906, followed by South Orkney and the South Sandwich Islands in 1911 by a combination of land stations and/or moored floating factories that were mostly operated by Norwegian interests (Tønnesen & Johnsen, 1982; Hart, 2006). A boom period followed between 1908–1914 (Hart, 2006), with high numbers of humpback whale catches (Best & Ross, 1989; Burnett, 2012). Returns on investments in the Southern Hemisphere and Antarctic whaling operations far outperformed returns in the Northern Hemisphere (Hart, 2006). Until 1914, humpback whale catches in South Georgia and the South Shetland Islands comprised up to 75% of the catch, equating to some 20,000 and 9,000 individuals, respectively (Tønnesen & Johnsen 1982; Hart, 2006; Allison 2013a). However, from 1914, declines of humpback whale catches and increased selectivity of larger and more valuable species resulted in whaling efforts which concentrated on blue and fin whales (Hart, 2006).

South Georgia

Initiated in 1904, South Georgia whaling (Mackintosh, 1942; Tønnesen & Johnsen, 1982; Burnett, 2012) was carried out all year around, even during the austral winter (Matthews, 1938; Mackintosh, 1942; Hart, 2006). The Compañia Argentina de Pesca S.A. operated the Grytviken station under lease from 1906 to 1962, although humpback whaling ceased at South Georgia in 1955 (Tønnesen & Johnsen, 1982; Hart, 2006; Allison, 2013a), and secured a second lease at Jason Harbour in 1909, although no whaling was carried out from there (Tønnesen & Johnsen, 1982; Hart, 2006). At Stromness Bay, A/S Tønsbergs Hvalfangeri operated the *Bucentaur* floating factory in 1907 and a land station at Husvik Harbour from 1911 to 1931 and again from 1945 to 1960 (Hart, 2006). This land station was reopened from 1960–61 by Albion Star Ltd. (Tønnesen & Johnsen, 1982), by which time humpback whaling had ceased. Sandefjord Hvalfangerselskab operated from Stromness Harbour using a floating factory from 1908 to 1912 and a land station until 1931, while, in Leith Harbour, on the north side of Stromness Bay, Chr. Salvesen and Co. operated a land station and floating factory from 1909 to 1961 (Tønnesen & Johnsen, 1982; Hart, 2006). Bryde and Dahl's Hvalfangerselskab A/S secured a lease in Godthul Harbour and operated a floating factory there from 1908 to 1929, whilst Ocean A/S operated a land station and a floating

factory in New Fortuna Bay between 1909 and 1920, before merging with Sandefjords Hvalfangerselskab A/S to form Vestfold A/S (Tønnesen & Johnsen, 1982; Hart, 2006). The Cape Town-based Southern Whaling and Sealing Company operated the factory vessel *Restitution* from 1911 until the vessel sank in 1916 (Hart, 2006), as well as a land station in Prince Olav Harbour from 1919 (as part of the Lever brothers' operation) until 1930 (Hart, 2006; Tønnesen & Johnsen, 1982). Until 1914, humpback whales comprised the main catch from South Georgia (Mackintosh, 1942; Allison, 2013a), with a peak in the 1910/11 season when more than 6,000 individuals, comprising almost 100% of the catch, were killed (Mackintosh, 1942; Burnett, 2012). A rapid decline followed and by 1914 this species comprised only 15% of the catch (Burnett, 2012).

Declining humpback catches off South Georgia led to a ban of humpback whaling by the Governor in the 1918/19 season (Tønnesen & Johnsen, 1982; Hart, 2006), although many companies flouted the ban (Hart, 2006). The ban was reinforced in 1921 and relaxed in the 1926/27 season. Although whalers believed that the stock had been replenished during the ban, humpback whales comprised only 10% of the total catch in South Georgia between 1926 and 1939, reflecting the decline in stocks (Tønnesen & Johnsen, 1982). Until 1931, more than 26,000 humpback whales were taken from land stations in South Georgia (Hart, 2006). In 1963, Japanese companies, *Kokusai Gyogyo Kabushike K.K. and* Nippon Suisan K.K. sub-leased Grytviken and Leith Harbour respectively, ending operations in 1965 and 1966 (Tønnesen & Johnsen, 1982; Hart, 2006). Neither company recorded humpback whale catches, as Southern Hemisphere humpback whales were protected from 1963 (Tønnesen & Johnsen, 1982).

Strait of Magellan and South Shetland Islands[8]

After identifying an abundance of rorqual and southern right whales in the Strait of Magellan, the Norwegian captain Adolfus Amandus Andresen commenced whaling in the region in late 1903 and established the *Sociedad Ballenera de Magallanes* and a whaling station in Punta Arenas, Chile, in 1905. Operations were extended with the floating factory *Gobernador Bories* operating in the natural harbour of Whalers Bay in Deception Island in the South Shetland Islands from 1906 to 1914 (Tønnesen & Johnsen, 1982; Hart, 2006). Andresen and Larsen's whaling success influenced the decision of Norwegian Christen Christensen of Ørnen A/S to dispatch the floating factory *Admiralen* to the southwestern Atlantic (Tønnesen & Johnsen, 1982; Hart, 2006). Failing to secure a concession in South Georgia, Ørnen A/S carried out whaling in the South Shetland Islands from 1905, and, with limited success, in the Falkland Islands (Hart, 2006). The *Admiralen* returned the following season, supported by the *Nor* and *Vesterlide*, as part of Christensen's new company Nor A/S and operated from Deception Island (Tønnesen & Johnsen, 1982; Hart, 2006). Rapid expansion in the South Shetland Islands operations after the 1909/10 season saw the number of established whaling companies increase to 10. These included *Chr. Salvesen & Co.* operating two floating factories, *Neko* and *Horatio*, from 1911, and Norge A/S operating *Solstreif* (Hart, 2006). A lease for a land station at Deception Island was granted to Hektor A/S which operated there from 1912 to 1916 (Tønnesen & Johnsen, 1982; Hart, 2006). Whaling continued in the South Shetland Islands and Graham Land during the First World War (July 1914 – November 1918), profiting from large numbers of blue whales (Hart, 2006). The post-war period saw seven companies operating eight factory ships in the South Shetland Islands under license from the Falkland Islands Government (Hart, 2006), although by 1928/29 the harbours were almost deserted. The Deception Island station closed for good after the 1930/31 season (Hart, 2006). Humpback whales formed the major component of catches in the South Shetland Islands and Graham Land, with almost 10,000 individuals taken until 1915 and a further 1,400 until 1931 (Hart, 2006).

Falkland Islands

Although Chr. Salvesen & Co. considered the Falkland Islands a permanent base from 1907, the poor catches which, until 1915, included only 200 humpback whales (Mackintosh, 1942; Hart, 2006), meant that the station closed, with the equipment transferred to Leith Harbour in South Georgia. The Falkland Islands were not used as a location for whaling thereafter (Tønnesen & Johnsen, 1982; Hart, 2006).

[8] The merged catch statistics for the early years in these two regions, resulting from Sociedad Ballenera de Magallanes operating in both areas, result in these areas being presented together.

South Orkney Islands

Despite the presence of abundant blue and humpback whales, as well as access to adequate water and sheltered harbours, whaling in the South Orkney Islands became compromised by sea-ice formations resulting in short seasons of only two to three months per year (Tønnesen & Johnsen, 1982; Hart, 2006). The factory ship *Sobraon* of the Newfoundland Steam Whaling Company initially operated in the South Orkney Islands in the 1907/08 season, before translocating to the South Shetland Islands, working for A/S Odd from 1910 (Hart, 2006). The Falkland Islands' licenses issued for South Orkney in 1910 were never utilised, although the floating factory *Roald Amundsen* of Laboremus A/S did operate during this season before moving to South Shetland the following year (Hart, 2006). In the 1912/13 season, operations were carried out (Mackintosh, 1942; Hart, 2006), although ice formations meant that whalers operated away from land at the ice-edge, resulting in possibly the first modern 'pelagic' whaling in the Southern Hemisphere (Tønnesen & Johnsen, 1982; Hart, 2006). The South Orkney whaling grounds were abandoned after the 1914/15 season (Hart, 2006), but pelagic whaling resumed in the region when many South Shetland-licenced companies operated in areas around the South Orkney Islands from 1920 to 1930 (Hart, 2006). Fin and blue whales comprised most catches, with 371 humpback whales from the 1911/12 to the 1914/15 season, and only a further 24 caught until 1931 (Hart, 2006).

South Sandwich Islands

Although several companies were given licenses to operate at South Sandwich Islands, only Kosmos A/S exercised the option in 1911 (Tønnesen & Johnsen, 1982) with floating factory *Tulla* which returned to Norway due to ice damage after one season and a catch including only 13 humpback whales (Tønnesen & Johnsen, 1982; Hart, 2006). Whaling returned to the area in 1927 (Hart, 2006), with Tønnessen and Johnsen (1982) reporting on floating factory expeditions described here under modern pelagic whaling.

The Kerguelen Islands (Southern Indian Ocean)

In 1908, a sealing and whaling license was granted to the Norwegian company Kerguelen A/S. Although an imposing shore station was constructed in 1908, whaling was abandoned in 1911 due to disappointing results (Tønnesen & Johnsen, 1982). The floating factory *Radioleine* operated off the Kerguelen Archipelago in the 1929 and 1930 seasons, as discussed under pelagic operations.

Low-latitude continental land-station catches

Modern whaling catches of humpback whales in low latitudes started in South America with a single catch at the end of 1903, in Southern Africa in 1908, New Zealand in 1910 and Australia in 2012, although net catches of humpback whales had been recorded at Whangamumu, New Zealand, from 1890.

South America

Tønnesen and Johnsen (1982) suggest that modern land-based whaling catches of humpback whales from South America were relatively insignificant compared with those from Southern Africa or Australia and New Zealand. Generally, whalers focused on sperm whales with a smaller and almost equal number of blue, fin and humpback whales (Mackintosh, 1942). Initial operations in the Strait of Magellan from Punta Arenas, Chile, from 1905 (despite a single catch in 1903) by Andresen's *Sociedad Ballenera de Magallanes* were strongly linked to the company's operations in the South Shetland Islands (see above) (Tønnesen & Johnsen, 1982). In 1909, Christen Christensen's *Vesterlide* sailed on the west coast of South America to the Gulf of Corcovado, where blue whale aggregations were known (Tønnesen & Johnsen, 1982). A similar expedition was attempted by Andresen in 1912, and, although this proved unsuccessful, he purchased the floating factory *Sabraon* in 1914 and followed the humpback migration northwards along the west coast of South America in the waters of Chile, Peru, Ecuador and Colombia (Tønnesen & Johnsen, 1982). Due to financial difficulties, Andresen sold his company in 1917 to the Sociedad Ballenera Corral S.A., a Chilean company which operated at Corral just south of Valdivia from 1910 to 1930 (Tønnesen & Johnsen, 1982) and again from 1935 to 1938 (Mackintosh, 1942). In 1913, the Sociedad Ballenera Corral S.A. acquired the shore station and floating factory of a further Norwegian company, the Sociedad Ballenera y Pescadora, which had been established by H.C. Korsholm in Valdivia in 1906 (Tønnesen & Johnsen, 1982). Whaling in Chile mainly comprised coastal operations and had a relatively low total number of

individuals caught in comparison with global levels (Pastene & Quiroz, 2010), with 669 humpback whales killed between 1907 and 1979 (Allison, 2013a). Whaling activities also took place in the waters of Peru. After the Second World War (September 1939 – September 1945), the German-Peruvian company, Consorcio Ballenero S.A., built a shore station at Pisco, south of Lima in 1953, and Compañia Ballenera del Norte built a station near Paita in 1957, with operations reaching a peak between 1959 and 1961 (Tønnesen & Johnsen, 1982). Mackintosh (1942) lists more than 1,700 humpback catches from Chile and Peru between 1909 and 1938, while Van Waerebeek *et al*. (1996) noted that the last humpback whale was caught in this area in 1968. Catch numbers were not available for 19th Century whaling off Ecuador and Colombia (Van Waerebeek *et al*., 1996), while unsubstantiated reports suggest a single station operated at Gorgona Island, Colombia, in 1914.

The initiation of modern whaling operations in Brazil appears to be of some debate, with activities from sailing vessels in 1903 in Bahia State (Allison, 2013a; Hart & Edmundson, 2017). Alternatively, activities from a land station apparently started from 1910 at Costinha (Allison, 2013a), but Williamson (1975) suggests this land station operated between 1904 and 1914 (presumably reflecting both open-boat and modern whaling) and again from 1924 to 1985. However, Tønnesen and Johnsen (1982) state that modern whaling in Brazil started in São Salvador by the local company Deider & Brother in 1911, with two Norwegian companies and one local company, the Companhia de Pesca Norte do Brasil (COPESBRA), initiating operations the following year. Both Norwegian companies terminated their whaling operations in 1913 and 1914 (Tønnesen & Johnsen, 1982). From 1951, COPESBRA operated a larger station at Costinha on the northeast coast and a smaller station at Imbituba in the southern part of Brazil (Tønnesen & Johnsen, 1982). Mackintosh (1942) lists humpback catches from Brazil of 1,113 from 1911 to 1914, while Tønnesen and Johnsen (1982) note that little humpback whaling information is available from Brazil before 1948 when the country joined the International Convention for the Regulation of Whaling (ICRW).

Central and Southern Africa

Between 1908 and 1930, the Southern Hemisphere coast of Africa was the most important humpback whaling ground outside the Antarctic, with approximately 31,000 humpback whale catches over this period (Best, 1994), with Findlay (2001) reporting over 47,000 humpback whales taken between 1908 and 1963. Southern African humpback whaling produced a smaller number of barrels per whale compared with the Antarctic as a result of humpbacks becoming leaner while in African waters during the summer months (Mackintosh, 1942; Tønnesen & Johnsen, 1982). Whaling operations in both the Antarctic feeding and African breeding grounds are the likely reason for the rapid decline of humpback stocks (Tønnesen & Johnsen, 1982; Hart, 2006) which resulted in 26 stations operating on the Southern African coast in 1913 (Olsen, 1915; Tønnesen & Johnsen, 1982), declining to five in 1917 (Best, 1994).

The Southern African whaling boom was initiated in Durban after the Norwegian Consul-General placed an advert in the Norwegian press in 1907 announcing the presence of large whales in Southern African waters, thus sparking Norwegian whaling interest. Consequently, the South African Whaling Company, established in 1908 by Norwegians Johan Bryde and Jacob Egeland, operated off Durban with a land station in Durban Harbour (Olsen, 1915; Tønnesen & Johnsen, 1982; Best & Ross, 1989; Best, 1994). Initial outcries resulted in the factory being relocated to the Bluff outside Durban Bay (Olsen, 1915; Tønnesen & Johnsen, 1982; Best & Ross, 1989). In 1913, the company ceased operations (Tønnesen & Johnsen, 1982; Best, 1994), although Egeland later went into business with Abraham Larsen, establishing the Union Whaling Company in 1921 (Tønnesen & Johnsen, 1982; Best, 1994) which operated until 1975 (Tønnesen & Johnsen, 1982; Best & Ross, 1989; Best, 1994). A second company, the Union Whaling and Fishing Company, opened in Durban from 1910 to 1916 (Best, 1994), and a third, the African Whales Ltd., established by George Irvin and C.O. Johnson, began whaling in 1911 (Tønnesen & Johnsen, 1982; Best, 1994). The Shepstone Whaling and Fishing Company aimed to open a station at Port Shepstone, but coastal conditions meant this company operated from Durban between 1912 and 1915. The Eastern Whaling Company operated from Durban in 1912, before being taken over by Premier Whaling in 1913. By 1913, a total of six companies operated in KwaZulu-Natal (at the Bluff in Durban or Park Rhynie) (Mackintosh, 1942), concentrating on the coastal humpback whale migration. By 1918, this number fell to one, the Grindrod Whaling Company (Best, 1994). After World War I, operations were carried out from the Bluff by Premier Whaling and, in 1921, by the

newly established Union Whaling Company, which acquired the Premier Whaling Company in 1930 (Best, 1994). Mackintosh (1942) lists more than 6,000 humpback catches from KwaZulu-Natal between 1912 and 1938.

