The SOWER programme in the Antarctic: Background, aims and objectives

P.B. Best[1], S. Ohsumi[2], H. Kato[2,3] and G.P. Donovan[4]

Contact email: corkblue1o@gmail.com

ABSTRACT

The International Whaling Commission (IWC) imposed limits on the catch of Antarctic minke whales close to the start of commercial whaling in the 1970s. These management efforts were hampered by the challenge of obtaining robust estimates of population size. Contemporary whale assessments largely relied on measuring changes in availability as a result of exploitation – usually catch per unit effort (CPUE). However, this approach was largely impractical for Antarctic minke whales due to: (a) the short time series of CPUE data; (b) the setting of relatively conservative catch limits, so that changes in CPUE due to exploitation were difficult to detect; and (c) the possibility that abundance had been increasing before this time due to over-exploitation of other baleen whales. The IWC initiated a series of assessment cruises in 1978 designed to obtain abundance estimates for targeted management areas in the Antarctic. Designed by the IWC's Scientific Committee, these cruises were independent of whaling operations. The vessels were chartered whale catchers provided by Japan for the duration of the programme – and by the Soviet Union for a period of seven years. With the eventual participation of 86 scientists from 16 IWC member states, this programme became a key part of the International Decade of Cetacean Research (IDCR), launched in 1975 as a response to the 1972 Stockholm Resolution that called for a 10-year moratorium on commercial whaling and the intensification of research efforts. While originally planned as 'Discovery' marking and sighting cruises, the programme eventually relied almost exclusively on sighting methods. Lasting over 30 years and involving three circumnavigations of the Southern Ocean, it became one of the largest whale monitoring exercises ever undertaken.

KEYWORDS: ABUNDANCE ESTIMATE; ANTARCTIC; ANTARCTIC MINKE WHALE; ASSESSMENT; MARK-RECAPTURE; VESSEL SURVEY

INTRODUCTION

When exploitation of minke whales first began in the Antarctic, there was believed to be a single worldwide species (*Balaenoptera acutorostrata*). There are now believed to be at least two species: the Antarctic minke whale, *Balaenoptera bonaerensis*, and the common minke whale, *B. acutorostrata* (Committee on Taxonomy, 2023). The common minke whale has two named subspecies (*B. a. acutorostrata*, the North Atlantic common minke whale; *B. a. scammoni*, the North Pacific common minke whale) and a third as-yet-unnamed subspecies which is colloquially known as the 'dwarf minke whale'. The Antarctic and dwarf minke whale are both found in the Southern Hemisphere. The dwarf minke whale largely occurs in warmer and more northerly coastal waters, covering a large longitudinal range: New Zealand (Baker, 1983), South Africa (Best, 1985), eastern Australia (Arnold *et al*., 1987), New Caledonia (Garrigue and Greaves, 2001), Uruguay (Baldas and Castello, 1986), Argentina

[1] Mammal Research Institute, University of Pretoria, PO Box 61 Cape Town 8000, South Africa. [Deceased April 2015]
[2] Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan. [Deceased November 2019]
[3] Tokyo University of Marine Science and Technology, 4-5-7 Kohnan, Minato-ku, Tokyo 104-8477, Japan.
[4] Beannacht, 4 High Street, Haddenham, Cambridgeshire, UK.

(Baldas and Castello, 1986) and Brazil (Zerbini *et al*., 1996; 1997). Both species migrate to higher latitudes in the summer, but dwarf minke whales generally occur further north and in smaller numbers, perhaps in isolated populations (Pastene *et al*., 2007).

The overall contribution of dwarf minke whales to sightings of 'minke' whales south of 60°S is probably negligible. For the first decade of intensified minke whaling in the Southern Hemisphere, the dwarf minke whale was apparently unknown in the commercial catch (Best, 1985), but it should be noted that the dwarf minke whale was not formally recognised as a separate species until 2000 (IWC, 2001). During the 1994/95 to 2003/04 cruises, there were only 12 confirmed sightings (Kato et al., in press). Japanese special permit whaling under the 'JARPA' programme initially took dwarf and Antarctic minke whales, but it was decided to stop catches of dwarf minke whales in 1993/94 (IWC, 1998). Only 16 dwarf minke whales had been caught under the programme since 1987/88 which further suggests that the proportion of dwarf minke whales in the Antarctic south of 60˚S is negligible (Kato and Fujise, 2000).

EARLY HISTORY OF EXPLOITATION

Until the early 1970s, Antarctic minke whales were of passing interest to Antarctic whaling fleets, given the abundance of larger and more valuable species. British and Norwegian expeditions would only occasionally take one for fresh meat or out of curiosity (Ash, 1962). It is unclear whether all such takes were recorded. Some individuals, examined by biologists (Van Utrecht and Van Spoel, 1962; Williamson, 1959), were not originally reported to the Bureau of International Whaling Statistics but have since been added to the most recent IWC catch database. The reported total catch of Antarctic minke whales between 1945/46 and 1970/71 was 1,956, with a maximum take per season of 605 (1967/68) and a total of 17 seasons with reported catch below 50, including eight seasons with no reported catch (Allison, 2016).[5]

Concerted exploitation of minke whales in the Southern Hemisphere commenced at the land stations at Costinha, Brazil, in 1966, and Durban, South Africa, in 1968. The first targeted operations in the Antarctic began in the 1971/72 season when the Japanese Company Taiyo Gyogyo KK sent catchers alongside the freezer ship *Jinyo Maru* to the Antarctic to take Antarctic minke whales. This was followed by the *Chiyo Maru* from 1972/73 to 1974/75. Neither vessel was designed as a factory ship with a stern slipway which meant the whales had to be hauled up a slide suspended over the side (Kawamura, 1980). A total pelagic Antarctic catch of 3,054 was reported in 1971/72 and 5,745 in 1972/73. The IWC imposed partial limits from 1972/73 onwards (Table 1).

