Annex R

A Proposal to Initiate a Sperm Whale In-Depth Assessment

Introduction

The sperm whale is a cosmopolitan species with large body size, high mobility, deep-diving behaviour, and an aggregate pre-exploitation abundance that almost certainly exceeded one million individuals; the sperm whale can be assumed to play a significant role in the ecology of the world's oceans, especially in little-studied pelagic ecosystems. Because of the long and intensive history of sperm whaling, an improved understanding of magnitude, trends and ecology of sperm whale populations would contribute to our understanding of the ecology and history of the world's oceans from many disciplinary perspectives, including biologists, ecologists, economists and historians.

Sperm whale population assessment was given high priority by the SC for roughly 20 years, from the mid-1960s to the mid-1980s. A variety of approaches were developed, all based on fishery-dependent data. Studies relied on reported and estimated catches, catch composition and catch rates from both 20th century and pre-20th century whaling. The mathematical population models used then suggested that sperm whale abundance in at least one portion of the North Pacific (Western Division) was smaller in 1825 than it was in 1947 (Tillman and Breiwick, 1983). Such a difference is inconsistent with general understanding of the population dynamics of marine organisms, and therein is a paradox. One would not expect abundance in the mid-20th century to be higher than it was in the early 1800s, and depending on the time frame and extent of harvesting, it would more likely be lower.

Several explanations have been offered for this apparent inconsistency, ranging from technical aspects of interpreting catch rates, to uncertainty about population dynamics, to uncertainty about population structure and movements. The latter concern, for example, includes the possible underestimation of 19th century removals of sperm whales from the populations using the 'Japan Grounds' by not accounting for removals from other portions of the ranges of sperm whales (see Smith and Reeves, 2003, appendix 2 for a more complete discussion).

In any event, the SC did not focus on sperm whales from the mid-1980s to 1997. In 1998, developments in six key areas were discussed: genetic mark-recapture methods; sightings survey estimates of abundance; population models of past abundance; review of historical catch data; review of sperm whale population regulation; and biological and ecological topics such as life history, social behaviour, ecosystem configurations and current anthropogenic mortality (IWC, 1999). Although the SC agreed then that the developments discussed would justify further consideration of sperm whales in 2000 and 2001, there was no further significant discussion until the 2002 meeting. The present Steering Group was established last year.

At its 2002 meeting, the SC endorsed the idea of planning for an in-depth assessment of sperm whales. The SC agreed that it would be desirable to get the available information organised and reviewed in the next few years and so conduct the assessment some time afterward. This report summarises several reviews of developing new methodology and some field studies, and outlines a process for conducting such an assessment over the next several years. The individuals participating in this planning process are listed in Appendix 1.

Methodological and field study reviews

The Group noted papers summarising key methodological topics and several recent and current sperm whale field studies (Table 1). In addition, the Group noted several other scientific papers that were submitted to the Scientific Committee meeting that addressed other issues and research results (Table 1). The Group considered the summaries of the solicited papers below, but did not review any of the primary papers in detail.

Methodological reviews

The five methodological reviews made available to the Steering Group are reviewed below. Other methodological reviews that were not available include: (1) life history (including age determination); and (2) population dynamics.

SC/55/O12 reviewed methods for studying sperm whale population structure and movements. The authors summarised current knowledge of movements by females and males, and of population structure drawing from Whitehead (2003). Population structure studies reveal differentiation among ocean basins and some population structure within. Movements of both sexes cover substantial parts of ocean basins, and males may breed in different ocean basins from the one in which they were born.

The authors review existing and new methods for determining population structure, noting for each the likely temporal scale over which it would be effective, as well as specific strengths and weaknesses. The methods include morphometrics, morphology, parasites, catch and sightings distribution patterns, patterns in catch or sighting rates, Discovery mark data, photo-identification, contaminant analyses, allozymes, mitochondrial DNA sequencing, and microsatellite distributions. They identify potential uses for many, but not all, of these methods for population discrimination.

The authors also evaluate newer methods under development, including satellite tagging, vocal analyses, trace analysis of tooth sections, single nucleotide polymorphisms and Y-chromosome sequence variation, all of which they judge to be potentially useful although needing testing and improvements

In conclusion, the authors suggest that examination of modal female movement patterns will be most profitable using photo-identification and satellite tagging, while

Table 1

Key methodological topics and selected field projects identified by the Sperm Whale In-Depth Assessment Steering Group, with number of related SC meeting document.

	Topic	SC paper number
	Solicited methodological summaries	
1.	Population structure and movements: genetic, acoustic, marks	SC/55/O12
2.	Population size estimation: sighting and acoustic surveys, photo-id	SC/55/O13
3.	Life history and vital rates, including age determination	Not available
4.	Social structure and effects of differential removals by sex	SC/55/O18
5.	Population dynamics modelling	SC/55/O22
6.	Catch history: 20th century	SC/55/O14
7.	Catch history: pre-20th century	SC/55/O16
	Solicited field study summaries	
8.	Recent and planned field studies in the Gulf of Mexico	SC/55/O15
9.	Sperm whale acoustic and sightings west of Ireland	Not available
10.	Preliminary report on the *Voyage of the Odyssey*	SC/55/O17
	Other papers submitted to SC/55	
11.	Sperm whale occurrence off Peru	SC/55/O11
12.	Sperm whale occurrence in the southeastern Pacific	SC/55/O24
13.	Sperm whale seasonality in breeding	SC/55/O20

genetics and coda dialects will reveal extreme movements. In contrast, while for males these techniques will also likely be useful, satellite tags and tooth layer analysis will likely be the more important. Such data would enable the development of population models based on density dependent habitat selection and spatial diffusion that would be useful in examining the effects of exploitation.