In the Southern Cape, land stations operated in Mossel Bay from 1911 to 1913 and in Plettenberg Bay from 1913 to 1916 (Best, 1994). Poor humpback catches from the latter station were attributed to migratory routes being further offshore than expected, as well as stations starting too late in the season (Olsen, 1915; Best & Ross, 1989). Of the 22 companies operating in South Africa in 1913, only three survived the First World War to re-commence operations in the 1920s (Best, 1994), with all modern whaling operations discontinued in South Africa in 1975 following the closure of the Union Whaling Company (Best & Ross, 1989), although humpback whales had been protected well prior to this (Tønnesen & Johnsen, 1982).

In Mozambique (Portuguese East Africa), whaling which focused almost exclusively on humpback whales (Macintosh, 1942) began in 1910, with the factory ship *Mangoro* operating off Bazaruto, as far offshore as Madagascar, although with poor results (Olsen, 1915; Budker, 1954; Best, 1994), Johan Bryde's Mozambique Whaling Company, a land station at Linga-Linga near Inhambane (Olsen, 1915; Tønnesen & Johnsen, 1982; Best, 1994), and the Lever Brothers' Premier Whaling Company station operating from 1912 to 1914 in Delagoa Bay (Tønnesen & Johnsen, 1982; Best 1994). The A/S Normanna operated the *Normanna* at Angoche in 1911 and 1912. Only the Linga-Linga station continued operating from 1914 to 1915, before reopening for a few months in 1923 (Tønnesen & Johnsen, 1982; Best, 1994). Until 1914, catches were exclusively humpback whales, with more than 3,000 caught (Mackintosh, 1942).

On the west coast of South Africa, humpback whales approach the shore far north of Saldanha Bay on their northward migration (Matthews, 1938). Near Saldanha Bay, at Donkergat, in 1909, Bryde's company expanded the east coast South African Whaling Company operating the floating factory *Vale* on the west coast and obtained the rights to build a land station at Donkergat which began operating in 1910 (Olsen, 1915; Mackintosh, 1942; Tønnesen & Johnsen, 1982; Best, 1994). This station was leased to the Southern Whaling and Sealing Company (Irvin and Johnson) from 1913 (Tønnesen & Johnsen, 1982; Best, 1994). This Southern Whaling and Sealing Company had been operating the floating factory *Restitution* between South Georgia (summer) and Angola (winter) prior to its loss in 1916 (Hart, 2006). All operations at Donkergat stopped at the end of the 1930 season (Tønnesen & Johnsen, 1982; Best, 1994), although Irvin and Johnsen made another attempt in 1936 and 1937 (Mackintosh, 1942; Tønnesen & Johnsen, 1982). After World War II, whaling was carried out by the Donkergat Whaling Company between 1947 and 1953, and, in 1957, by the reorganised Saldanha Whaling Company which operated the station until 1967 when operations closed for good (Tønnesen & Johnsen, 1982). The Southern Whaling Company operated the floating factory *Sven Foyn* in Saldanha Bay during the 1909 season (Best & Ross, 1989; Best, 1994). In 1911, Hans Ellefsen Ltd. constructed a land station located at Salamander Bay just to the north of Donkergat (Best, 1994). This company operated intermittently until 1930. A third company, the Southern Cross Whaling Company, operated a land station near Cape Hangklip from 1913 to 1914. The Shepstone Whaling and Fishing Company acquired the assets of the bankrupt Southern Cross operation in 1915 and began to operate at Cape Hangklip from 1916 to 1920. This station was further operated by Irvin and Johnsen from 1926 to 1930 (Best, 1994).

In Namibia (then German South-West Africa), whaling commenced in Walvis Bay in 1912 (Mackintosh, 1942; Tønnesen & Johnsen, 1982; Best & Ross, 1989) with the Durban Whaling Company factory ship moored in the bay and the Walvis Bay Whaling Company operating a land station. In 1913, a further land station opened in Stormvogelbucht, near Lüderitz (Best & Ross, 1989; Best, 1994). Operations were disrupted in 1914 by the onset of World War I (Tønnesen & Johnsen, 1982; Best, 1994) but the land station in Walvis Bay resumed operations from 1923 until 1930 (Mackintosh, 1942; Tønnesen & Johnsen, 1982; Best & Ross, 1989).

In Angola (Portuguese West Africa), the floating factory *Ambra* initiated humpback whaling in July 1909, while land-based operations were carried out at Lobito Bay, Elephant Bay, Mossamedes, Porto Alexandre and Tiger Bay from 1911 (Mackintosh, 1942; Tønnesen & Johnsen, 1982; Best, 1994). By 1916, only one company recorded catches but closed by the end of the season (Tønnesen & Johnsen, 1982; Best & Ross, 1989; Best, 1994). Until 1914, catches were predominantly humpback whales, with more than 10,000 individuals of the species caught in Angola between 1909 and 1928 (Mackintosh, 1942).

In Gabon (French Congo), whaling at Cape Lopez (Budker, 1954; Tønnesen & Johnsen, 1982), targeting almost exclusively humpback whales, began with a single floating factory operation in 1912 (Mackintosh, 1942), expanding to four new factories by 1913 (Tønnesen & Johnsen, 1982). Six companies operated in 1914 (Budker, 1954) before the suspension of whaling during World War I (Budker, 1954; Tønnesen & Johnsen, 1982), including the *Imo*, operated by the South Pacific Whaling Co., and the *Aviemore*, operated by the Alfa & Beta Company in Libreville during 1913 and 1914. Operations re-commenced in 1922 with one land station and one floating station at Cape Lopez until 1926 (Mackintosh, 1942; Budker, 1954; Tønnesen & Johnsen, 1982; Best, 1994). Whaling resumed for one season in 1930 and again in 1934 (Best, 1994). Undermining the ICRW, and despite warnings that renewed whaling would destroy stocks, the French-Norwegian company Sopecoba (Société des Pecheries Cotieres a la Baleine) operated a floating factory and land station at Cape Lopez from 1949 to 1951. During the 1949/50 season, a record catch of 1,400 humpbacks was followed by a slump in the following year during which Sopecoba resorted to catching sei (*Balaenoptera borealis*) and sperm whales (Tønnesen & Johnsen, 1982). Single whaling seasons also occurred at Fernando Po (1914), São Tomé (1951) and off Cape Lopez (1959).

Australia and New Zealand

Just as happened in South Africa, in 1909, the Norwegian consul in Sydney drew attention to the abundance of whales in Australian waters (Tønnesen & Johnsen, 1982). Modern whaling then began unsuccessfully with the operation of a Norwegian floating factory, the *Loch Tay*, in Tasmania in early 1912 (Colwell, 1969; Tønnesen & Johnsen, 1982).

In Western Australia, a further Norwegian whaling expedition, the Spermacet Company, operated from 1912 at Shark Bay, catching mostly humpback whales on their northbound migration in the winter (Matthews, 1938; Mackintosh, 1942; Tønnesen & Johnsen, 1982). The expedition spent the following summer at a shore station in Frenchman's Bay near Albany before proceeding north again to Point Cloates ('Norwegian Bay') in May 1913 for a further winter season. The West Australian authorities regulated humpback whaling in 1913, granting only three licenses (Tønnesen & Johnsen, 1982) to the Spermacet Company, as well as two other Norwegian concerns, the Fremantle Whaling Company and the West Australian Company. These two latter companies sailed for Point Cloates in June 1914 and returned in 1915 to build a land station. The Fremantle Company closed at the end of 1915 (Colwell, 1969), followed by the West Australian Whaling Company in 1916. Meanwhile, the Spermacet Company continued whaling from Frenchman's Bay in the south, terminating operations in 1916 (Mackintosh, 1942; Colwell, 1969). Whaling was intermittent in Western Australia thereafter until 1948. In 1921, the North West Whaling Company started whaling again (Colwell, 1969) but the Company was liquidated in 1924. In 1925, the Norwegian Bay Whaling Company of Sandefjord began to rent the station in Point Cloates until 1928. By this time, Norwegian whalers had built and tested factory ships with slipways in the stern (Colwell, 1969). During 1936, two Norwegian factory ships, the *Frango* and the *Anglo-Norse*, worked the grounds outside territorial waters off the coast Western Australia, killing over 3,000 humpback whales (Colwell, 1969). After recording catches of nearly 16,000 humpback whales from 1912 to 1938 (Mackintosh, 1942), whales were left in peace during World War II (Colwell, 1969). Between 1946 and 1948, an unsuccessful trial attempt was made to re-establish whaling from Albany. The Nor' West Whaling Co. was formed in 1949, operating the old shore station at Point Cloates, until 1955, and then in Carnavon until 1963. Two Albany stations, the Cheynes Beach Whaling Company and the Albany Whaling Company, operated from 1952, while state-run operations at Carnarvon were initiated in September 1950 and continued until 1963 (Colwell, 1969; Tønnesen & Johnsen, 1982).

On the Australian east coast, limited operations were carried out from a floating factory operating in Jervis Bay from 1912 to 1913 (Tønnesen & Johnsen, 1982). In 1952, whaling resumed from Tangalooma on Moreton Island, where an unsuccessful attempt had first been made in 1912, with Whales Products Pty Ltd. catching whales for 10 years. A second license was granted to the Byron Bay Whaling Company to operate south of Brisbane from 1954 to 1962, which, along with the Norfolk Island Whaling Company (1956 to 1962), operated from Norfolk Island from 1955 to 1961 (Chittleborough, 1965; Colwell, 1969; Tønnesen & Johnsen, 1982), after the South Seas Whaling and Sharking Company[9] had operated from Norfolk Island in 1949.

[9] Some literature (e.g., Van Pel, 1959) refers to this company as South East Whaling and Sharking, and as having operated in 1949 and 1950.

Catches of humpback whales in New Zealand waters, including net whaling and small-boat modern whaling operations, resulted in catches of more than 5,000 humpback whales. Net whaling of humpback whales was carried out from a single operation at Whangamumu in the Bay of Islands between 1890 and 1910, where steel nets were used to catch whales passing between an offshore rock and a headland (Ommaney, 1933; Dawbin, 1956; Tønnesen & Johnsen, 1982). From 1901, a steam launch was incorporated to retrieve the whales, and from 1910 to 1931, the operation started using harpoon guns from motor-powered vessels, abandoning the net whaling practices (Tønnesen & Johnsen, 1982). Land-based modern whaling concerns operated from the coast of New Zealand, including from Kaikoura between 1917 and 1922, and in the Torey Channel of Cook Strait from 1909 until 1963, where the Perano family took advantage of the migration of humpback whales, using a light harpoon operation from small fast boats rather than conventional catchers (Grady, 1982; Tønnesen & Johnsen, 1982).

Pelagic modern whaling catches

Following the introduction of whaling vessels with slipways and associated catcher fleets, the 1923 Antarctic whaling season saw the advent of pelagic whaling in the Southern Ocean (Mackintosh, 1942; Tønnesen & Johnsen, 1982; Burnett, 2012). Although some floating factories had worked independently of the shore in some years, such as *Bas II* in the Congo or the A/S Tønsberg Hvalfangeri fleet along the ice edge off the South Orkney Islands in 1912, operations were difficult as whales could not be flensed alongside vessels in rough seas (Tønnesen & Johnsen, 1982; Best & Ross, 1989; Hart, 2006). The stern slipway design, which enabled whales to be flensed onboard, meant that whaling was no longer limited to the vicinities of land stations, thus opening large pelagic areas of the Southern Ocean to whaling pressure. Initially, relatively few humpbacks were caught in pelagic whaling, but from the mid-1930s, considerable numbers were caught along the ice edge in various locations (Hart, 2006). Findlay (2001) reports pelagic catches of 34,683 humpback whales in the region south of 40°S between 1904 and 1974.

Ross Sea

Although several companies applied for whaling licences in the Ross Sea as early as 1912 (Tønnesen & Johnsen, 1982), only in late 1923, the Sir James Clark Ross of the Ross Sea Whaling Company ventured the Ross Sea with five catcher vessels under the command of C.A. Larsen. Mooring at Discovery Inlet, whales were flensed alongside under difficult and cold weather conditions. By the end of the season, in early March, some 10 fin and 211 blue whales had been taken, with Larsen quoted to have said: 'If only we had a floating factory to hoist the whales on deck, we certainly need not have despaired'. Expeditions to the Ross Sea in the next two years (Larsen died in 1924) were far more successful, resulting in the Company operating the factory ship *C.A. Larsen* from the 1926/27 season. This ship had a bow slipway allowing whales to be hauled on deck for flensing. Operations in the Ross Sea expanded, such that, while heavily based on blue and fin whales, catches of 890 humpback whales were recorded between 1926 and 1930 (Tønnesen & Johnsen, 1982; Hart, 2006).

Antarctica

In 1925, A/S Globus's *Lancing*, the first floating factory with a stern slipway (Tønnesen & Johnsen, 1982; Hart, 2006; Burnett, 2012), sailed for the South Orkney Islands, where it followed blue whale migrations southwest of the Bransfield Strait (Tønnesen & Johnsen, 1982). Both this expedition and those to the Ross Sea set the foundation for the future of the Southern Ocean whaling industry (Tønnesen & Johnsen, 1982; Hart, 2006), with land-based stations abandoned in favour of new Antarctic ice-edge whaling fields from South Georgia to the Ross Sea (Hart, 2006). By 1927, 17 pelagic floating factories with 61 catchers were operating in the Antarctic (Tønnesen & Johnsen, 1982; Holt, 2001; Hart, 2006). A further 23 new whaling companies, with 41 factory ships and 200 catchers, began whaling during the Southern Ocean expansion period of 1927 to 1931 (Tønnesen & Johnsen, 1982; Best & Ross, 1989; Yablokov & Zemsky, 2000; Holt, 2001; Hart, 2006), opening three-quarters of the Southern Ocean to whaling (Hart, 2006). As conversions of moored floating factories to slipway floating factories were costly (Tønnesen & Johnsen, 1982), in 1928, the Kosmos Whaling Company developed the first purpose built floating factory with a stern slipway and flensing deck (Risting, 1929; Tønnesen & Johnsen, 1982; Hart, 2006), the *Kosmos* (Tønnesen & Johnsen, 1982; Hart, 2006), which began whaling off the Balleny Islands, with expansions of pelagic whaling fleets following soon thereafter (Tønnesen & Johnsen, 1982).