The imposition of quotas by species across six management areas (Areas I–VI; Donovan, 1991; Figure 1) in the Southern Hemisphere was unique in the history of whale management. Most of these quotas were based on the best available scientific evidence at the time, even though this may now be considered inadequate. This approach successfully prevented the previous massive escalation in catches when a new species or stock became the focus of exploitation. For the Southern Hemisphere sei whale, annual pelagic catches surged from about

Table 1

Quotas and catches at the start of Antarctic whaling for the Antarctic minke whale.

		Catches			
Season	Catch limit	Pelagic	Land station	Total	Notes
1971/72	None	3,054	837	3,891	
1972/73	5,000	5,745	823	6,568	Quota for Antarctic only
1973/74	5,000	7,713	882	8,595	Quota for Antarctic only. Japan and USSR objected and set independent quota of 8,000
1974/75	7,000	7,000	1,149	8,149	Quota for Antarctic only, set by 3 combined adjacent areas
1975/76	6,810	6,034	776	6,810	Quota includes land stations. Antarctic quota set by 6 individual areas
1976/77	8,900	7,900	1,000	8,900	Quota includes land stations. Antarctic quota set by 6 individual areas
1977/78	5,690	5,000	690	5,690	Quota includes land stations. Antarctic quota set by 6 individual areas
1978/79	6,221	5,465	734	6,199	Quota includes land stations. Antarctic quota set by 6 individual areas

[5] Catches in the Antarctic occurred during the austral summer which meant the season spanned two calendar years: e.g., November 1946 to March 1947.

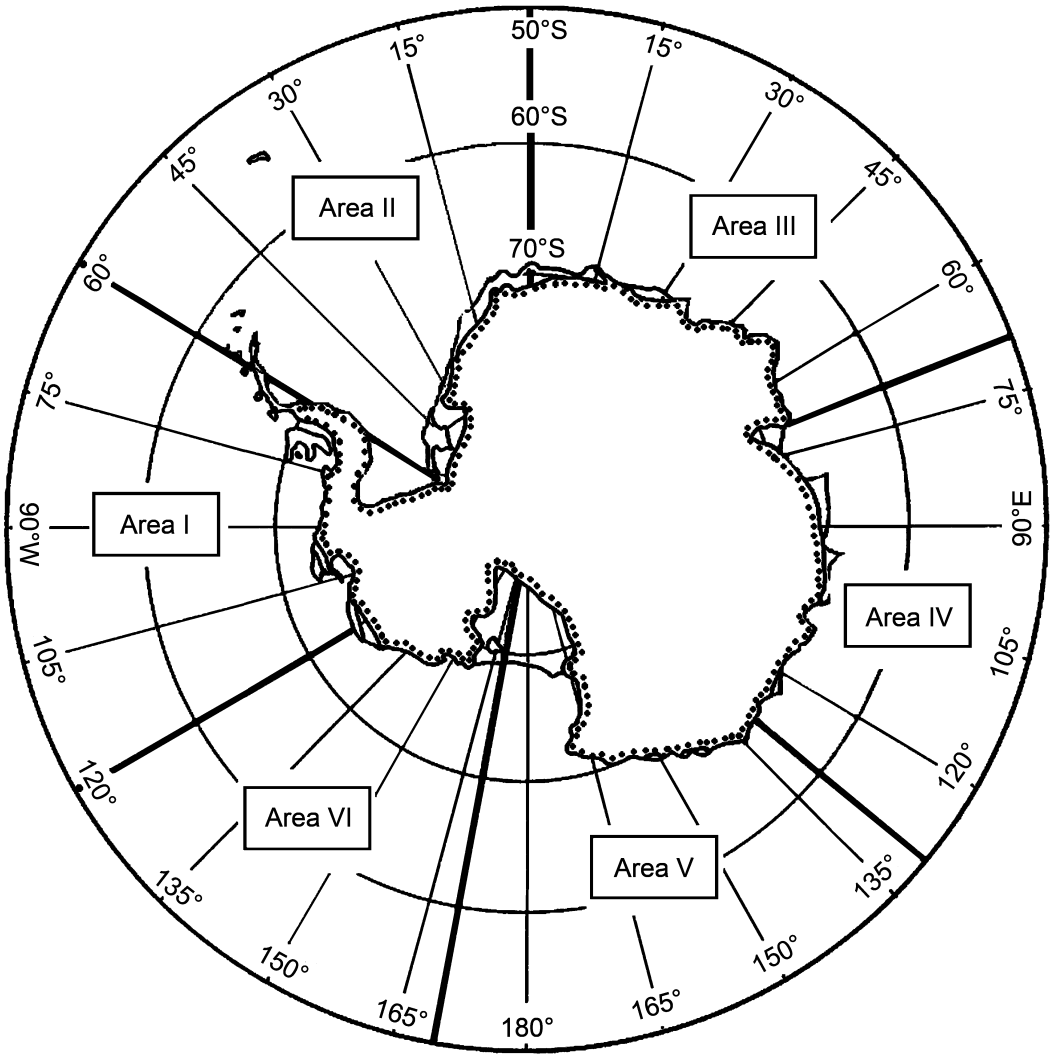

Fig. 1. Southern Hemisphere 'areas' for baleen whales (except Bryde's whales).