The 1930s also saw two new nations entering the Antarctic pelagic whaling industry (Tønnesen & Johnsen, 1982; Holt, 2001). Japan commenced whaling in Antarctica in 1934 with the *Antarctic*, rechristened the *Tonan Maru* by Nippon Suisan K.K., while, in 1936, Taiyo Hogei K.K. launched the first Japanese-built floating factory, the *Nishin Maru* (Tønnesen & Johnsen, 1982). From 1937, Japan stepped up operations in the Antarctic on a substantial scale (Tønnesen & Johnsen, 1982; Holt, 2001; Burnett, 2012), with two additional floating factories in operation before World War II (Tønnesen & Johnsen, 1982). Meanwhile, Germany's desire to procure whale oil without spending foreign currency led to the procurement of several factories, such as the *Jan Wellem* (Tønnesen & Johnsen, 1982). By 1937, nine Southern Ocean expeditions sailed under the German flag, including two newly built, technologically advanced vessels, the *Unitas* and the *Walter Rau* (Tønnesen & Johnsen, 1982; Holt, 2001).

The Antarctic 1936/37 season reached an all-time high, with the largest number of whale catcher boats to date (Best & Ross, 1989; Zemsky, 2000), during which 4,457 humpback whales were taken (Tønnesen & Johnsen, 1982). The pelagic whaling contribution to whaling pressure increased from 11% in the 1925/26 season to 79% in 1930/31 (Best & Ross, 1989; Hart, 2006), with most of the global catch between 1930 and 1940 caught in the Southern Ocean (Zemsky, 2000).

Following the sinking of three floating factories at South Georgia in 1940, pelagic whaling was paused during World War II, although whaling continued from shore bases in New Zealand, South Africa, Chile and the Antarctic (Tønnesen and Johnsen, 1982). During the war, whaling fleets were largely used as tankers to carry bulky war materials, with several lost (Tønnesen & Johnsen, 1982; Holt, 2001), which meant the whaling fleet was severely reduced, with a total of seven post-war floating factories in 1946 as opposed to 37 in 1939 (Tønnesen & Johnsen, 1982). Expeditions increased again after the war, reaching a peak in 1960–62, paradoxically, in inverse proportion to whale stocks. Average production slumped from a daily 110 barrels in 1952/53 to 57 in 1962/63 (Tønnesen & Johnsen, 1982). These rapidly declining whale stocks were a turning point for many British and Norwegian expeditions, with sales of floating factories signalling the winding down of operations (Tønnesen & Johnsen, 1982; Holt, 2001). In 1965, a further five floating factories terminated operations in the Antarctic, with only Japan and the Soviet Union operating in the pelagic whaling grounds south of the equator after 1968 (Tønnesen & Johnsen, 1982). Humpback whales had been totally protected across the Southern Hemisphere since October 1963.

Whaling regulation

As early as 1906, catch regulations were imposed across the 'Colony of the Falkland Islands', which placed limitations on the number of whaling licences for shore stations and moored floating factories, the areas of operation of each licence, and the number of whales allowed to be taken per annum under each licence, and introduced oversight of operations by a whaling inspector (Tønnesen & Johnsen, 1982). Between 1907 and 1910, Jens Andreas Mörch, a Norwegian whaling engineer with experience in the South Georgia operations, identified the wasteful use of carcasses, and advocated research (funded by license fees) to assist the management of whale stocks. Such management was considered challenging given 'the lack of scientific information' (Hinton, 1915). These discussions were important to align interests of conservation of whale stocks, largely by research interests, and conservation of the whaling industry by industrial governance interests (Burnett, 2021), stimulating British research initiatives, resulting in the development of the Discovery Investigations from 1923 onwards (Deacon, 1955). Humpback whaling was banned from South Georgia from the 1918/19 season, although catches continued to some degree until 1921/22 when it was reinforced (Findlay, 2001). While relaxed in 1926, humpback catches remained low compared with other species due to a strong shift in catch selectivity.

The Norwegian Whaling Act, in place for Norwegian entities between 1929 and 1932, was the first law designed to regulate whaling on the open seas (Tønnesen & Johnsen, 1982; Hart, 2006) and encompassed full protection of right whales; a ban on catching calves, sexually immature whales and lactating mothers of all whale species; a requirement for full utilisation of whale carcasses; fixing whalers' bonuses according to yield and not numbers of whales caught; operation under a license; appointment of inspectors; a requirement to maintain a log book and to supply statistical information to the Bureau of International Whaling Statistics in Norway (Tønnesen & Johnsen, 1982; Holt, 2001; Hart, 2006).

Derived in large parts from Norwegian Whaling Act of 1929, expedition quotas were established by the 1931 Geneva Convention (Tønnesen & Johnsen, 1982; Holt, 2001; Hart, 2006; Burnett, 2012), involving government representation from France, Germany, Japan, Norway, Portugal, the UK and the USA. Crucially, the Convention only came into force four years later as Britain delayed ratification until 1934 (Tønnesen & Johnsen, 1982; Best & Ross, 1989; Holt, 2001). In 1936, after the entry of other nations to Antarctic pelagic whaling, Germany ratified the successors to the Geneva Convention, but Japan did not (Tønnesen & Johnsen, 1982; Holt, 2001). In 1932, a negotiated production agreement introduced barrel and whale quotas (Tønnesen & Johnsen, 1982; Holt, 2001; Hart, 2006), resulting in a dispute about the basis for quotas, with Norwegian companies arguing for these to be based on tank capacity while British companies argued for quotas to be expressed as numbers of whales rather than quantities of oil (Tønnesen & Johnsen, 1982; Holt, 2001). The resultant Blue Whale Unit (BWU), initially based on the assumption that one blue whale would yield 110 barrels of oil, allocated equivalents for other species (e.g., one BWU = two fin whales, 2.5 humpback whales or six sei whales), a measure which prevailed in Antarctic whaling management until 1972 (Tønnesen & Johnsen, 1982; Holt, 2001; Burnett, 2012). Such a catch limitation process allowed for total catch limits for the Antarctic whaling region to be declared. For example, during the 1932/33 season, the limit was set at 18,584 BWU. This limit was renegotiated for the 1933/34 season at 17,074 BWU but calculated at 115 barrels per BWU. While intended to reduce catches to sustainable levels, this value was not based on any scientific evidence (Tønnesen & Johnsen, 1982; Holt, 2001). As such, quotas set in BWU permitted whalers to make their own decisions about which whales to take, and therefore made no allowance for the conservation status of a particular species or specific population. The large catches of humpbacks between the 1934/35 and 1937/38 seasons resulted in the species becoming protected in Antarctic waters from 1938 to 1949 through the International Agreement for the Regulation of Whaling (ARW). A temporary relaxation in the 1940/41 season and continued catches by Japan (non-members of the ARW) saw some continuation of humpback catches during this period (Findlay, 2001).

The 1938 London Conference Protocol included a total ban on catching humpback whales south of 40°S from 1 October 1938 to 30 September 1939 and a total ban on catching baleen whales for two years from December 1938 in the waters between the South Shetland Islands and the eastern borders of the Ross Sea (an area referred to as a Sanctuary) (Mackintosh, 1942; Hart, 2006; Tønnesen & Johnsen, 1982; Best & Ross, 1989). In addition, no floating factory operating in the Antarctic was permitted to catch baleen whales in any other grounds within 12 months of the conclusion of their Antarctic season (Tønnesen & Johnsen, 1982; Hart, 2006; Burnett, 2012). A four-day grace period after the annual BWU catch limit had been achieved meant that catches remained high (Tønnesen & Johnsen, 1982).

Humpback whales were protected from pelagic whaling south of 40°S between 1938 and 1949, except for 883 individuals taken by Japanese fleets in 1938 and 1939, and 2,675 individuals taken during a relaxation of the ban in 1940/1941 season. Although no research-based knowledge of the whale stocks was available in the 1940s, the whaling hiatus caused by World War II and the pelagic ban created erroneous expectations that whale stocks had sufficient time to recover (Tønnesen & Johnsen, 1928; Burnett, 2012). During the 1949/50 season, an annual quota of 1,250 humpback whales was arbitrarily chosen for pelagic whaling in the Southern Ocean (Tønnesen & Johnsen, 1982), with whaling expeditions required to submit a weekly report to the Bureau of International Whaling Statistics. From 1954 to 1962, permission to pursue humpback whales was only granted for four days each season (Holt, 2001). Such pelagic whaling excluded the declared Sanctuary between 70°W and 160°W from the 1949/50 season up to the 1955/56 season. From 1954/55, the area south of 40°S and between 0° and 70°W was closed to humpback whaling, although, in 1958/59, the western limit of this closure shifted eastwards to 60°W. High-latitude pelagic humpback reported catches[10] varied from a high of 2,394 in 1958/59 to a low of 270 in 1962/63 (Tønnesen & Johnsen, 1982). In 1963, humpback whales were protected south of the equator (Tønnesen & Johnsen, 1982; Holt, 2001), even though illegal whaling continued (see next section).

Following the almost total cessation of whaling during World War II, the ICRW was developed and signed by all major whaling nations in 1946, resulting in the creation of the IWC in 1947. The IWC was established to regulate whaling through research on whale stocks, including abundance estimation, population structure and

[10] This means the numbers reported here do not include illegal catches.

the setting of associated quotas. Among results of efforts by the IWC, the Moratorum on Commercial Whaling was established in 1982, coming into effect in 1986.

Illegal, unregulated and unreported catches

As per regulation, catches of all large whale species had to be reported to the Bureau of International Whaling Statistics in Norway each year, with further regulations for certain areas of the Southern Hemisphere as to the extent and distribution of whale catches (see above) (Tønnesen & Johnsen, 1982; Holt, 2001). Although humpback whales were officially protected in October 1963 (Tønnesen and Johnsen, 1982; Holt, 2001), and the Soviet Union had signed the Convention in 1946 (Clapham & Baker, 2009), Soviet fleets violated catch and reporting regulations (Chernyi, 2000; Golovlev, 2000; Burnett, 2012), failing to observe whaling seasons, protected species and size restrictions (Zemsky *et al*., 1995; Tønnesen & Johnsen, 1982; Golovlev, 2000). Significant illegal catches were made from the 1946/47 season, only terminating in 1973 with the introduction of international observers on whaling vessels. Large misreporting of catches by the four Soviet fleets, the *Slava* operating from 1946/47[11] to 1965/1966, the *Sovetskaya Ukraina* operating from 1959/60 to 1979/80, the *Yury Dolgoruky* operating from 1960/61 to 1974/75, and the *Sovetskaya Rossiya* operating from 1961/62 to 1979/1980 (Zemsky *et al*., 1995; Tønnesen & Johnsen, 1982), continued each year, with true catches of humpback whales between 1946 and 1973 exceeding the reported catches of 2,707 humpback whales (Golovlev, 2000; Yablokov & Zemsky, 2000), with a total of more than 48,000 catches (Findlay, 2001). Furthermore, the Onassis operation, Olympic Whaling, operated the *Olympic Challenger* fleet under the Panamanian flag outside the Convention. The fleet operated between 1950 and 1955, killing 4,585 in the Antarctic and another 105 off the west coast of South America (Findlay, 2001; Allison, 2013a).

The International Whaling Commission (IWC) Catch Database

Comprehensive dataset

The IWC's comprehensive Catch Database (version 5.5) (Allison, 2013a; 2013b) contains records of 215,928 individual humpback whale catches in distinct operational eras across the period from 1890 to 1979, although the most recent humpback whale catches are from Tonga up to 1978. The distinct eras in this period include the net whaling from Whangamumu, New Zealand, between 1890 and 1910, high and low-latitude modern land-based and floating factory whaling from 1903 to 1963, high and low-latitude legal pelagic whaling from 1923 to 1963, and high and low-latitude illegal pelagic whaling from 1948 to 1973. Recent humpback whale catches from Tonga between 1961 and 1978 are included in the dataset.

Years of operations of land stations, moored floating factories, legal and illegal pelagic operations, and net operations by whaling era and station location or vessel, as extracted from the dataset, are provided in Tables S1 to S6.

An estimated 112 individuals were taken by net whaling off Whangamumu, New Zealand, while land station and moored floating factory whaling accounted for takes of an estimated 116,890 individual humpback whales (Table 1). Legal pelagic whaling and illegal pelagic whaling accounted for catches of an estimated 45,401 and 53,411 individual humpback whales, respectively, while recent whaling off Tonga resulted in catches of an estimated 114 individuals up to 1978.

Catches by year and catch location for the different whaling eras are shown in Tables S7 to S12, with the number of catches per year per breeding stock displayed in Figure 7. No attempt has been made to account for effort in these catch totals because, while the catcher fleet numbers are available, both the size and catch efficacy and different catch conditions under which the catcher fleets were operating are unknown.

Spatial analyses

Of the 215,928 individual humpback whale catches recorded in the IWC Catch Database, a subset of 145,245 individuals have associated locations of various confidences (Table 1).

[11] For the first two seasons of operations by *Slava* (1946/47 and 1947/48), there were Norwegian instructors onboard and, as such, the data are understood to be reliable.

Table 1

Catches of humpback whales from operations across the Southern Hemisphere by location confidence (individual location, confined to within a small area (10° by 10°; e.g., South Georgia), confined to a broader area (20° by 20° or broader; e.g., Western Australia), by station or moored floating factory position (e.g., Durban) and more broadly by ocean basin (e.g., South Atlantic)).

Type of whaling operation	Catches with known location per level of confidence					Summary		
	Individual catch location	Small area (within 10° x 10°)	Relatively broad area (within 20° x 20°)	Whaling station or moored floating factory position	Ocean Basin	Known location – Total	Unknown location – Total	Total
Net	0	0	0	112	0	112	0	**112**
Low-latitude land station and moored floating factory	8,932	742	679	61,288	0	71,641	0	**0**
High-latitude land station and moored floating factory	0	204	0	17,760	0	17,964	0	**0**
Land station and moored floating factory – Total	**8,932**	**946**	**679**	**79,048**	**0**	**89,605**	**27,285**	**116,890**
Low-latitude pelagic – Legal	14	989	16,567	0	0	17,570	0	**0**
High-latitude pelagic – Legal	976	804	25,847	0	0	27,627	0	**0**
Legal pelagic – Total	**990**	**1,793**	**42,414**	**0**	**0**	**45,197**	**204**	**45,401**
Low-latitude pelagic – Illegal	0	0	0	0	2,716	2,716	0	**0**
High-latitude pelagic – Illegal	0	0	0	0	7,501	7,501	0	**0**
Illegal pelagic – Total	**0**	**0**	**0**	**0**	**10,217**	**10,217**	**43,194**	**53,411**
Recent	0	114	0	0	0	114	0	**114**
Totals	**9,922**	**2,853**	**43,093**	**79,160**	**10,217**	**145,245**	**70,683**	**215,928**

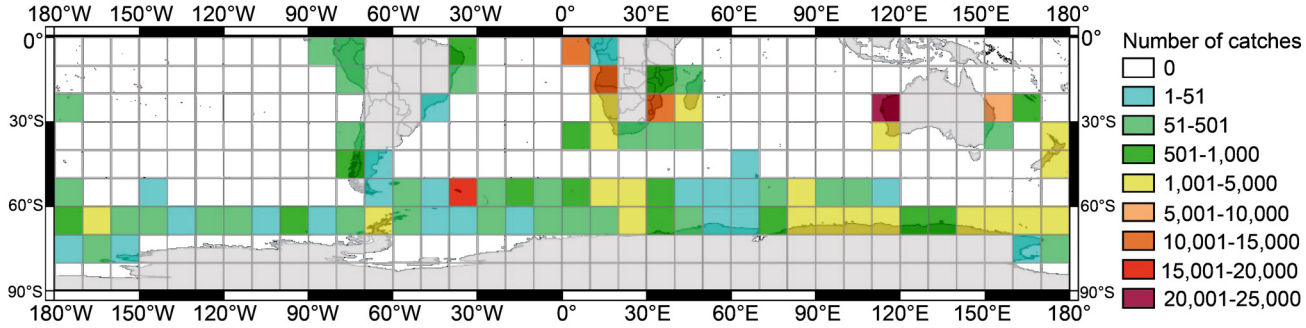

Figure 7. The distribution of an estimated 145,245 known-position humpback whale catches in the International Whaling Commission Catch Database, from land-based, moored floating factory, pelagic and other (net) operations per 10° by 10° grid across the Southern Hemisphere between 1890 and 1973.