5,000 in 1960/61 and 1962/63 to almost 20,000 in 1964/65. This demonstrates how the IWC's 'Blue Whale Unit' proved unable to prevent overexploitation of whale stocks (Allen, 1980; Donovan, 1992).[6] In addition, the basic biological data necessary for the assessment models used at the time had been collected right from the start of pelagic whaling for minke whales (Ohsumi *et al*., 1970). In the 1971/72 and 1972/73 seasons, over 5,000 minke whales were examined by Japanese scientists or whaling inspectors. Preliminary results giving age/length keys, age and length at sexual maturity, pregnancy rate, ovulation rate, natural mortality rate and age at recruitment were presented to the IWC Scientific Committee as early as 1974 (Ohsumi and Masaki, 1975). Data of this quality and quantity had never before been available at such an early stage in the history of whale stock exploitation. But despite the availability of these data, the IWC Scientific Committee faced great difficulties in attempting to assess the stock structure and abundance of Antarctic minke whales.

EARLY STOCK ASSESSMENTS

Up to 1977

The first attempted assessment of Antarctic minke whales (then called Southern Hemisphere minke whales) was undertaken by Ohsumi *et al*. (1970). This – and all subsequent assessments until 1975 – was based entirely on

[6] Quotas were set by the Blue Whale Unit (BWU). One BWU was equivalent to one blue whale, two fin whales, 2.5 humpback whales or six sei whales, roughly based on oil yield. While this approach did limit the total catch, it didn't set a limit by individual species, thereby allowing overexploitation of individual species.

Table 2

Early estimates of abundance of Antarctic minke whales by year of meeting.

Meeting	Area T	Area TT	Area TTT	Area T	Area	Area T	Circumpolar	Method	References
1970	–	–	–	23,200	–	–	>70,000	Sightings	Ohsumi *et al.* (1970)
1971	–	–	–	–	–	–	127,300–217,000	Sightings	Ohsumi and Masaki (1971)
1972	–	–	–	–	–	–	>150,200	Sightings	Masaki (1973)
1973	–	–	–	–	–	–	299,000	Sightings	Ohsumi and Masaki (1974)
1974	No new estimate								
1975	18,100	31,500	36,100	14,000	13,000	9,300	122,000	Modelling	IWC (1976c)
1976	16,100	31,500	48,900	26,800	26,500	7,100	156,900	Modelling	IWC (1977b)

sightings data (Table 2), although the methods would not be considered robust by modern standards. Modern distance sampling methods did not exist at the time; that approach was only developed for cetaceans in the 1980s (Buckland *et al*., 1993). These great improvements in the estimation of abundance from sightings survey data have in large part been due to work undertaken by the Scientific Committee, including developments made as a result of the SOWER programme that are the subject of this special volume. The general tendency for population estimates to increase thereafter was mainly due to the increasing geographical coverage by scouting vessels, particularly in Series B (60–70°S) and C (70–80°S), and close to the ice edge, where the highest densities of minke whales occurred.

In Area IV in 1975, the first decline in CPUE was detected. This was used in the modified deLury method to obtain a population estimate for Area IV that was then extrapolated to the remaining areas of the Antarctic using relative indices of abundance (Ohsumi, 1976; Crittenden, 1983; IWC, 1976c). This extrapolation approach was used in all subsequent estimates of population size up to 1980, when an independent estimate for Area III was produced (Horwood, 1981). Before 1980, estimates only varied due to differences in the detectable rate of CPUE decline in Area IV and/or changes in the methods used to extrapolate to other areas.

During the 1977 assessment (IWC, 1978), it was noted that the estimated natural mortality rate proposed from a time-specific analysis of the age composition of the catch in Ohsumi and Masaki (1975) was much higher than might be expected from comparison with other baleen whale species. The correspondence of the natural mortality rate (M) with the slope of the right-hand limb of an age composition depends on the assumption that the population is stationary. If a population has been increasing for some time before the samples were taken, one would expect the age composition to be unstable, containing a higher proportion of younger animals, thereby biasing estimates of M upwards. Two pieces of evidence were proposed in support of this hypothesis: (1) an apparent increase in the rate of sightings of minke whales of *ca* 3.7% per year since 1965/66 (Masaki and Yamamura, 1978); and (2) the fact that most management areas showed no significant decline in abundance from CPUE or sightings data despite exploitation, presumably being balanced by increased recruitment.

Assuming an intrinsic population growth rate of 3.7% p.a., a modified deLury analysis was carried out for Area IV, the only area where an apparent downward trend in CPUE could be detected. The result was extrapolated to other areas using relative indices of abundance (Table 1). There was considerable uncertainty in this approach and disagreement over plausibility and interpretation as reflected in the Scientific Committee's report (IWC, 1978).

In 1975, the IWC introduced the 'New Management Procedure' (NMP) (Allen, 1980; Donovan, 1992), aimed at bringing all whale stocks to an optimum level at which the largest number of whales could be taken consistently – the maximum sustainable yield (MSY) – without depleting the stock. The NMP required all stocks to be classified into one of three categories, assuming the MSY level to occur at 60% of the population size before exploitation:

(1) Initial Management Stocks: over 72% of the original stock size; catch limits always set below MSY to ensure the stock does not fall below 60%;

(2) Sustainable Management Stocks: between 54–72% of the original stock size; catch limits set below MSY, depending on how far the stock is below MSY level;

(3) Protection Stocks: those below 54% of the original stock size; no catches allowed.