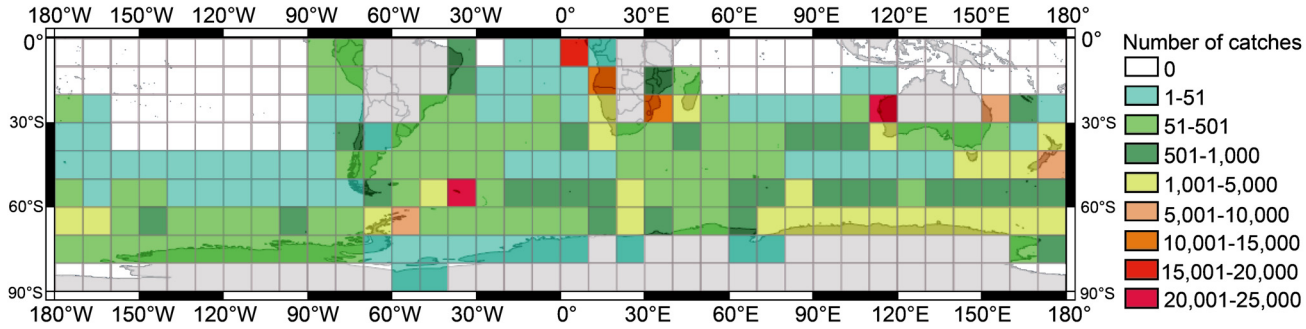

Figure 8. The distribution of the 215,928 catches taken between 1890 and 1973, accounted for in the International Whaling Commission Catch Database, including both known catch locations and unknown catch locations assigned to best confidence grids of 10° of latitude by 10° of longitude across the Southern Hemisphere .

The remaining 70,683 catches, for which catch positions are not well understood, comprise 27,285 individuals associated with historical moored floating factory positions, 204 individuals captured by pelagic floating factories, while 43,189 catches of individuals occurred during the high-latitude illegal pelagic operations.

A total of 145,245 catches with a known catch position were allocated into 10° by 10° grid cells (Fig. 7) based on the individual catch location, known land station or floating factory position, small or broad area location, or ocean basin (Table 1).

The random assignment of the remaining 70,683 catches to their 'best confidence polygons' allowed for catch distributions to be determined per 10° by 10° grid, as shown in Figure 8.

Figures 7 and 8 show the same grids cells with the highest number of catches in several localised areas, namely off the coasts of Gabon and Angola (breeding sub-stock B1); off Durban and Mozambique (breeding sub-stock C1); off northwestern Australia (Breeding Stock D); and northeastern Australia (breeding sub-stock E1) within the breeding grounds, and off South Georgia within the feeding grounds. The relatively high number of unknown locations of Soviet illegal catches, assigned to broad best confidence polygons for these fleets (as per Figs. 3–6), contribute significantly to the spread of catches across pelagic areas of the Southern Hemisphere.

DISCUSSION

In this work, we present a review of humpback whaling in the Southern Hemisphere, compiling information on its history, and using the IWC Catch Database to improve catch allocation over time, providing new information relevant to an In-depth Assessment of the species. Comprehensive and In-depth Assessments of baleen whale populations are critical for their management and our understanding of their conservation status, particularly in relation to their extensive exploitation over the last 300 years. While the IWC identified Comprehensive Assessments as an important contribution to the Moratorium on Commercial Whaling, there was no agreement on what Comprehensive Assessments should entail. The IWC's Scientific Committee (SC) later agreed these should include investigations of current stock identity and size, population trends, carrying capacity and productivity

(Donovan, 1989; IWC, 1989). Between 2000 and 2010, the SC undertook the extensive Comprehensive Assessment of Southern Hemisphere humpback whales on a regional breeding stock basis, a process reviewed and described by Jackson *et al*. (2015). A critical component of this exercise related to the assignment of whale catches to regional breeding stocks, as these largely drive the estimates of pre-whaling abundance, and the current population status in relation to such abundance estimates.

Allocation of low-latitude catches to the seven IWC humpback whale breeding stocks currently identified across the Southern Hemisphere is a relatively simple exercise. However, high-latitude catches also require allocation to particular breeding stocks, a process far more complex given: (1) the potentially broader longitudinal ranging of whales on their feeding grounds than low-latitude breeding grounds and, therefore, potential mixing of breeding stock individuals on the feeding grounds; and (2) the greater uncertainty of catch positions at high latitudes resulting from the pelagic operations, ranging over far broader longitudinal areas than the coastal land station and pelagic catches in low-latitude areas. The habitat use of individuals from each breeding stock in high latitudes and the level of mixing among them are still not well understood, although recent tagging studies by area are giving light to this matter (e.g., Reisinger *et al*., 2021; Johnson *et al*., 2022). The approach proposed here represents an advancement in the catch allocation process by providing the assignment of catches lacking a precise location from the IWC Catch Database to grids of 10° of latitude by 10° of longitude, if not to a smaller area. This represents progress towards a better understanding on the spatial distribution of humpback whale catches in the Southern Hemisphere and can be used in the next In-depth Assessment of the species. As part of it, high-latitude catches of the species can be assigned to different breeding stocks, ideally considering a rate of exchange of individuals in feeding grounds, as individuals can have longitudinal dispersion in these areas (Reisinger *et al*., 2021; Johnson *et al*., 2022), and boundaries of the feeding grounds might be porous (Marcondes *et al*., 2021; Ramos *et al*., 2023). It is therefore strongly recommended that revised stock dispersal models across breeding and feeding grounds consider the full range of available Discovery Investigation's whale mark-recapture data, satellite track, photo-identification and any other information (e.g., lost and recovered harpoons). Other relevant information to be considered so assessments are as accurate as possible include pre-modern whaling catches (e.g. Zerbini *et al*., 2019) and rates of struck-and-lost animals (Baker & Clapham, 2004; Vighi *et al*., 2020).

In the Southern Ocean, the exploitation of marine mammal top predators includes takes of an estimated two million baleen whales and over 1.5 million fur seals, which is considered 'the largest human-induced perturbation of a marine ecosystem anywhere in the world' (Mori & Butterworth, 2004). The understanding of the impacts of such exploitation on the ecosystem can be rather complex. For example, the removal of top predators from Southern Ocean systems was believed to result in a release of Antarctic krill (*Euphausia superba*) predation pressure, leading to an available annual krill surplus of up to 150 million tonnes, in what was defined as the 'krill surplus hypothesis' (Laws, 1977). For some researchers, this increase did not seem proportional to the number of whales killed. For instance, Smetacek (2008) suggested that the actual surplus of krill would be significantly larger. Over time, this theory remained unconfirmed, giving rise to what is known as the 'krill paradox'. Such paradox may be linked to rising krill demand from other predators, such as seals and penguins, whose biomasses and reproductive rates have increased due to reduced competition for food with whales (Laws et al., 1977). However, despite significant advances in understanding the influence of various physical factors on the Antarctic ecosystem, subsequent trends in the abundance of these predators have not provided conclusive evidence or have divergent findings (Mori & Butterworth, 2006; Emslie & Patterson, 2007; Nicol *et al*., 2007; Smetacek, 2008; Surma *et al*., 2014; Hoffman *et al*., 2022). From these, Surma *et al*. (2014) used ecosystem modelling to investigate the role of the krill surplus hypothesis on Southern Ocean food webs and found that, while the hypothesis was a plausible explanation of some mid-20th Century biomass trends, declines in primary productivity between 1975 and 1995 resulted in declines in excess krill biomass. These authors attribute drivers of such declines to include reductions in whale-estimated refertilisation during the last quarter of the 20th Century.

That relates to the fact that baleen and large toothed whales can contribute to the Southern Ocean ecosystem structure by refertilising the water column with micro-nutrients (particularly iron) through defecation, which results in increased productivity (e.g., Nicol *et al*., 2010; Roman *et al*., 2014; Ratnarajah *et al*., 2018). Consequent enhanced primary productivity is hypothesised to have driven an increased abundance of Antarctic krill, providing a positive feedback loop for consumer abundance in a relatively low-productive Southern Ocean (Smetacek,

2008). Therefore, while the major interaction between whales and their primary krill prey has long been thought to centre on top-down pressures on prey populations, this bottom-up effect is currently recognized as relevant. Both top-down and bottom-up drivers can lead to system changes that, in turn, may influence marine mammal top-predators carrying capacity (K) and then the recovery of the stocks since the cessation of whaling. Such carrying capacity is believed to be changing over time. While estimates of pre-whaling abundance provide some measure of historic carrying capacity, both the absence of baselines against which changes can be assessed and a lack of understanding of all factors influencing the carrying capacities of high trophic-level consumers make assessments of the pressures and impacts of global change particularly complex. In fact, 'disentangling the effects of human exploitation of upper trophic levels from basin-wide, decade-scale climate cycles to identify long-term, global trends is a daunting challenge facing polar bio-oceanography' (Smetacek & Nicol, 2005). For Southern Hemisphere humpback whales, such a challenging task would ideally entail evaluating the effect of different threats to the species, including climate change effects on their breeding and feeding grounds and migratory corridors (e.g. Derville *et al*., 2019; Tulloch *et al.,* 2019; Meynecke *et al*., 2020, 2021; Seyboth *et al*., 2021; van Weelden *et al*., 2021), ship strikes (Van Waerebeek *et al*., 2007; Smith *et al*., 2020), entanglements (Groom & Coughran, 2012; Ott *et al*., 2016; Félix *et al*., 2020; Santora *et al*., 2020), underwater noise (Rossi-Santos, 2015; Dunlop, 2019; Dunlop *et al*., 2020), and pollution (Besseling *et al*., 2015; Das *et al*., 2017; Casà *et al*., 2019; Remili *et al*., 2020), noting that the level of impact of each of these factors might differ among breeding stocks.

Altogether, these stocks seem to have recovered to about 80% of their pre-modern whaling abundance (Seyboth *et al*., 2023), estimated as 140,000 individuals in the early 1900s (IWC, 2016). However, in light of the aforementioned threats, a more detailed understanding of their trajectories and projections is to evaluate whether specific management strategies are necessary. The information provided in this review, if used for an In-depth Assessment of Southern Hemisphere humpback whales to shed light on the whaling impact on each breeding stock, can be relevant in this process.

AUTHOR CONTRIBUTIONS

KF and ES conceptualised the review. SP and KF performed the literature review and wrote the sections related to this component of the review. ES and KF reviewed the International Whaling Commission Catch Database built by CA as part of her work at the IWC. ES carried out computations relating to the spatial allocation of the catches and wrote the text relating to this analyses. All authors revised the manuscript.

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REFERENCES

Aguilar, A. (1985). Aboriginal whaling off Pagalu (Equatorial Guinea). *Rep. Int. Whal. Comm.* 35: 385–1386.

Allison, C. (2013a). IWC summary large whale Catch Database Version 5.5. [Available from the IWC Statistics Team]

Allison, C. (2013b). IWC individual Catch Database Version 5.5. [Available from the IWC Statistics Team]

Andrews-Goff, V., Bestley, S., Gales, N.J., Laverick, S.M., Paton, D., Polanowski, A.M., & Double, M.C. (2018). Humpback whale migrations to Antarctic summer foraging grounds through the southwest Pacific Ocean. *Sci. Rep.* 8(1): 1–14. [Available at: *https://doi.org/10.1038/s41598-018-30748-4*]

Andriolo, A., Rocha, J.M.D., Zerbini, A.N., Simões-Lopes, P.C., Moreno, I.B., Lucena, A., Danilewicz, D., & Bassoi, M. (2010). Distribution and relative abundance of large whales in a former whaling ground off eastern South America. *Zoologia* 27(5): 741–750. [Available at: *https://doi.org/10.1590/S1984-46702010000500011*]

Baker, C.S., & Clapham, P.J. (2004). Modelling the past and future of whales and whaling. *TREE* 19(7): 365–371. [Available at: *https://doi.org/10.1016/j.tree.2004.05.005*]

Bergersen, B., Lie, J., & Ruud, J.T. (1939). Pelagic whaling in the Antarctic. VIII. The Season 1937–1938. *Hvalrådets Skrifter* 20.