Using the NMP for increasing stocks was found to be problematic as the stocks could be much larger than the estimated initial population size. Other difficulties in providing management advice arose from disagreement over: (a) the actual rate of population increase; and (b) the methods used to estimate mortality and recruitment. Only interim catch limits based on Replacement Yield (RY) were therefore proposed to the Commission. In order to resolve these uncertainties, a special meeting was held in 1978 (IWC, 1979b).

1978: A key year

The Special Meeting on Southern Hemisphere minke whales was held in Seattle, May 1978 (IWC, 1979b), and had access to an unprecedented amount of unpublished data and analyses, primarily produced by Japanese scientists. Very little information was provided by Soviet scientists. The available biological data provided some support for the hypothesis of an unstable stock prior to exploitation, particularly that the transition phase layer in the earplug (believed to coincide with attainment of sexual maturity; Lockyer, 1972) occurred at age 14 in animals born before 1944 but at progressively younger ages in animals born thereafter, reaching six to seven years in the most recent samples (Masaki, 1979). A comparative study of natural mortality rates and body size in both mysticetes and odontocetes indicated that the natural mortality of Antarctic minke whales might be about 0.095 (Ohsumi, 1979). These studies have subsequently been criticised on procedural grounds and for failing to recognise potential biases, but, at the time, they provided convincing evidence of population instability prior to exploitation.

Given this apparent instability, the only way to obtain estimates of total (i.e., natural plus fishing) mortality (Z), excluding its effects, was to incorporate an 'acceptable' index of CPUE in the analysis. Correcting CPUE data to account for factors such as weather and fixed operational times, within seasonal changes to density, that might preclude it from being a suitable proxy for whale numbers, was complex. Several indices were calculated and then narrowed down to two: weather corrected and uncorrected. Values of Z were obtained for Areas III and IV which had the longest history of exploitation, but these were highly variable. As the only positive values were for Area IV (IWC, 1979b), estimates of population size could only be obtained for this Area.

The Scientific Committee reconvened for its annual meeting on 12 June 1978. Discussions over the assessment of Southern Hemisphere minke whales continued, with Area IV remaining the keystone area because of the larger catches (IWC, 1979d). A number of different approaches and datasets were tried while assessing Area IV. As a result, 15 different estimates of average stock size were produced, ranging from 10,682 to 89,035. After reconsideration, this was reduced to three procedures, while the average stock sizes for 1971/72 to 1977/78 were prorated to other areas using relative abundance indices, producing 'current' (1978/79) stock size estimates for the whole Antarctic varying from 110,519 to 389,256. No confidence intervals were provided or indeed possible to calculate. The Scientific Committee noted the uncertainty of these estimates and raised questions about the adequacy of assessments based solely on CPUE data. The only independent evidence available at the time from sightings was too variable to enable confident detection of anything other than major changes in abundance. These circumstances therefore indicated the need for a properly organised and scientifically supervised marking and sightings survey aimed at providing estimates of current abundance, independent of whaling operations.

As can be seen in Table 3, the 'best' estimates developed in 1977 and 1978 were considerably different, emphasising the need for abundance estimates obtained using independent methods. The agreed 'best estimates' from the second circumpolar set of SOWER surveys are also shown, illustrating the inadequacy of these early assessments.

THE INTERNATIONAL DECADE OF CETACEAN RESEARCH (IDCR)

Many things were happening on the political front during the 1970s. In early June 1972, the United Nations Conference on the Human Environment in Stockholm, Sweden, called for the IWC to adopt a 10-year moratorium on commercial whaling and for governments to strengthen the Commission and increase international research efforts (Donovan, 1992). This resolution was tabled at the 1972 IWC meeting. Apart from comments on the appropriateness of a moratorium, the Scientific Committee's response was to propose a decade of intensified

Table 3

Summary of the results of the assessments made at the 1977 and 1978 Committee meetings (mtg) taken from IWC (1978, Table 13) and IWC (1979a, Table 2). For comparison, the final column (CPTT) shows the 'best estimates' for the second circumpolar set of IDCR-SOWER surveys (1985/86–1990/91).

Area	Season of first catches (initial)	'Initial' abundance		'Current' abundance		% current 1977 mtg	% of initial 1978 mtg	'CPTT' Abundance (see text)
		1977 mtg	1978 mtg	1977/78	1978/79			
Area T	1972/73	20,950	9,407	18,200	7,753	86.9	82.4	85,700
Area TT	1965/66	28,700	21,717	29,800	22,589	103.8	104.0	130,000
Area TTT	1967/69	46,400	42,630	47,500	51,181	102.4	120.1	93,200
Area TV	1971/72	32,600	25,422	25,000	16,404	76.7	64.5	55,200
Area V	1974/75	25,500	6,646	24,100	6,082	94.5	91.5	300,200
Area VT	1975/76	17,500	4,257	17,800	5,666	101.7	133.1	55,600
Total		171,650	110,079	162,400	109,675	94.6	99.6	720,000

research on cetaceans, eventually termed the International Decade of Cetacean Research (IDCR). At the 1974 Scientific Committee meeting, a discussion paper on the proposed IDCR was tabled, which documented current levels of research expenditure by individual nations and suggested that the IDCR be used to promote a major international programme to collect new data on stock identity, population size and trend for Southern Hemisphere stocks, using an integrated programme of survey cruises, covering both the Antarctic whaling grounds in summer and lower latitudes in winter (Best, 1974; IWC, 1975).

At the same meeting, three subcommittees were established to develop specific research proposals for the North Atlantic, North Pacific and Southern Hemisphere, that would later be submitted to UNEP, FAO and other potential funding agencies. The Southern Hemisphere subcommittee met in La Jolla, USA, in December 1974. Recommendations were tabled at the next IWC meeting in June 1975, consolidated with proposals from the other two subcommittees (IWC, 1976a; 1976b). Under 'population estimation', a marking and sighting survey for Antarctic minke whales in Areas III and IV in each of five years was proposed, combined with experimental catching to compare biological parameters between exploited and unexploited populations. This was assigned 'Medium Priority' and an associated budget of US$210,000 per year proposed to the Commission, as part of an overall cost for the programme of US$3,256,000.

In response, the Commission passed a resolution recommending that member nations assist with providing vessels, personnel or additional funds as contributions to any IDCR proposals, particularly in the areas of stock monitoring and identification in the Southern Hemisphere, and that UNEP should be approached as its assistance would be 'most useful' (IWC, 1977).

In 1976, the Scientific Committee reminded the Commission about the consolidated proposals and urged it to consider funding them, either through a research fund or direct support by member states. The Finance and Administration Committee responded by requesting further advice on priorities, which led the Scientific Committee to select four programmes with a first-year funding of US$175,000. These included a marking and sighting cruise in the Indian Ocean (US$70,000). A voluntary research fund was established, which accumulated £10,281 by May 1977, increasing to £14,182 in 1978.

The IDCR programme was submitted to the FAO/ACMRR Working Party ahead of the Scientific Consultation on the Conservation and Management of Marine Mammals and their Environment, held in Bergen, Norway, August–September 1976, where it was consolidated into a broader programme of marine mammal research (FAO, 1978). This consolidated programme was never fully funded or implemented (Gambell, 1995).

The road to the first IWC IDCR-SOWER cruise

Immediately after this Special Meeting, some delegates attended the International Conference on the Population Dynamics of Large Mammals at Utah State University from 25–27 May 1978. Speakers included many of the leading marine mammal scientists, including K. R. Allen, J. R. Beddington, D. G. Chapman, C. W. Fowler, D. De Master, J. Harwood, S. G. Holt, J. Horwood, R. M. Laws and T. Smith (Fowler and Smith, 1981). While Antarctic minke whales received only passing mention, informal discussions outside the meeting produced the germ of an idea: that if whaling continues under the constraints of the NMP, then the chances of major changes in

availability occurring (at least due to whaling) would be reduced, if not eliminated, meaning the accumulation of information on stock status would be minimal using the traditional CPUE-based assessment methods (Best, 1978). On the other hand, experimental management of one or more stocks, causing deliberately large changes in abundance that could be measured, might be possible, but, if these changes were still to be monitored by unsatisfactory indices of abundance, then the process would be largely fruitless. Thus, a method entirely independent of changes in CPUE was required.

The two methods available at the time to obtain independent estimates of abundance were mark-recapture and sightings (line transect/strip census).[7] While both had been previously attempted for Antarctic minke whales, the effort had either been inadequate (only 69 whales tagged), or in the case of visual surveys, the design was not systematic (being directed searches). Both methods could be combined in a single survey provided there was suitable scientific design and surveillance.

In order to increase the robustness of the mark-recapture estimate, the geographical extent of such a survey needed to be limited to maximise the density of marked animals, perhaps to one management area per year. Assuming an average stock size per area of 20,000 animals, with an annual catch of *ca* 3.5% (or 700 animals), a target of about 600 marked whales would be needed to provide a population estimate with 95% confidence limits within 50% of the mean (considered to be a reasonable management objective at the time). Average catch rates for the 1976/77 season ranged from 5.7 to 10.1 minke whales per boat per day. Assuming the time to mark a minke whale was the same as to catch one, one fully committed vessel could achieve the marking target in three months at a rate of 6.7 whales per day.

Further requirements were also identified:

(1) a substantial proportion of the animals should be double tagged to check for 'tag loss';

(2) efficiency of tag recovery should be monitored through the installation of metal detectors in the factory ship and/or the seeding of carcasses with tags; and

(3) marks should be distributed as evenly as possible throughout the Area.

In order to allow mixing of marked and unmarked animals, exploitation of whales in the target area should be stopped for the season of marking. This would allow 3,000–4,000 whales to be marked in six years, with recoveries in the following seasons to provide estimates of exploitable stock size.

Given Area IV's history of exploitation and population estimates, it was the natural choice for the first survey. The following survey design was proposed: six North–South legs 10° of longitude apart, extending from 55°S to the ice edge (*ca* 65°S), commencing at 75°E. Successive legs would be connected at their northern or southern limits by East–West legs. The total distance to be covered (c.5,700 n. miles) would require an average daily coverage of 63 n. miles to be completed in three months by a single vessel. If conducted from December to February, this would ensure the main season and location of expected high minke whale density in summer was covered. The ideal vessel for such a survey would be a whale catcher manned by experienced personnel. Costs of supplying scientific personnel, marking guns and Discovery marks could be covered by IWC research funds, while the nations involved in the southern minke whale fishery would be expected to contribute to the operating costs as they stood to gain most from any immediate benefits of the programme.

Other benefits of the survey would include the opportunity to monitor any recovery of the Antarctic blue whale, a species of great conservation concern, for which no reliable estimates of population size or trend were available. The species was given full protection in 1967, although some illegal Soviet whaling was later discovered to have occurred until the early 1970s (Yablokov and Zemsky, 2000).