Besseling, E., Foekema, E.M., Van Franeker, J.A., Leopold, M.F., Kühn, S., Rebolledo, E.B., Heße, E., Mielke, L., Ijzer, J., Kamminga, P., & Koelmans, A.A. (2015). Microplastic in a macro filter feeder: humpback whale *Megaptera novaeangliae*. *Mar. Pollut. Bull.* 95: 248–252. [Available at: *https://doi.org/10.1016/j.marpolbul.2015.04.007*]

Best, P.B. (1987). Estimates of the landed catch of right (and other whalebone) whales in the American fishery, 1805–1909. *Fish. Bull.* 85(3): 403–18.
Best, P.B. (1994). A review of the catch statistics for modern whaling in Southern Africa, 1908–1930. *Rep. Int. Whal. Comm.* 44: 467–485.
Best. P.B., & Ross G.J.B. (1989). Whales and whaling. In*:* A.I.L. Payne, R.J.M. Crawford (eds.), *Oceans of Life off Southern Africa* (pp.215–38). Cape Town: Vlaeberg Publishers.
Bestley, S., Andrews-Goff, V., van Wijk, E., Rintoul, S.R., Double, M.C., & How, J. (2019). New insights into prime Southern Ocean forage grounds for thriving Western Australian humpback whales. *Sci. Rep.* 9(1): 1–12. [Available at: *https://doi.org/10.1038/s41598-019-50497-2*]
Booth, A.R. (1964). American whalers in South African waters*. South African J. Econ.* 32: 278–282.
Branch T.A., & Butterworth D.S. (2001). Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. *J. Cetacean Res. Manage.* 3(3): 251–270. [Available at: *https://doi.org/10.47536/jcrm.v3i3.877*]
Budker, P. (1954). Whaling in French Overseas territories. *Norsk Hvalfangst-Tidende* 41: 320–325.
Burnett, D.G. (2012). *The Sounding of the whale: Science and cetaceans in the 20th Century*. The University of Chicago Press.
Casà, M.V., van Mourik, L.M., Weijs, L., Mueller, J., & Nash, S.B. (2019). First detection of short-chain chlorinated paraffins (SCCPs) in humpback whales (*Megaptera novaeangliae*) foraging in Antarctic waters. *Environ. Pollut.* 250: 953–959. [Available at: *https://doi.org/10.1016/j.envpol.2019.04.103*]
Chernyi, E.I. (2000). Several strokes to an image of the Soviet whaling. In: A.V. Yablokov, V.A. Zemsky (eds.), *Soviet Whaling Data (1949–1979)* (pp.25–30)*.* Centre for Russian Environmental Policy Marine Mammal Council.
Chittleborough, R.G. (1958). The breeding cycle of the female humpback whale, *Megaptera nodosa* (Bonnaterre). *Mar. Freshw. Res.* 9(1): 1–18.
Chittleborough, R.G. (1965). Dynamics of two populations of the humpback whale *Megaptera novaeangliae* (Borowski). *Aust. J. Mar. Freshw. Res.* 16: 33–128.
Clapham, P.J. (1996). The social and reproductive biology of humpback whales: an ecological perspective. *Mamm. Rev.* 26(1): 27–49. [Available at: *https://doi.org/10.1111/j.1365-2907.1996.tb00145.x*]
Clapham, P.J., & Baker, C.S. (2009). Modern whaling. pp. 1239–1242. In: W.F. Perrin, B. Würsig, J.G.M. Thewissen (eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1239–42). Academic Press.
Colwell, M. (1969). *Whaling around Australia*. Rigby: Adelaide.
Das, K., Malarvannan, G., Dirtu, A., Dulau, V., Dumont, M., Lepoint, G., Mongin, P., & Covaci, A. (2017). Linking pollutant exposure of humpback whales breeding in the Indian Ocean to their feeding habits and feeding areas off Antarctica. *Environ. Pollut.* 220: 1090–1099. [Available at: *https://doi.org/10.1016/j.envpol.2016.11.032*]
Dawbin, W.H. (1956). The migrations of humpback whales which pass the New Zealand coast. *Trans. Proc. R. Soc. N. Z.* 84(1): 147–196.
Dawbin, W.H. (1959). Evidence on growth-rates obtained from two marked humpback whales. *Nature* 183(4677): 1749–1750.
Dawbin, W.H. (1964). *Movements of humpback whales marked in the South West Pacific Ocean 1952 to 1962*. University of Sydney.
Dawbin, W.H. (1966). The seasonal migratory cycle of the humpback whale. In: K. Norris (ed.) *Whales, Dolphins and Porpoises* (pp. 145–70). University of California Press.
Deacon, G.E.R. (1955). The discovery investigations in the Southern Ocean. *Eos, Trans. AGU* 36(5): 877–880.
Derville, S., Torres, L.G., Albertson, R., Andrews, O., Baker, C.S., Carzon, P., Constantine, R., Donoghue, M., Dutheil, C., Gannier, A., Oremus, M., Poole, M.M., Robbins, J., & Garrigue, C. (2019). Whales in warming water: Assessing breeding habitat diversity and adaptability in Oceania's changing climate. *Glob. Change Biol.* 25: 1466–1481. [Available at: *https://doi.org/10.1111/gcb.14563*]
Donovan, G.P. (1989). Preface to the Comprehensive Assessment of Whale Stocks. *Rep. Int. Whal. Comm.* Special Issue 11: iii–iiv.
Dunlop, R.A. (2019). The effects of vessel noise on the communication network of humpback whales. *R. Soc Open Sci*. 6: 190967. [Available at: *https://doi.org/10.1098/rsos.190967*]
Dunlop, R.A., McCauley, R.D., & Noad, M.J. (2020). Ships and air guns reduce social interactions in humpback whales at greater ranges than other behavioral impacts. *Mar. Pollut. Bull.* 154: 111072. [Available at: *https://doi.org/10.1016/j.marpolbul.2020.111072*]
Emslie, S.D., & Patterson, W.P. (2007). Abrupt recent shift in $\delta^{13}C$ and $\delta^{15}N$ values in Adélie penguin eggshell in Antarctica. *Proc. Natl. Acad. Sci. U.S.A*. 104(28): 11666–11669.
Félix, F., & Guzmán, H.M. (2014). Satellite tracking and sighting data analyses of Southeast Pacific humpback whales (*Megaptera novaeangliae*): Is the migratory route coastal or oceanic? *Aquat. Mamm*. 40(4): 329–340. [Available at: *https://doi.org/10.1578/AM.40.4.2014.329*]
Félix, F., Abras, D.R., Cheeseman, T., Haase, B., Santos, J.D.A.F., Marcondes, M.C.C., Southerland, K., & Acevedo, J. (2020). A new case of interoceanic movement of a humpback whale in the Southern Hemisphere: the El Niño link. *Aquat. Mamm.* 46: 578–584. [Available at: *https://doi.org/10.1578/AM.46.6.2020.578*]
Findlay, K.P. (2001). A review of humpback whale catches by modern whaling operations in the Southern Hemisphere. *Mem. Queensl. Mus.* 47(2): 411–20.
Findlay, K.P., Best, P.B., & Meÿer, M.A. (2011). Migrations of humpback whales past Cape Vidal, South Africa, and an estimate of the population increase rate (1988–2002). *Afr. J. Mar. Sci.* 33(3): 375–392. [Available at: *https://doi.org/10.2989/1814232X.2011.637345*]
Findlay, K., Seakamela, M., Meÿer, M., Kirkman, S., Barendse, J., Cade, D., Hurwitz, D., Kennedy, A., Kotze, P.G.H., McCue, S., Thornton, M., Vargas Fonseca, O., & Wilke, C. (2017). Humpback whale 'super-groups': A novel low-latitude feeding behaviour of Southern Hemisphere humpback whales (*Megaptera novaeangliae*) in the Benguela Upwelling System. *PLoS One* 12(3): e0172002. [Available at: *https://doi.org/10.1371/journal.pone.0172002*]
Fleming, A., & Jackson, J. (2011). Global Review of Humpback Whales (*Megaptera novaeangliae*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, NOAA-TM-NMFS-SWFSC-474.

Fossette, S., Heide-Jørgensen, M.P., Jensen, M.V., Kiszka, J., Bérubé, M., Bertrand, N., & Vély, M. (2014). Humpback whale (*Megaptera novaeangliae*) post breeding dispersal and southward migration in the western Indian Ocean. *J. Exp. Mar. Bio. Ecol.* 450: 6–14. [Available at: *https://doi.org/10.1016/j.jembe.2013.10.014*]

Franklin, T., Franklin, W., Brooks, L., Gibbs, N., Childerhouse, S., Smith, F., Burns, D., Paton, D., Garrigue, C., Constantine, R., Poole, M., Hauser, N., Donoghue, M., Russell, K., Mattila, D.K., Robbins, J., Ostermann, A., Leaper, R., Baker, S., & Clapham, P. (2008). Migratory movements of humpback whales (*Megaptera novaeangliae*) between eastern Australia and the Balleny Islands, Antarctica, confirmed by photo-identification. SC/60/SH2 presented to the IWC Scientific Committee, Santiago, Chile, 2008. [Available from the IWC Publications Team]

Gill, P.C., & Burton, C.L.K. (1995). Photographic resight of a humpback whale between Western Australia and Antarctic Area IV. *Mar. Mamm. Sci.* 11: 96–100.

Golovlev, I.F. (2000). Mysteries of whales. In: A.V. Yablokov, V.A. Zemsky (eds.), *Materials of the soviet whaling industry (1947–1979)* (pp.11–24). Center for Environmental Policy of Russia. Marine Mammal Council.

Grady, D. (1982). *The Perano whalers of Cook Strait 1911–1964*. Reed, Wellington, NZ.

Groom, C.J., & Coughran, D.K. (2012). Entanglements of baleen whales off the coast of Western Australia between 1982 and 2010: patterns of occurrence, outcomes and management responses. *Pac. Conserv. Biol.* 18: 203. [Available at: *https://doi.org/10.1071/PC130203*]

Hart, I.B. (2006). *Whaling in the Falkland Islands Dependencies 1904-1931: A history of shore and bay-based whaling in the Antarctic*. Pequena.

Hart, I., & Edmundson, E. (2017). *A History of Whaling in Brazil: From royal fish to Japanese delicacy*. Pequena.

Hinton, M.A.C. (1915). Report on the papers left by the late Major Barrett-Hamilton, relating to the whales of South Georgia. Inter-departmental committee on whaling and the protection of whales. Crown Agents for the Colonies, London.

Hjort, J., Lie, J., & Ruud, J. (1932). Norwegian pelagic whaling in the Antarctic I: whaling grounds in 1929–1930 and 1930–1931. *Hvalrådets Skrifter* 3: 1–37.

Hjort, J., Lie, J., & Ruud, J. (1933a). Norwegian pelagic whaling in the Antarctic II. *Hvalrådets Skrifter* 7: 128–52.

Hjort, J., Lie, J., & Ruud, J. (1933b). Norwegian pelagic whaling in the Antarctic III. *Hvalrådets Skrifter* 8: 1–36.

Hjort, J., Lie, J., & Ruud, J. (1934). Norwegian pelagic whaling in the Antarctic IV: 1933–1934. *Hvalrådets Skrifter* 9: 1–59.

Hjort, J., Lie, J., & Ruud, J. (1935). Pelagic whaling in the Antarctic V: 1934–35, *Hvalrådets Skrifter* 12: 1–52.

Hjort, J., Lie, J., & Ruud, J. (1937). Pelagic whaling in the Antarctic VI: 1935–1936, *Hvalrådets Skrifter* 14: 1–45.

Hjort, J., Lie, J., & Ruud, J. (1938). Pelagic whaling in the Antarctic VII: 1936–1937, *Hvalrådets Skrifter* 18: 1–44.

Hoffman, J.I., Chen, R.S., Vendrami, D.L., Paijmans, A.J., Dasmahapatra, K.K., & Forcada, J. (2022). Demographic reconstruction of Antarctic fur seals supports the krill surplus hypothesis. *Genes* 13(3): 541. [Available at *https://doi.org/10.3390/genes13030541*]

Holt, S.J. (2001). Sharing the catches of whales in the Southern Hemisphere. *FAO Fisheries Technical Paper*, 322–371.

International Whaling Commission (1998). Report of the Scientific Committee. *Rep. Int. Whal. Comm.* 48: 53–118.

International Whaling Commission (1963). Schedule to the International Whaling Convention, 1946, revised to include the amendments that came into operation after the 15th meeting in London 1963.

International Whaling Commission (1989). Report of the Scientific Committee. *Rep. Int. Whal. Comm.* 39: 33–157.

International Whaling Commission (1998). Report of the Scientific Committee. *Rep. Int. Whal. Comm.* 48: 53–118.

International Whaling Commission (2007). Report of the Scientific Committee. Annex H: Report of the sub-committee on other Southern Hemisphere Whale Stocks. *J. Cetacean Res. Manage.* Suppl. 9: 188–209.

International Whaling Commission (2011). Report of the Scientific Committee. *J. Cetacean Res. Manage.* Suppl. 12: 1–75.

International Whaling Commission (2016). Report of the Scientific Committee. Annex H: Report of the Sub-Committee on Other Southern Hemisphere Whale Stocks. *J. Cetacean Res. Manage.* Suppl. 17: 250–282.

Jackson, J. A., Ross-Gillespie, A., Butterworth, D., Findlay, K., Holloway, S., Robbins, J., Rosenbaum, H., Weinrich, M., Baker, C.S., & Zerbini, A.N. (2015). Southern Hemisphere humpback whale Comprehensive Assessment: A synthesis and summary: 2005–2015. SC/66A/SH3 presented to the IWC Scientific Committee, San Diego, USA, 2015. [Available from the IWC Publications Team]

Johnson, C.M., Reisinger, R.R., Palacios, D.M., Friedlaender, A.S., Zerbini, A.N., Willson, A., Lancaster, M., Battle, J., Graham, A., Cosandey-Godin, A., Jacob, T., Felix, F., Grilly, E., Shahid, U., Houtman, N., Alberini, A., Montecinos, Y., Najera, E., & Kelez, S. (2022). Protecting Blue Corridors: Challenges and solutions for migratory whales navigating national and international seas. Zenodo. [Available at *https://doi.org/10.5281/zenodo.6196131*]

Kaufman, G.D., Osmond M.G., Ward A.J., & Forestell P.H. (1990). Photographic documentation of the migratory movement of humpback whale (*Megaptera novaeangliae*) between east Australia and Antarctic Area V. *Rep. Int. Whal. Comm.* Special Issue 12: 265–267.

Kellogg, R. (1929). What is known of the migrations of some of the whalebone whales? Reports of the Smithsonian Institution 1928: 467–494.

Kershaw, F., Carvalho, I., Loo, J., Pomilla, C., Best, P. B., Findlay, K. P., Cerchio, S., Collins, T., Elgen, M.H., Minton, G., Ersts, P., Barendse, J., Kotze, P.G.H., Razafindrakoto, Y., Ngouessono, S., Meyer, M., Thorton, M., & Rosenbaum, H.C. (2017). Multiple processes drive genetic structure of humpback whale (*Megaptera novaeangliae*) populations across spatial scales. *Mol. Ecol.* 26(4): 977–994.

Laws, R.M. (1977). Seals and Whales of the Southern Ocean. *Philos. Trans. R. Soc. B. Biol. Sci*. 279(963): 81–96.

Mackintosh, N.A. (1942). The southern stocks of whalebone whales. *Discovery Reports* 22: 197–300.

Mackintosh, N.A. (1965). *The Stocks of Whales*. Fishing News.

Mackintosh, N.A., & Wheeler, J.F.G. (1929). Southern blue and fin whales. *Discovery Reports* 1: 257–540.