The 1978 IWC meeting

The subcommittee on minke whales strongly recommended that this research cruise proposal be undertaken the following year so that a proper basis for assessment could be developed (IWC, 1979c). While this

[7] Mark-recapture involved using 'Discovery' marks: stainless steel numbered tags shot into the whale and recovered during whaling operations (Brown, 1975).

recommendation was not reemphasised by the full Scientific Committee (IWC, 1979a), it was noted that the Japanese government had budgeted ¥300,000 for marking and sightings in 1978/79, some of which was intended for Southern Hemisphere minke whales. Neither did the Chairman of the Commission specifically refer to this recommendation in his report. Nevertheless, negotiations continued behind the scenes.

On 29 June 1978, the penultimate day of the Commission meeting in London, discussions were held between scientists from Australia, Japan, New Zealand, South Africa, the UK and USA, along with members of the Japanese Government and representatives of the whaling industry, specifically Shigeru Hasui (Managing Director of Nippon Kyodo Hogei Kaisha (NHK)), Kazuo Yamamura (NHK) and Ryusuke Suzuki (Chief of the Whaling Section, Department of Far Seas Fisheries, Fisheries Agency, Government of Japan). While it was agreed that the research proposal was the right approach in principle, certain practical problems had to be considered. The most important of these was the limited endurance of the Japanese scouting boats (28 days), which meant arrangements for refuelling would have to be added to the plan.

It was agreed that the Japanese Government would provide two scouting boats for two months, prior to the arrival of the Japanese factory ship in Area IV. Approximately half of this time would be spent in transit to and from a suitable port or factory ship for refuelling. The reduced operational time meant that sightings coverage would have to be less than originally planned. Consequently, as a choice had to be made between a survey based essentially on sightings or marking, the latter was considered to be more valuable. Hence, it was decided to shift survey coverage to higher latitudes where higher densities of minke whales could be expected. Two 'foreign' researchers would join each vessel throughout the survey, with an additional researcher scheduled to transfer to the Japanese factory ship at mid-cruise refuelling to carry out mark-recovery experiments (Best and Butterworth, 1980; Kato, 1981).

Post 1978 IWC meeting

Negotiations over vessels, the number and identity of participants, survey design and schedule, continued after the meeting, facilitated by cruise organisers Best and Ohsumi. It was confirmed that Japan would provide two scouting vessels: *Toshimaru 16* and *Toshimaru 18*. It was proposed that they would work a grid pattern with legs of 3° latitude and 5° longitude, where one vessel was deployed between 58°–61°S and the other between 62°–65°S. The area would be divided into western and eastern strata (IV–W and IV–E). Refuelling would take place at the Japanese factory ship after completion of the first half of the programme. The role of each vessel would switch for the second half. Nippon Kyodo Hogei (NKH) also agreed to install a metal detector on the production line of the factory ship *Nissin Maru No. 3* to improve the efficiency of whale-mark detection.

The survey still needed official recognition as part of the IWC's IDCR programme. On 31 July 1978, the IWC Secretary, Ray Gambell, sent a circular to all commissioners, contracting governments and members of the Scientific Committee, informing them of the status of the survey and requesting names of possible participants and levels of funding from national groups. Australia, South Africa and the USA expressed their intention to nominate scientists, with the latter two also contributing funds. The agreement of other pelagic whaling nations was still needed. On 10 August 1978, the Chair of the Scientific Committee wrote to the USSR's IWC Commissioner, requesting that the Soviet fleet refrain from operating in Area IV while the survey was in progress. The Japanese Government had already agreed to this arrangement. This request was reiterated by the IWC Secretary on 12 October 1978. The Soviet Deputy Minister of Fisheries, Mr Bystrov, then arranged for no Soviet whaling to occur during the research period.

An informal pre-cruise planning meeting was held in the Hotel La Valencia, La Jolla, California, in December 1978, in combination with a Special Meeting of the Scientific Committee on sperm whale stocks. Survey participants were selected. Details of track design and data collection procedures were finalised. Given its location with respect to Area IV, Fremantle, Western Australia, was chosen as the home port for both the start and finish. It was agreed that there would also be a pre-cruise meeting involving both ships' personnel and researchers.

On 18–19 December 1978, the *Toshimaru 16* and *Toshimaru 18* arrived in Fremantle and the long-awaited survey began at last. The results are reported in Best and Butterworth (1980).

POSTSCRIPT

Nobody could have foreseen that this survey programme would continue uninterrupted for another 31 years, including three complete circumnavigations of the Southern Ocean, 86 scientists from 16 member nations, to become one of the largest cetacean monitoring programmes ever undertaken. In retrospect, there are a number of factors which helped create the appropriate atmosphere. The vastly reduced whaling effort in the Antarctic certainly helped, creating a less competitive environment and making partial or temporary area closures possible. The 1976 merger of Japanese whaling companies into a single entity, Nippon Kyodo Hogei (NKH), greatly facilitated the possibility of reaching agreement. Decommissioning two long-range *Shonan* boats in 1981 due to their unsuitability for minke whaling meant these vessels were available for the SOWER programme. While the proposal for an International Decade of Cetacean Research was a direct response to calls for the moratorium and was never as ambitious as originally intended, it formed a convenient and politically acceptable platform for the survey programme. Without doubt, the most important factor of all was the far-sighted decision made by the Japanese Government and NKH to support the survey under IWC auspices and provide vessels, personnel and funding to ensure its success.