Marcondes, M.C.C., Cheeseman, T., Jackson, J.A., Friedlaender, A.S., Pallin, L., Olio, M., Wedekin, L.L., Daura Jorge, F.G., Cardoso, J., Santos, J.D.F., Fortes, R.C., Araújo, M.F., Bassoi, M., Beaver, V., Bombosch, A., Clark, C.W., Denkinger, J., Boyle, A., Rasmussen, K., Savenko, O., Avila, I. C., Palacios, D.M., Kennedy, A.S., & Sousa Lima, R.S. (2021). The Southern Ocean Exchange: porous boundaries between humpback whale breeding populations in southern polar waters. *Sci. Rep*. 11: 1–12. [Available at: *https://doi.org/10.1038/s41598-021-02612-5*]

Matthews, L.H. (1938). The humpback whale, *Megaptera nodosa*. *Discovery Reports* 7: 239–252.
Maury, M.F. (1852). Whale chart of the world (the wind and current charts), Series F. National Observatory, Bureau of Ordnance and Hydrography 11.
Meynecke, J.O., Seyboth, E., De Bie, J., Menzel Barraqueta, J.L., Chama, A., Prakash Dey, S., Lee, S.B., Tulloch, V., Vichi, M., Findlay, K., Roychoudhury, A.N., & Mackey, B. (2020). Responses of humpback whales to a changing climate in the Southern Hemisphere: Priorities for research efforts. *Mar. Ecol.* 41: e12616. [Available at: *https://doi.org/10.1111/maec.12616*]
Meynecke, J. O., De Bie, J., Barraqueta, J. L. M., Seyboth, E., Dey, S. P., Lee, S. B., Samanta, S., Vichi, M., Findlay, K., Roychoudhury, A., & Mackey, B. (2021). The role of environmental drivers in humpback whale distribution, movement and behavior: A review. *Front. Mar. Sci.* 8: 720774. [Available at: *https://doi.org/10.3389/fmars.2021.720774*]
Minton, G., Collins, T., Findlay, K., & Baldwin, R. (2010). Cetacean distribution in the coastal waters of the Sultanate of Oman. *J. Cetacean Res. Manage.* 11*:* 301–313. [Available at: *https://doi.org/10.47536/jcrm.v11i3.610*]
Morais, I.O.B., Danilewicz, D., Zerbini, A.N., Edmundson, W., Hart, I.B., & Bortolotto, G.A. (2017). From the southern right whale hunting decline to the humpback whaling expansion: A review of whale catch records in the tropical western South Atlantic Ocean. *Mamm. Rev.* 47(1): 11–23. [Available at: *https://doi.org/10.1111/mam.12073*]
Mörch, J.A. (1911). On the natural history of whalebone whales. *Proc. Zool. Soc. Lond.* 81(3): 661–676. [Available at: *https://doi.org/10.1111/j.1096-3642.1911.tb01952.x*]
Mori, M., & Butterworth, D.S. (2004). Consideration of multispecies interactions in the Antarctic: a preliminary model of the minke whale–blue whale–krill interaction. *Afr. J. Mar. Sci.* 26: 245–259. [Available at: *https://doi.org/10.2989/18142320409504060*]
Mori, M., & Butterworth, D.S. (2006). A first step towards modelling the krill–predator dynamics of the Antarctic ecosystem. *CCAMLR Science* 13: 217–277.
Nemoto, T., Best, P.B., Ishimaru, K., & Takano, H. (1980). Diatom films on whales in South African waters. *Sci. Rep. Whal. Res. Inst. Tokyo* 32: 97–103.
Nicol, S., Bowie, A., Jarman, S.N., Lannuzel, D., Meiners, K.M., & Van Der Merwe, P. (2010). Southern Ocean iron fertilization by baleen whales and Antarctic krill. *Fish Fish.* 11: 203–209. [Available at: *https://doi.org/10.1111/j.1467-2979.2010.00356.x*]
Olsen, Ø. (1915). *Hvaler og hvalfangst i Sydafrika*. Bergens Museum. Arbok 1914–1915. 7: 1–56.
Ommaney, F.D. (1933). Whaling in the Dominion of New Zealand. *Discovery Reports* 7: 239–252.
Omura, H. (1973). A review of pelagic whaling operations in the Antarctic based on the effort and catch data in 10° squares of latitude and longitude. *Sci. Rep. Whal. Res. Inst. Tokyo* 25: 105–203.
Ott, P.H., Milmann, L., Santos, M.D.O., Rogers, E.M., Rodrigues, D.D.P., & Siciliano, S. (2016). Humpback whale breeding stock 'A': increasing threats to a recently down-listed species off Brazilian fauna. SC/66b/SH/04 presented to the IWC Scientific Committee, Bled, Slovenia, 2016. [Available from the IWC Publications Team]
Pastene, L.A., & Quiroz, D. (2010). An outline of the history of whaling in Chile. In: *Human Culture from the Perspective of Traditional Maritime Communities* (pp.73–98).
R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
Ramos, E.A., Cheeseman, T., Marcondes, M.C.C., Olio, M., Vogel, A., Elwen, S., Melo, T.H.M., Facchola, C., Cipolotti, S., Southerland, K., Findlay, K., Seyboth, E., McCue, S.A., Kotze, P.G.H., & Seakamela, S.M. (2023). Interchange of southern hemisphere humpback whales across the South Atlantic Ocean. *Sci. Rep.* 13(1): 4621. [Available at: *https://doi.org/10.1038/s41598-023-31358-5*]
Rasmussen, K., Palacios, D., Calambokidis, J., Saborío, M., Dalla Rosa, L., Secchi, E., Steiger, G., Allen, J., & Stone, G. (2007). Southern hemisphere Humpback whales wintering off Central America: insights from water temperature into the longest mammalian migration. *Biol. Lett.* 3: 302–305. [Available at: *https://doi.org/10.1098/rsbl.2007.0067*]
Ratnarajah, L., Nicol, S., & Bowie, A.R. (2018). Pelagic iron recycling in the Southern Ocean: exploring the contribution of marine animals. *Front. Mar. Sci.* 5: 109. [Available at: *https://doi.org/10.3389/fmars.2018.00109*]
Rayner, G.W. (1940). Whale marking: progress and results to December 1939. *Discovery Reports* 19: 245–284.
Reisinger, R.R., Friedlaender, A., Zerbini, A., Palacios, D.M., Andrews-Goff, V., Dalla Rosa, L., Double, M., Findlay, K., Garrigue, C., How, J., Jenner, C., Mate, B., Rosenbaum, H.C., Seakamela, S.M., & Constantine, R. (2021). Combining Regional Habitat Selection Models for Large-Scale Prediction: Circumpolar Habitat Selection of Southern Ocean Humpback Whales. *J. Remote Sens.* 13: 2074. [Available at *https://doi.org/10.3390/rs13112074*]
Remili, A., Gallego, P., Pinzone, M., Castro, C., Jauniaux, T., Garigliany, M.M., Malarvannan, G., Covaci, A., & Das, K. (2020). Humpback whales (*Megaptera novaeangliae*) breeding off Mozambique and Ecuador show geographic variation of persistent organic pollutants and isotopic niches. *Environ. Pollut.* 267: 115575. [Available at: *https://doi.org/10.1016/j.envpol.2020.115575*]
Richards, R., & Du Pasquier, T. (1989). Bay whaling off southern Africa, c. 1785–1805. *S. Afr. J. Mar. Sci.* 8: 231–250. [Available at *https://doi.org/10.2989/02577618909504564*]
Risting, S. (1929). De flytende kokerier. 25 aar. Norsk Hvalfangst-tidende (pp.202–213).
Rocha, R.C., Clapham, P.J., & Ivashchenko, Y.V. (2015). Emptying the oceans: A summary of industrial whaling catches in the 20th century. *Mar. Fish. Rev.* 76(4): 37–48. [Available at *https://doi.org/dx.doi.org/10.7755/MFR.76.4.3*]
Rock, J., Pastene, L.A., Kaufman, G., Forestell, P., Matsuoka, K., & Allen, J. (2006). A note on East Australia Group V Stock humpback whale movement between feeding and breeding areas based on photo-identification. *J. Cetacean Res. Manage.* 8(3): 301–305. [Available at: *https://doi.org/10.47536/jcrm.v8i3.727*]
Roman, J., Estes, J.A., Morissette, L., Smith, C., Costa, D., McCarthy, J., Nation, J.B., Nicol, S., Pershing, A., & Smetacek, V. (2014). Whales as marine ecosystem engineers. *Front. Ecol. Environ*. 12(7): 377–85. [Available at: *https://doi.org/10.1890/130220*]
Rosenbaum, H.C., Maxwell, S.M., Kershaw, F., & Mate, B. (2014). Long-range movement of humpback whales and their overlap with anthropogenic activity in the South Atlantic Ocean. *Conserv. Biol.* 28(2): 604–615. [Available at: *https://doi.org/10.1111/cobi.12225*]
Rossi-Santos, M.R. (2015). Oil industry and noise pollution in the humpback whale (*Megaptera novaeangliae*) soundscape ecology of the southwestern Atlantic breeding ground. *J. Coast. Res.* 31: 184–195. [Available at: *https://doi.org/10.13140/2.1.2620.2249*]

RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA.

Santora, J. A., Mantua, N.J., Schroeder, I.D., Field, J.C., Hazen, E.L., Bograd, S.J., Sydeman, W.J., Wells, B.K., Calambokidis, J., Saez, L., Lawson, D., & Forney, K.A. (2020). Habitat compression and ecosystem shifts as potential links between marine heatwave and record whale entanglements. *Nat. Commn.* 11: 536. [Available at: *https://doi.org/10.1038/s41467-019-14215-w*]

Seyboth, E., Félix, F., Lea, M.A., Dalla Rosa, L., Watters, G.M., Reid, K., & Secchi, E. (2021). Influence of krill (*Euphausia superba*) availability on humpback whale (*Megaptera novaeangliae*) reproductive rate. *Mar. Mammal Sci.* 37: 1498–1506. [Available at: *https://doi.org/10.1111/mms.12805*]

Seyboth, E., Meynecke, J-O., de Bie, J., Roychoudhury, A., & Findlay, K. (2023). A review of post-whaling abundance, trends, changes in distribution and migration patterns, and supplementary feeding of Southern Hemisphere humpback whales. *Front. Mar. Sci* 10: 997491. [Available at: *https://doi.org/10.3389/fmars.2023.997491*]

Smetacek, V. (2008). Are declining Antarctic krill stocks a result of global warming or of the decimation of the whales? In: C.M. Duarte (ed.), *Impacts of Global Warming on Polar Ecosystems* (pp.46–83). Fundación BBVA.

Smetacek, V., & Nicol, S. (2005). Polar ocean ecosystems in a changing world. *Nature* 437(7057): 362–368. [Available at: *https://doi.org/10.1038/nature04161*]

Smith, J.N., Kelly, N., Childerhouse, S., Redfern, J.V., Moore, T.J., & Peel, D. (2020). Quantifying ship strike risk to breeding whales in a multiple-use marine park: the great barrier reef. *Front. Mar. Sci.* 7: 61. [Available at: *https://doi.org/10.3389/fmars.2020.00067*]

Smith, T.D., Josephson, E., & Reeves, R.R. (2006). 19th Century Southern Hemisphere humpback whale catches. SC/A06/HW53 presented to the IWC Workshop on Comprehensive Assessment of Southern Hemisphere Humpback Whales, Hobart, Australia, 2006. [Available from the IWC Publications Team]

Smith, T.D., Reeves, R.R., Josephson, E.A., & Lund, J.N. (2012). Spatial and Seasonal Distribution of American Whaling and Whales in the Age of Sail. *PLoS One* 7(4): e34905. [Available at *https://doi.org/10.1371/journal.pone.0034905*]

Stone G.S., Flórez-González, L., & Katona S. (1990). Whale migration record. *Nature* 346: 705.

Surma, S., Pakhomov, E.A., & Pitcher, T.J. (2014). Effects of whaling on the structure of the Southern Ocean food web: insights on the 'Krill Surplus' from Ecosystem Modelling. *PLoS One* 9(12): e114978. [Available at: *https://doi.org/10.1371/journal.pone.0114978*]

Tønnesen, J.N., & Johnsen, A.O. (1982). *The History of Modern Whaling*. University of California Press.

Tormosov, D.D., Mikhalev, Y., Best, P., Zemsky, V., Sekiguchi, K., & Brownell, R. (1998). Soviet catches of southern right whales *Eubalaena australis*, 1951–1971: Biological data and conservation implications. *Biol. Conserv*. 86: 185–197. [Available at: *https://doi.org/10.1016/S0006-3207(98)00008-1*]

Townsend, C.H. (1935). The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica* 19(1): 1–50.

Tulloch, V.J., Plagányi, É.E., Brown, C., Richardson, A. J., & Matear, R. (2019). Future recovery of baleen whales is imperiled by climate change. *Glob. Change Biol*. 25: 1263–1281. [Available at: *https://doi.org/10.1111/gcb.14573*]

Valsecchi, E., Palsboll, P., Hale, P., Glockner-Ferrari, D., Ferrari, M., Clapham, P., Larsen F., Mattila, D., Sears, R., Sigurjonsson, J., Brown, M., Corkeron, P., & Amos, B. (1997). Microsatellite genetic distances between oceanic populations of the humpback whale (*Megaptera novaeangliae*). *Mol. Biol. Evol.* 14: 355–362.

Van Pel, H. (1959). Report on the fisheries of Norfolk Island. South Pacific Commission.

Van Waerebeek, K., Alfaro-Shigueto, J., & Arias-Schreiber, M. (1996). Humpback whales off Peru: New records and a rationale for renewed research. SC/48/SH/01 presented to the IWC Scientific Committee, Aberdeen, UK, 1996. [Available from the IWC Publications Team]

Van Waerebeek, K., Baker, A.N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G.P., Secchi, E., Sutaria, D., van Helden, A., & Wang, Y. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Lat. Am. J. Aquat. Mamm.* 6(1): 43–69. [Available at: *https://doi.org/10.5597/lajam00109*]

van Weelden, C., Towers, J.R., & Bosker, T. (2021). Impacts of climate change on cetacean distribution, habitat and migration. *Clim. Change Ecol*. 1: 100009. [Available at: *https://doi.org/10.1016/j.ecochg.2021.100009*]

Vighi, M., Borrell, A., Jackson, J.A., Carroll, E.L., Pennino, M.G., & Aguilar, A. (2020). The missing whales: relevance of 'struck and lost' rates for the impact assessment of historical whaling in the southwestern Atlantic Ocean. *ICES J. Mar. Sci.* 78 (1): 14–24. [Available at: *https://doi.org/10.1093/icesjms/fsaa205*]

Williamson, G.R. (1975). Minke whales off Brazil. *Sec. Rep. Whal. Res. Inst*. 27: 37–59.

Wray, P., & Martin, K.R. (1983). Historical whaling records from the western Indian Ocean. *Rep. Int. Whal. Comm.* Special Issue 5: 212–241.

Yablokov, A.V., & Zemsky, V.A. (2000). *Soviet whaling data (1949–1979)*. Center for Russian Environmental Policy Marine Mammal Council, Moscow, Russia.

Zemsky, V.A., Berzin, A.A., Mikhalyev, Yu. A., & Tormosov, D.D. (1995). *Soviet Antarctic Whaling Data (1947–1972)*. Center for Russian Environmental Policy, Moscow, Russia.

Zemsky, V.A. (2000). Extermination of populations of commercial whale species. In: A.V. Yablokov, V.A. Zemsky (eds.), *Soviet Whaling Data (1949–1979)* (pp.249–259). Centre for Russian Environmental Policy Marine Mammal Council, Moscow, Russia.

Zerbini, A., Andriolo, A., Heide-Jørgensen, M.P., Pizzorno, J., Geyer, Y., VanBlaricom, G., DeMaster, D., Simões-Lopes, P., Moreira, S., & Bethlem, C. (2006). Satellite-monitored movements of humpback whales in the Southwest Atlantic Ocean. *Mar. Ecol. Prog. Ser*. 313: 295–304. [Available at *https://doi.org/10.3354/meps313295*]

Zerbini, A.N., Adams, G., Best, J., Clapham, P.J., Jackson, J.A., & Punt, A.E. (2019). Assessing the recovery of an Antarctic predator from historical exploitation. *R. Soc. Open Sci.* 6(10): 190368. [Available at *https://doi.org/10.1098/rsos.190368*]

Supplementary Material

Table S1

Location of Scotia Arc and Southern Ocean land stations, moored floating factories and associated offshore operations listing years in operation. Years represent the first year of the summer season (e.g., 1904/05 season is denoted by 1904).