The initial emphasis on marking rather than sighting was understandable, particularly as: (a) the seminal work of Burnham *et al*. (1980) with respect to obtaining abundance from sightings had not yet appeared; and (b) the Scientific Committee's previous experience with sighting analysis (with the notable exception of Nasu and Shimadzu (1970)) had largely been confined to empirical models of searching and whale behaviour (Doi, 1971). Nevertheless, despite targets of 700 marked whales being achieved on each of the first two surveys, the low number of mark returns meant that the resultant population estimates had low levels of precision (Best and Butterworth, 1980). This forced the Scientific Committee to look more closely at using the sightings data. The Scientific Committee convened a workshop on the design of sightings surveys in Seattle, September 1980 (IWC, 1982), where the design shifted to sightings rather than marking. This move was accelerated after the adoption of the whaling moratorium in 1982, when the possibility of recovering marks ended, except in a limited number of catches under Japanese scientific permits.

ACKNOWLEDGEMENTS

While there is a large number of individuals and governments who made the SOWER programme a reality, we would especially like to acknowledge the tireless energy and enthusiasm of our two deceased friends, colleagues and co-authors, Peter Best and Seiji Ohsumi (Bannister *et al*., 2015; Yong-Rock, 2021). Without their expertise and drive, this long-term programme would have remained a dream.

REFERENCES

Allen, K.R., 1980. *Conservation and Management of Whales*. University of Washington Press.

Allison, C., 2016. IWC individual and summary catch databases. Version 6.1; 18 July 2016. [Available from the IWC Publications Team]

Arnold, P., Marsh, H., Heinsohn, G., 1987. *The occurrence of two forms of minke whales in east Australian waters with a description of external characters and skeleton of the diminutive or dwarf form.* Scientific Reports of the Whales Research Institute, Tokyo 38: 1–46.

Ash, C., 1962. *Whaler's Eye*. Macmillan.

Baker, A.N., 1983. *Whales and Dolphins of New Zealand and Australia: An Identification Guide*. Victoria University Press.

Baldas, M.I., Castello, H.P., 1986. Sobre el hallazgo de ejemplares juveniles de ballena minke (*Balaenoptera acutorostrata*) en el estuario del Rio de la Plata y sur de Brasil [in Spanish]. Proc. 1a. Reun. Trab. Esp. Mam. Acuat. Am. del Sur, Buenos Aires, Argentina, June 1984.

Bannister, J.L., Findlay, K., Brownell, R.L. Jr, Butterworth, D.S., Cawthorn, M.W., Donovan, G.P., Gambell, R., Kato, H., Mate, B., Moore, M., Ohsumi, S., Perrin, W.F., Reeb, D., Reeves, R.R., Rowntree, V., Shaughnessy, P., 2015. Memories. *Marine Mammal Science*. 31(4): 1594 [Available at: *https://doi.org/10.1111/mms.12277*]

Best, P.B., 1974. The proposed international decade of cetacean research: some considerations. SC/26/27 presented to the IWC Scientific Committee, 1974. [Available from the IWC Publications Team]

Best, P.B., 1978. *IWC meeting on Southern Hemisphere minke whales, Seattle, 17–23 May 1978*. Report for US Marine Mammal Commission.

Best, P.B., 1985. *External characters of southern minke whales and the existence of a diminutive form*. Scientific Reports of the Whales Research Institute, Tokyo 36: 1–33.

Best, P.B., Butterworth, D.S., 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. Int. Whal. Comm.* 30: 257–83.