Area / Place	Latitude	Longitude	Years of operation
Deception Island, South Shetland	–62.09	–58.49	1906–1914–1928; 1929–1930
Falkland Islands	–51.83	–59.37	1907; 1908–1914
Godthul, South Georgia	–54.3	–36.28	1908–1929
Grytviken, South Georgia	–54.28	–36.51	1904–1962; 1963–1965
Husvik Harbour, South Georgia	–54.18	–36.71	1907; 1911–1932; 1945–1960;
South Sandwich	–59.06	–26.51	1911–1912; 1927–1928
Leith Harbour, South Georgia	–54.14	–36.69	1909–1920; 1921–1960
New Fortuna Bay, South Georgia	–54.44	–36.19	1909–930
Prince Olav Harbour, South Georgia	–54.06	–37.15	1916; 1919–1930
Stromnes Harbour, South Georgia	–54.15	–36.71	1907–1912; 1913–1919; 1920–1930
Off South Georgia	–33.5	–35	1910; 1911; 1912–1914; 1922
Off South Orkneys	–61.5	–45	1911–1914; 1920;
Off South Shetlands	–61.7	–58.60	1908–1931
Kerguelen Archipelago	–49.34	70.2	1908 –1909; 1910

Table S2

Location of Southern Hemisphere South American land stations, moored floating factories and offshore operations by location listing years in operation. Offshore operations include those carried out by vessels listed in Table S6 after 1928.

Type	Location	Latitude	Longitude	Years of operation
Land	San Pedro	–43.35	–73.73	1909–1912
Land	Costinha, Brazil	–6.5	–33	1910–1914; 1924–1985
Land	Bahia, Brazil	–13	–38.62	1911–1911; 1912–1913; 1914–1915; 1919
Land	Paraiba, Brazil	–7	–34.85	1914
Land	S. Maria Island	–37.04	–73.5	1932–1949
Land	Talcahuano / San Vincent	–36.72	–73.11	1935; 1950–1963; 1964–1969; 1970–1983
Land	Valparaiso	–33	–71.60	1939
Land	Quintay, Chile	–33.19	–71.7	1944–1958; 1960–1961; 1964–1967
Land	Imbituba, Santa Catarina, Brazil	–28	–48.51	1948–1957
Land	Pisco, Chile	–13.73	–76.22	1951–1963
Land	Chancay, Chile	–11.57	–77.27	1954–1956; 1958–1963
Land	Bajo Molle, Iquique, Chile	–20.29	–70.13	1956–1965
Land	Paita, Chile	–5.08	–81.11	1957–1983
Land	Cabo Frio, Brazil	–22.89	–42.03	1960–1963
Offshore	Magallanes, Chile	–41.48	–72.96	1903; 1905; 1909–1912; 1934–1935
Offshore	Combined stations off Chile	–41	–78	1907–1935; 1938–1939;
Offshore	Off Brazil	–18	–39	1912–1913; 1914
Offshore	Off South American West Coast	–26	–78	1914–1915; 1926–1928; 1951–1951; 1954–1954
Offshore	Off Peru	–12	–80	1925–1927; 1936–1937; 1938–1939; 1941–1943; 1947; 1948–1949; 1951

Table S3

Location of Southern Hemisphere African land stations, moored floating factories, and offshore operations by location listing years in operation. Offshore operations include those carried out by vessels listed in Table S6 after 1928. WIO = western Indian Ocean.

Type	Location	Latitude	Longitude	Years of operation
Land	The Bluff, Durban, South Africa	–29.89	31.04	1908–1975
Land	Donkergat, South Africa	–33.08	18	1909–1912; 1916–1920; 1922–1930; 1936–1937; 1947–953
Land	Porto Alexandre, Angola	–15.8	11.85	1909–1915
Land	Mossamedes, Angola	–15.19	12.13	1910–1916; 1926–1928
Land	Lobito Bay, Angola	–12.34	13.58	1911
Land	Angoche, Mozambique	–16.23	39.9	1911–1912
Land	Mossel Bay, South Africa	–34.18	22.15	1911–1913
Land	Salamander Bay, South Africa	–33.07	17.99	1911–1913; 1915–1920; 1922–1930
Land	Linga Linga, Mozambique	–23.74	35.4	1911–1915; 1923
Land	Elephant Bay, Angola	–12.23	12.74	1911–1916; 1924–1925
Land	Park Rynie, Durban, South Africa	–30.32	30.74	1911–1921
Land	Quelimane, Mozambique	–18.02	37	1912
Land	Delagoa Bay, Inhaca Island	–26.02	32.95	1912–1913
Land	Cape Lopez, Gabon	–0.72	8.78	1912–1914; 1922–1926; 1930; 1934; 1949–1951; 1959
Land	Walvis Bay, Namibia	–22.95	14.5	1912–1914; 1923–1930
Land	Libreville	–0.5	9.33	1913–1914
Land	Luderitz Bay, Namibia	–26.63	15.11	1913–1914
Land	Cape Hangklip, South Africa	–34.37	18.89	1913–1914; 1916–1920; 1926–1930
Land	Plettenberg Bay, South Africa	–34.05	23.4	1913–916
Land	Bioko (Fernando Po), Equatorial Guinea	–3.46	8.46	1914
Land	Seychelles	–4.7	55.42	1914–1918
Land	Sao Tomé	–0.33	6.73	1951
Offshore	Bazaruto Is, Mozambique	–21.63	35.46	1910
Offshore	Off Angola	–12	10	1910; 1923–1925; 1935–1937
Offshore	Off Namibia	–24	11	1912
Offshore	Mozambique Channel and Madagascar	–26	45.70	1912
Offshore	Off Gabon	–1.30	7	1914; 1935–1936
Offshore	WIO	–28	45	1937–1939; 1949–1950

Table S4

Location of Southern Hemisphere Australian and New Zealander land stations, moored floating factories and offshore operations by location listing years in operation. Offshore operations include those carried out by vessels listed in Table S6 after 1928.

Type	Location	Latitude	Longitude	Years of operation
Land	Whangamumu; Bay of Islands, New Zealand	–35.2	174.28	1890–1910 (net); 1910–1931
Land	Campbell Island, New Zealand	–52.53	169.12	1909
Land	Tory Channel; Cook Strait, New Zealand	–41.28	174	1909–1963
Land	Point Cloates, Western Australia	–22.72	113.68	1912, 1913–1916; 1922–1923; 1925–1928; 1949–1955
Land	Albany, Western Australia	–34.88	118.4	1914–1916; 1947–1948; 1952–1978
Land	Kaikoura, New Zealand	–42.41	173.7	1917–1922
Land	Norfolk Island, Australia	–29.05	167.98	1949–1950; 1956–1962
Land	Carnarvon, Western Australia	–24.89	113.66	1950–1963
Land	Tangalooma, Queensland, Australia	–27.18	153.37	1952–1962
Land	Byron Bay, NSW, Australia	–28.64	153.61	1954–1962
Land	Whangaparapara, Great Barrier Island, New Zealand	–36.27	175.5	1956–1957; 1959–1962
Offshore	Jervis Bay, NSW, Australia	–43.22	150.69	1912–1913
Offshore	Off New Zealand	–47.5	175	1912; 1933
Offshore	Off West Australia	–28	112	19121914; 1936–1938
Offshore	Off South Australia	–35.5	135	1936–1937
Offshore	Tonga	–21.13	175.22	1957–1961; 1973–1978

Table S5

Pelagic whaling company and vessels that operated in the Ross Sea, between 1923 and 1930.

Company	Vessel	Years of operation
A/S Rosshavet	*Sir James Clark Ross*	1923–1929
A/S Rosshavet	*C.A. Largen*	1926–1930
A/S Kosmos	*Kosmos*	1929
A/S Polaris	*N.T. Nielsen-Alonso*	1926–1929
Southern Whaling and Sealing	*Southern Princess*	1929

Table S6

Pelagic high and low-latitude whaling operations between 1925 and 1974.

Company	Vessel	Years of operation
Africa A/S	*Ready*	1930
Africa A/S	*Strombus*	1934
American Whaling Company	*Frango*	1930
Anglo Norse Company Ltd.	*Anglo-Norse*	1929/30
Atlas A/S	*Solglimt*	1929/30
Antarctic A/S	*Antarctic*	1945–1951
Blåhval A/S	*C.A. Larsen*	1936–1938
British Ministry	*Empire Venture*	1945
British Ministry	*Empire Victory*	1945
Bryde and Dahls Hvalfangerselskab	*Thor I*	1929/30
Bryde and Dahls Hvalfangerselskab	*Thorshammer*	1928–1930, 1932, 1935–1940, 1943–1961
Chr. Salvesen and Company	*Southern Venturer*	1959
Congo A/S	*Congo*	1929/30
Erste Deutsche Walfang GmbH	*Jan Wellem*	1936–1938
Falkland Whaling Company	*Polar Chief*	1929/30, 1936
Frango A/S	*Frango*	1928/29
Franterniaskompanie	*Fraternitas*	1930, 1936
Globus A/S	*Lancing*	1925–1930, 1932, 1934–1939
Hektor Whaling Ltd	*Hektoria*	1932–1939
Hektor A/S	*Ronald*	1928–1930
Hektor A/S	*Maudie*	1929/30
Jurgens vd Bergh Marg	*Unitas*	1937/38
Kerguelen Whaling and Sealing Co (I&J)	*Tafelberg*	1932–1939
Kerguelen Whaling and Sealing Co (I&J)	*Radioleine*	1929/30
Kosmos A/S	*Kosmos*	1930, 1932, 1934–1936, 1938/39
Kosmos A/S	*Kosmos II*	1932–1939
Kosmos A/S	*Kosmos III*	1947–1951, 1953, 1955–1960
Kosmos A/S	*Kosmos IV*	1946–1953, 1955–1963, 1967
Kyokuyo Hogei Co	*Baikal Maru*	1951
Kyokuyo Hogei Co	*Kyokuyo Maru II*	1956–1961, 1968
Laboremus A/S	*Roald Amundsen*	1928–1930
Mexico A/S	*Esperanza*	1929/30
Nederlandsche Maatschappij voor de Valvischavaart NV	*Willem Barendsz*	1946–1954, 1955, 1957–1960
Nippon Hogei	*Antarctic Maru*	1934
Nippon Suisan K. K.	*Tonan Maru*	1935–1938, 1951–1956, 1958–1961
Nippon Suisan K. K.	*Tonan Maru II*	1937/38, 1957–1961, 1968/69, 1971/72
Nippon Suisan K. K.	*Tonan Maru III*	1938
Nippon Suisan K. K.	*Hashidate Maru*	1946–1950
Norge A/S	*Solstreif*	1927–1930
Norsk Hvalprodukter A/S	*Maudie*	1935
Norsk Hvalprodukter A/S	*Sydis*	1934, 1936
Odd A/S	*Solglimt*	1932–1939
Odd A/S	*Thorshovdi*	1948–1951, 1953–1960
Oelmuhlen-Walfang-K	*Wikinger*	1938
Oelmuhlen-Walfang-K	*Südmeer*	1937/38
Pelagos A/S	*Pelagos*	1933–1940, 1945–1961
Pioner A/S	*Pioner*	1934/35
Polaris A/S	*N.T. Nielsen-Alonso*	1930, 1933, 1935–1939
Polhavet A/S	*Sevilla*	1930
Pontos A/S	*Pontos*	1929/30
Polaris A/S & Globus A/S	*Norhval*	1945–1953, 1956

Company	Vessel	Years of operation
Rosshavet A/S	*Sir James Clark Ross*	1930, 1932/33, 1935–1939, 1944–1954, 1956–1958, 1960
Sevilla	*Sevilla*	1929
Sevilla A/S	*Strombus*	1936
Sevilla Whaling Company	*Southern Venturer*	1945–1961
Sevilla A/S	*New Sevilla*	1930
Sevilla Whaling Company	*New Sevilla*	1932–1939
Skytteren A/S	*Skytteren*	1929/30, 1932–1938
South Georgia Company Ltd	*Salvestria*	1929–1939
South Georgia Company Ltd	*Sourabaya*	1929–1939
South Georgia Company Ltd	*Southern Harvester*	1946–1961
Southern Whaling and Sealing	*Southern Empress*	1928–1940
Southern Whaling and Sealing	*Southern Princess*	1930–1939
Star Whaling Company Ltd.	*Svend Foyn*	1932–1940
Suderøy A/S	*Suderøy*	1929/30, 1933–1939, 1945–1958
Sydhavet A/S	*Svend Foyn I*	1927–1930
Taiyo Fishery, Nitto	*Chiyo Maru*	1972–1974
Taiyo Gyogyo K. K.	*Kinjyo Maru*	1954–1956, 1958–1960
Taiyo Gyogyo K. K.	*Nisshin Maru*	1936–1938, 1946–1950, 1951–1962
Taiyo Gyogyo K. K.	*Nisshin Maru II*	1937/38, 1958–1964
Taiyo Gyogyo K. K.	*Nisshin Maru III*	1961/62, 1965–1968, 1972/73
Torrodd Huse & Co	*Peder Huse*	1971
United Whalers Ltd.	*Terje Viken*	1936–1939
United Whalers Ltd.	*Balaena*	1946–1958
Union Whaling Company	*Empire Victory*	1946–1949
Union Whaling Company	*Abraham Larsen*	1950–1956
Union Whaling Company	*Uniwaleco*	1937, 1939
Vestfold Corporation	*Vestfold*	1935–1939
Vestfold Corporation & Viking A/S	*Vestfold*	1932–1934
Viking A/S	*Vikingen*	1935/36
Walter Rau Neusse	*Walter Rau*	1937/38
Western Operating Company	*Ulysses*	1937–1939
Ørnen A/S	*Ole Wegger*	1932–1940
Ørnen A/S (Thor Dahl)	*Thorshavet*	1947–1955, 1957–1961
Ørnen A/S	*Falk*	1929/30
Unknown	*Floating factories 1–6*	1939/40

Table S7

Humpback whale catches from the Strait of Magellan, the Scotia Arc and Kerguelen Archipelagos, between 1903 and 1963.

Year	South Shetland Island/Chile	South Georgia	Falkland Island	South Shetland Island	Kerguelen Island	South Orkney Island	South Sandwich	Antarctic	Total
1903	1	0	0	0	0	0	0	0	1
1904	0	180	0	0	0	0	0	0	180
1905	0	288	1	22	0	0	0	0	311
1906	201	240	0	0	0	0	0	0	441
1907	130	1,261	0	0	0	0	0	0	1,391
1908	925	1,849	9	310	217	0	0	0	3,310
1909	0	3,391	94	1,481	118	0	0	0	5,084
1910	0	6,197	70	2,176	87	0	0	0	8,530
1911	0	5,635	0	1,689	0	114	13	0	7,451
1912	0	2,360	8	976	0	138	0	0	3,482
1913	0	512	7	1,038	0	109	0	0	1,666
1914	0	827	12	656	0	10	0	0	1,505
1915	0	1,614	0	219	0	0	0	0	1,833
1916	0	395	0	21	0	0	0	0	416
1917	0	59	0	69	0	0	0	0	128
1918	0	65	0	81	0	0	0	0	146
1919	0	82	0	181	0	0	0	0	263
1920	0	102	0	149	0	0	0	0	251
1921	0	9	0	0	0	0	0	0	9
1922	31	355	0	173	0	9	0	0	568
1923	0	130	0	96	0	3	0	0	229
1924	0	262	0	102	0	4	0	0	368
1925	0	236	0	163	0	4	0	0	403
1926	0	0	0	78	0	4	0	0	82
1927	2	0	0	1	0	0	0	0	3
1928	0	15	0	4	0	0	0	0	19
1929	0	46	0	0	0	0	0	0	46
1930	0	64	0	1	0	0	0	13	78
1931	0	6	0	0	0	0	0	0	6
1932	0	0	0	0	0	0	0	0	0
1933	0	92	0	0	0	0	0	0	92
1934	0	37	0	0	0	0	0	0	37
1935	0	41	0	0	0	0	0	0	41
1936	0	17	0	0	0	0	0	0	17
1937	0	40	0	0	0	0	0	0	40
1938–1940	0	0	0	0	0	0	0	0	0
1941	0	16	0	0	0	0	0	0	16
1942	0	0	0	0	0	0	0	0	0
1943	0	4	0	0	0	0	0	0	4
1944	0	60	0	0	0	0	0	0	60
1945	0	238	0	0	0	0	0	0	238
1946	0	30	0	0	0	0	0	0	30
1947	0	24	0	0	0	0	0	0	24
1948	0	18	0	0	0	0	0	0	18
1949	0	26	0	0	0	0	0	0	26
1950	0	8	0	0	0	0	0	0	8
1951	0	10	0	0	0	0	0	0	10
1952	0	9	0	0	0	0	0	0	9
1953	0	11	0	0	0	0	0	0	11
1954	0	2	0	0	0	0	0	0	2
Total	**1,290**	**26,863**	**201**	**9,686**	**422**	**395**	**13**	**13**	**38,883**

Table S8

Humpback whale catches from Southern Africa, between 1908 and 1973
WSA = western South Africa, ESA = eastern South Africa, and WIO = western Indian Ocean.

Year	Gabon	Angola	Gabon/Angola	Namibia	WSA	ESA	Mozambique	WIO	Total
1908	0	0	0	0	0	104	0	0	**104**
1909	0	236	0	0	307	149	0	0	**692**
1910	0	718	0	0	244	524	108	0	**1,594**
1911	0	2,281	0	0	339	1,043	537	0	**4,200**
1912	418	3,417	0	559	216	915	1,398	0	**6,923**
1913	2,227	2,419	0	521	130	741	1,064	0	**7,102**
1914	1,843	596	0	204	54	428	402	0	**3,527**
1915	0	201	0	0	5	134	200	25	**565**
1916	0	65	0	0	4	94	0	0	**163**
1917	0	0	0	0	10	7	0	0	**17**
1918	0	0	0	0	10	9	0	0	**19**
1919	0	0	0	0	17	91	0	0	**108**
1920	0	0	0	0	40	148	0	0	**188**
1921	0	0	0	0	0	251	0	0	**251**
1922	613	0	0	0	13	285	0	0	**911**
1923	685	2	0	199	13	122	61	0	**1,082**
1924	879	47	0	77	19	187	0	0	**1,209**
1925	717	17	0	60	9	167	205	0	**1,175**
1926	0	6	0	96	19	124	0	0	**245**
1927	0	3	0	32	12	86	0	0	**133**
1928	0	37	0	10	21	62	0	0	**130**
1929	0	0	0	10	40	99	0	0	**149**
1930	578	0	0	6	30	134	0	0	**748**
1931	0	0	0	0	0	72	0	0	**72**
1932	0	0	0	0	0	307	0	0	**307**
1933	0	0	0	0	0	162	0	0	**162**
1934	0	0	723	0	0	514	0	0	**1,237**
1935	549	0	689	0	0	418	0	0	**1,656**
1936	345	0	497	0	27	300	0	0	**1,169**
1937	0	0	300	0	28	242	0	1,223	**1,793**
1938	0	0	0	0	0	177	0	1,752	**1,929**
1939	0	0	0	0	0	200	0	0	**200**
1940	0	0	0	0	0	176	0	0	**176**
1941	0	0	0	0	0	79	0	0	**79**
1942	0	0	0	0	0	156	0	0	**156**
1943	0	0	0	0	0	80	0	0	**80**
1944	0	0	0	0	0	115	0	0	**115**
1945	0	0	0	0	0	116	0	0	**116**
1946	0	0	0	0	0	93	0	0	**93**
1947	0	0	0	0	5	89	0	0	**94**
1948	0	0	0	0	14	182	0	0	**196**
1949	1,356	0	0	0	15	190	0	1,333	**2,894**
1950	1,404	0	0	0	7	151	0	714	**2,276**
1951	1,106	0	0	0	9	103	0	0	**1,218**
1952	265	0	0	0	15	111	0	0	**391**
1953	0	0	0	0	9	89	0	0	**98**
1954	0	0	0	0	0	28	0	0	**28**
1955	0	0	0	0	0	49	0	0	**49**
1956	0	0	0	0	0	36	0	0	**36**
1957	0	0	0	0	3	34	0	0	**37**

Year	Gabon	Angola	Gabon/Angola	Namibia	WSA	ESA	Mozambique	WIO	Total
1958	0	0	0	0	2	39	0	0	**41**
1959	161	0	0	0	7	38	0	0	**206**
1960	0	0	0	0	4	36	0	0	**40**
1961	0	0	0	0	4	36	0	0	**40**
1962	0	0	0	0	9	37	0	0	**46**
1963	0	0	0	0	3	38	0	0	**41**
1973	0	0	0	0	0	1	0	0	**1**
Total	**13,146**	**10,045**	**2,209**	**1,774**	**1,713**	**10,398**	**3,975**	**5,047**	**48,307**

Table S9

Humpback whale catches from South America between 1908 and 1969.

Year	Chile	Brazil	Chile/Peru/Ecuador	Colombia	Peru	Total
1909	1	0	0	0	0	**1**
1910	0	0	0	0	0	**0**
1911	0	102	0	0	0	**102**
1912	19	342	67	0	0	**428**
1913	0	352	0	0	0	**352**
1914	23	317	83	89	0	**512**
1915	10	82	20	0	0	**112**
1916	15	68	0	0	0	**83**
1917	15	62	0	0	0	**77**
1918	23	62	0	0	0	**85**
1919	24	29	0	0	0	**53**
1920	21	0	0	0	0	**21**
1921	21	0	0	0	0	**21**
1922	19	0	0	0	0	**19**
1923	16	0	0	0	0	**16**
1924	34	62	0	0	0	**96**
1925	17	42	0	0	231	**290**
1926	19	32	16	0	242	**309**
1927	0	47	0	0	22	**69**
1928	36	40	0	0	0	**76**
1929	26	0	0	0	0	**26**
1930	33	0	0	0	0	**33**
1931	53	0	0	0	0	**53**
1932	21	0	0	0	0	**21**
1933	11	0	0	0	0	**11**
1934	13	0	0	0	0	**13**
1935	31	0	0	0	0	**31**
1936	14	0	0	0	4	**18**
1937	19	0	0	0	9	**28**
1938	6	0	0	0	0	**6**
1939	7	0	0	0	0	**7**
1940–1945	0	0	0	0	0	**0**
1946	15	0	0	0	0	**15**
1947	17	11	0	0	2	**30**
1948	5	21	0	0	0	**26**
1949	6	17	0	0	0	**23**
1950	5	24	0	0	0	**29**
1951	3	28	0	0	23	**54**
1952	7	9	0	0	20	**36**
1953	23	8	0	0	6	**37**
1954	0	18	105	0	0	**123**
1955	5	9	0	0	2	**16**
1956	3	17	0	0	7	**27**
1957	5	0	0	0	0	**5**
1958	0	5	0	0	0	**5**
1959	3	8	0	0	0	**11**
1960	2	13	0	0	0	**15**
1961	3	13	0	0	37	**53**
1962	4	11	0	0	0	**15**
1963	1	12	0	0	1	**14**
1964	0	0	0	0	36	**36**

Year	Chile	Brazil	Chile/Peru/Ecuador	Colombia	Peru	Total
1965	6	0	0	0	137	**143**
1966	7	0	0	0	54	**61**
1967	0	0	0	0	0	**0**
1968	1	0	0	0	2	**3**
1969	1	0	0	0	0	**1**
Total	**669**	**1,863**	**291**	**89**	**835**	**3,747**

Table S10

Humpback whale catches from Australia, New Zealand and Tonga between 1908 and 1978.

Year	New Zealand	Western Australia	Eastern Australia	Norfolk Island	Australia/ New Zealand	Tonga	Total
1890–1908	152	0	0	0	0	0	**152**
1909	16	0	0	0	0	0	**16**
1910	77	0	0	0	0	0	**77**
1911	77	0	0	0	0	0	**77**
1912	63	234	0	0	30	0	**327**
1913	92	993	348	0	0	0	**1,433**
1914	93	1,968	0	0	0	0	**2,061**
1915	106	1,297	0	0	0	0	**1,403**
1916	82	0	0	0	0	0	**82**
1917	94	0	0	0	0	0	**94**
1918	90	0	0	0	0	0	**90**
1919	119	0	0	0	0	0	**119**
1920	107	0	0	0	0	0	**107**
1921	89	0	0	0	0	0	**89**
1922	57	155	0	0	0	0	**212**
1923	79	166	0	0	0	0	**245**
1924	107	0	0	0	0	0	**107**
1925	96	669	0	0	0	0	**765**
1926	78	735	0	0	0	0	**813**
1927	127	996	0	0	0	0	**1,123**
1928	105	1,035	0	0	0	0	**1,140**
1929	102	0	0	0	0	0	**102**
1930	78	0	0	0	0	0	**78**
1931	109	0	0	0	0	0	**109**
1932	18	0	0	0	0	0	**18**
1933	44	0	0	0	0	0	**44**
1934	52	0	0	0	0	0	**52**
1935	57	0	0	0	0	0	**57**
1936	69	3,076	0	0	0	0	**3,145**
1937	55	3,250	0	0	0	0	**3,305**
1938	75	917	0	0	0	0	**992**
1939	80	0	0	0	0	0	**80**
1940	107	0	0	0	0	0	**107**
1941	86	0	0	0	0	0	**86**
1942	71	0	0	0	0	0	**71**
1943	90	0	0	0	0	0	**90**
1944	88	0	0	0	0	0	**88**
1945	107	0	0	0	0	0	**107**
1946	110	0	0	0	0	0	**110**
1947	101	2	0	0	0	0	**103**
1948	92	4	0	0	0	0	**96**
1949	141	190	0	3	0	0	**334**
1950	79	388	0	0	0	0	**467**
1951	111	1,224	0	0	0	0	**1,335**
1952	121	1,187	600	0	0	0	**1,908**
1953	109	1,300	700	0	0	0	**2,109**
1954	180	1,320	718	0	0	0	**2,218**
1955	112	1,126	720	0	0	0	**1,958**
1956	143	1,119	720	150	0	0	**2,132**
1957	184	1,120	721	120	0	16	**2,161**

Year	New Zealand	Western Australia	Eastern Australia	Norfolk Island	Australia/ New Zealand	Tonga	Total
1958	183	967	720	120	0	16	**2,006**
1959	318	700	810	150	0	16	**1,994**
1960	361	545	810	170	0	16	**1,902**
1961	80	580	731	170	0	16	**1,577**
1962	32	543	173	4	0	0	**752**
1963	9	87	0	0	0	0	**96**
1973–1978	0	0	0	0	0	34	**34**
Total	**5,660**	**27,893**	**7,771**	**887**	**30**	**114**	**42,355**

Table S11

Humpback whale pelagic catches from the Southern Ocean between 1923 and 1973.

Year	Legal Pelagic	Ross Sea	Kerguelen	South Shetland	Illegal Pelagic	Total
1923	0	0	0	0	0	**0**
1924	0	0	0	0	0	**0**
1925	14	0	0	0	0	**14**
1926	26	82	0	0	0	**108**
1927	1	16	0	0	0	**17**
1928	11	17	11	4	0	**43**
1929	25	775	11	0	0	**811**
1930	504	0	0	0	0	**504**
1931	178	0	0	0	0	**178**
1932	160	0	0	0	0	**160**
1933	780	0	0	0	0	**780**
1934	1,944	0	0	0	0	**1,944**
1935	3,121	0	0	0	0	**3,121**
1936	4,457	0	0	0	0	**4,457**
1937	2,040	0	0	0	0	**2,040**
1938	883	0	0	0	0	**883**
1939	6	0	0	0	0	**6**
1940	2,684	0	0	0	0	**2,684**
1941–1945	0	0	0	0	0	**0**
1946	0	0	0	0	1	**1**
1947	2	0	0	0	0	**2**
1948	13	0	0	0	112	**125**
1949	2,081	0	0	0	511	**2,592**
1950	1,516	0	0	0	1,325	**2,841**
1951	1,309	0	0	0	862	**2,171**
1952	752	0	0	0	396	**1,148**
1953	444	0	0	0	253	**697**
1954	208	0	0	0	1,488	**1,696**
1955	1,183	0	0	0	2,962	**4,145**
1956	679	0	0	0	275	**954**
1957	336	0	0	0	2,235	**2,571**
1958	1,974	0	0	0	4,039	**6,013**
1959	618	0	0	0	12,944	**13,562**
1960	416	0	0	0	12,529	**12,945**
1961	39	0	0	0	5,501	**5,540**
1962	7	0	0	0	2,924	**2,931**
1963	2	0	0	0	691	**693**
1964	0	0	0	0	234	**234**
1965	1	0	0	0	2,051	**2,052**
1966	0	0	0	0	1,035	**1,035**
1967	0	0	0	0	928	**928**
1968	0	0	0	0	2	**2**
1969–1970	0	0	0	0	0	**0**
1971	0	0	0	0	3	**3**
1972	0	0	0	0	5	**5**
Total	**28,414**	**890**	**22**	**4**	**53,306**	**82,636**

Table S12

Illegal humpback whale catches by Soviet and Olympic Challenger fleets per operational season.

Season	Vessel				
	Slava	***Sovetskaya Ukraina***	***Yury Dolgoruky***	***Sovetskaya Rossiya***	***Olympic Challenger***
1946/47	1	0	0	0	0
1947/48	0	0	0	0	0
1948/49	112	0	0	0	0
1949/50	511	0	0	0	0
1950/51	945	0	0	0	380
1951/52	595	0	0	0	267
1952/53	311	0	0	0	85
1953/54	253	0	0	0	105
1954/55	361	0	0	0	1,127
1955/56	236	0	0	0	2,726
1956/57	275	0	0	0	0
1957/58	2,235	0	0	0	0
1958/59	4,039	0	0	0	0
1959/60	5,425	7,519	0	0	0
1960/61	4,046	5,573	2,910	0	0
1961/62	1,640	1,078	1,095	1,688	0
1962/63	746	660	945	573	0
1963/64	97	299	145	150	0
1964/65	0	3	85	146	0
1965/66	80	709	1,039	223	0
1966/67	0	487	360	188	0
1967/68	0	181	623	124	0
1968/69	0	0	0	2	0
1969/70	0	0	0	0	0
1970/71	0	0	0	0	0
1971/72	0	0	3	0	0
1972/73	0	1	2	2	0
Total	**21,908**	**16,510**	**7,207**	**3,096**	**4,690**