Brown, S.G., 1975. Marking of small cetaceans using 'Discovery' type whale marks. *J. Fish. Res. Board Can.* 32(7): 1,237-40.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman & Hall.
Burnham, K.P., Anderson, D.R., Laake, J.L., 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72: 1–202.
Committee on Taxonomy, 2023. List of marine mammal species and subspecies. Society for Marine Mammalogy.
Crittenden, R., 1983. An evaluation of the Leslie-DeLury method and of a weighted method for estimating the size of a closed population. *Fish. Res.* 2(2): 149–58.
Doi, T., 1971. Further development of sighting theory on whale. *Bull. Tokai Reg. Fish. Res. Lab.* 68: 1–22.
Donovan, G.P., 1991. A review of IWC stock boundaries. *Rep. Int. Whal. Comm.* Special Issue 11: 39–68.
Donovan, G.P., 1992. The International Whaling Commission: Given its past, does it have a future? In: J. J. Symoens (Ed.), *Whales: Biology, Threats, Conservation* (pp.23–44). Royal Academy of Overseas Sciences.
Food and Agriculture Organisation, 1978. *Mammals in the Seas*. Food and Agriculture Organisation of the United Nations.
Fowler, C.W., Smith, T.D., 1981. *Dynamics of Large Mammal Populations*. John Wiley & Sons.
Gambell, R., 1995. The International Decades of Cetacean Research, 1975–1985 and 1985–1995. IWC/47/20 presented to the International Whaling Commission, Dublin, Ireland, 1995. [Available from the IWC Publications Team]
Garrigue, C.G., Greaves, J., 2001. Cetacean records for the New Caledonian area (Southwest Pacific Ocean) *Micronesica* 34(1): 27–33.
Horwood, J.W., 1981. Results from the IWC/IDCR minke marking and sighting cruise, 1979/80. *Rep. Int. Whal. Comm.* 31: 287–313.
International Whaling Commission, 1975. Report of the Scientific Committee. *Rep. Int. Whal. Comm.* 25: 62–282.
International Whaling Commission, 1976a. International Decade of Cetacean Research: Consolidated research proposals. *Rep. Int. Whal. Comm.* 26: 116–20.
International Whaling Commission, 1976b. International Decade of Cetacean Research: Research proposals for the Southern Hemisphere. *Rep. Int. Whal. Comm.* 26: 121–37.
International Whaling Commission, 1976c. Report of the Scientific Committee: Annex K. *Rep. Int. Whal. Comm.* 26: 52–53.
International Whaling Commission, 1977. Chairman's Report of the 27th Meeting. *Rep Int. Whal. Comm.* 27: 6–15.
International Whaling Commission, 1978. Report of the Scientific Committee. *Rep. Int. Whal. Comm.* 28: 38–74.
International Whaling Commission, 1979a. Report of the Scientific Committee. *Rep. Int. Whal. Comm.* 29: 38–105.
International Whaling Commission, 1979b. Report of the Special Meeting on Southern Hemisphere Minke Whales, Seattle, 17–23 May 1978. *Rep. Int. Whal. Comm.* 29: 349–58.
International Whaling Commission, 1979c. Report of Scientific Committee: Annex F. *Rep. Int. Whal. Comm.* 29: 74–80.
International Whaling Commission, 1979d. Report of the subcommittee on requirements for data on catching effort. *Rep. Int. Whal. Comm.* 29: 96–7.
International Whaling Commission, 1982. Report of the Workshop on the Design of Sightings Surveys, Seattle, September 1980. *Rep. Int. Whal. Comm.* 32: 533–49.
International Whaling Commission, 1998. Chairman's Report of the 49th Annual Meeting. *Rep. Int. Whal. Comm.* 48: 17–52.
International Whaling Commission, 2001. Report of the Scientific Committee. *J. Cetacean Res. Manage.* (Suppl.) 3: 1–76.
Kato, H., 1981. Trial-firing of .410 marks at a minke whale carcass on the factory ship, 1979/80 Antarctic season. *Rep. Int. Whal. Comm.* 31: 367–70.
Kato, H., Fujise, Y., 2000. Dwarf minke whales: morphology, growth and life history with some analyses on morphometric variation among the different forms and regions. SC/52/OS3 presented to the IWC Scientific Committee, June 2000, Adelaide, Australia. [Available from the IWC Publications Team]
Kato, H., Matsuoka, K., Nakamura, G., Best, P.B., in press. Sightings of dwarf minke whales in the Southern Hemisphere made under the IWC's IDCR-SOWER Programme. *J. Cetacean Res. Manage.*
Kawamura, A., 1980. Chronological notes on the commissioned Japanese whaling factory ships. *Bull. Fish. Sci. Hokkaido Univ.* 31(2): 184–90.
Lockyer, C., 1972. The age at sexual maturity of the southern fin whale (*Balaenoptera physalus*) using annual layer counts in the earplug. *J. Cons. Int. Explor. Mer.* 34(2): 276–94.
Masaki, Y., 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. Int. Whal. Comm.* 29: 375–95.
Masaki, Y., Yamamura, K., 1978. Japanese pelagic whaling and whale sighting in the 1976/77 Antarctic season. *Rep. Int. Whal. Comm.* 28: 251–61.
Nasu, K., Shimadzu, Y., 1970. Report of the Scientific Committee. Annex J. *Rep. Int. Whal. Comm.* 20: 114–29.
Ohsumi, S., 1976. An attempt to standardise fishing efforts as applied to the stock assessment of the minke whale in the Antarctic Area IV. *Rep. Int. Whal. Comm.* 26(2): 404–08.
Ohsumi, S., 1979. Interspecies relationships among some biological parameters in cetaceans and estimation of the natural mortality coefficient of the Southern Hemisphere minke whale. *Rep. Int. Whal. Comm.* 29: 397–406.
Ohsumi, S., Masaki, Y., 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish. Res. Board Can.* 32(7): 99–1004.
Ohsumi, S., Masaki, Y., Kawamura, A., 1970. Stock of the Antarctic minke whale. *Scientific Reports of the Whales Research Institute, Tokyo* 22: 75–125.
Pastene, L.A., Goto, M., Kanda, N., Zerbini, A.N., Kerem, D., Watanabe, K., Bessho, Y., Hasegawa, M., Nielsen, R., Larsen, F., Palsbøll, P.J., 2007. Radiation and speciation of pelagic organisms during periods of global warming: the case of the common minke whale (*Balaenoptera acutorostrata*) *Mol. Ecol.* 16(7): 1481–500.
Van Utrecht, W.L., Van Spoel, S., 1962. Observations on a minke whale from the Antarctic. *Mamm.* 27(4): 217–21.

Williamson, G.R., 1959. Three unusual rorqual whales from the Antarctic. *Proc. Zool. Soc. London* 133(1): 135–44.
Yablokov, A.V., Zemsky, V.A., 2000. *Soviet whaling data (1949–1979).* Centre for Russian Environmental Policy, Marine Mammal Council, Moscow.
Yong-Rock, A., 2021. Recollections of Seiji Ohsumi, *Cetacean Popul. Stud.* 10(3): 9–51
Zerbini, A.N., Secchi, E.R., Siciliano, S., Simöes-Lopes, P.C., 1996. The dwarf form of the minke whale (*Balaenoptera acutorostrata*, Lacépède, 1804) in Brazil. *Rep. Int. Whal. Comm.* 46: 333–40.
Zerbini, A.N., Secchi, E.R., Siciliano, S., Simöes-Lopes, P.C., 1997. A review of the occurrence and distribution of whales of the genus *Balaenoptera* along the Brazilian coast. *Rep. Int. Whal. Comm.* 47: 407–17.