SC/55/O13 reviewed methods for estimating sperm whale population size, including visual and acoustic surveys and mark-recapture. The author identified the principal limitation of visual surveys as accounting for whales that stay submerged while the survey platform is passing. Sperm whales have been shown to vocalise for the majority of the time they are underwater, and in many surveys no whales have been sighted that were not also detected acoustically. A Workshop on acoustic assessment of cetaceans (Anon., 1996) concluded that sperm whales were the most amenable to use of acoustic detection methods.

Three acoustic survey methods were described, two involving passing mode and one involving closing mode. One passing mode survey method estimated range and bearings statistically based on assignment of targets into 45 degree sectors, and does not require determination of the numbers of whales vocalising. Another method used target-motion analysis to estimate range and bearing, but requires an estimate of the number of whales remaining silent during vessel passage. This latter problem is partially overcome by the closing mode survey technique of approaching to obtain a visual count of group size.

The author noted that during joint visual and acoustic surveys the acoustic effective strip-width was greater than that for visual sightings, and that overall acoustic methods may be more cost effective. However, further methodological development of acoustic methods is required to better account for larger group sizes in temperate and tropical regions, and that a combination of visual and acoustic methods may prove to be best.

The author described several localised mark-recapture estimates based on photographic identification using the trailing edge of the tail fluke. The patterns are distinctive and relatively long lasting. A centralised catalogue in the Atlantic and Mediterranean regions contains over 3,400 images from 29 research organisations. Further, the author noted that genetic analyses of tissue samples could also be used to identify individuals. Mark-recapture estimates of sperm whales are subject to the usual problems for cetaceans, but some additional difficulties arise because of the long terms relationships among animals due to the social structure of sperm whales. Nonetheless, such estimates provide the possibility of validating survey based estimates, and may also provide other data on social organisation, movements and demography.

SC/55/O18 reviewed methods for studying sperm whale social structure. The authors summarised current knowledge, drawing from Whitehead (2003). Female and immature sperm whales have been observed to occur in long-term associations (social units) of roughly ten animals, usually comprised of more than one matriline. These units school with other units over a period of days, and communal defense against predators has been observed. Groups of social units occur in clans that possess very similar repertoires of coda vocalisations, and four or five such clans have been identified across the Pacific. Males have been observed in aggregations of 10-25 spread across 10s of kilometres. Large breeding males move between groups of females, and remain in lower latitudes for periods at least of months.

The authors summarised strengths and weaknesses of existing research methodologies, including photo identification, visual behaviour observations, mtDNA and microsatellites, vocalisation analyses and inference and comparisons from other species, all of which have proven useful. They also identify several methods under development that may prove useful for future studies, including advanced genetic studies, acoustic analysis using arrays, satellite tagging and short-term tagging.

The authors suggested two plausible mechanisms for the effects of exploitation on sperm whales. One is that harvest of males may change sex ratios, thereby reducing conception rates. The other is that harvest of females may disrupt stable female social units, affecting female fitness. Although there is no consistent direct evidence for these mechanisms, apparent changes in exploited sperm whale populations have been noted relative to the first possibility and known effects in the behaviourally similar African elephant are suggestive of the second. Developing and testing population models for such effects would be important.

SC/55/O16 reviewed the status of sperm whale catch data prior to the 20th century. Although there was no systematic reporting of catches in this period, public records of voyages and sperm oil returns were recorded for customs purposes, which along with newspaper records and voyage logbooks

indicate that there were approximately 15,000 US voyages in the late 18th through the early 20th centuries (Lund, 2001). Somewhat more limited records are available for fisheries conducted by several other countries. Some of these records have been used previously for population assessment purposes (e.g. see papers in Tillman and Donovan, 1983), and further efforts are underway to validate some of the sources.

Estimates of annual global sperm whale catches have been made based on sperm oil returns, and efforts are underway to improve these. Estimates of catches and various catch rates from two 'whaling grounds' (between Hawaii and Japan and around the Galapagos Islands) exist for selected years, but no estimates for other regions are known.

This paper summarised a workshop conducted in 2002 (Smith and Reeves, 2003) that outlined a research program designed to provide annual regional estimates of catches of sperm whales by all fisheries from the mid-18th century to the early 20th century. This program was designed to make use of voyage logbooks to determine the changing spatial distribution of sperm whaling over time, as well as oil yields per whale caught and numbers of sighted vessels. The largest costs will be reading a representative sample of the roughly 5,000 extant logbooks from the US fishery. Subsequent to that workshop, a complete database of information about each of the US voyages has been assembled. This database will be augmented with information to be obtained from a sample of logbooks proposed to be read in detail, and information on numbers and distribution of sperm whale catches for those voyages will be used to estimate regional annual catches.

SC/55/O14 reviewed the status of sperm whale catch data from the 20th century fisheries, noting that in this century, catches were routinely reported unlike in previous centuries. However, there was significant misreporting for several fisheries that would need to be addressed to complete an in-depth assessment. Of the known misreporting cases, the author focused on those by the former Soviet Union and Japan.

The USSR under-reported sperm whales from at least some of its Southern Hemisphere expeditions for at least 11 years, from the 1961/62 to the 1971/72 seasons. In the North Pacific, total catches were under-reported in the 1960s and 1970s, and more so for females than for males. Although there does not appear to be large scale misreporting since the introduction of the international observer scheme in 1972, our understanding of the degree of USSR misreporting of North Pacific sperm whale catches in the 1950s to 1970s is extremely poor.

Japan misreported sperm whale catches by both small and large-type coastal whalers for several years. Although small-type whalers were prohibited from taking sperm whales, some operations caught this species. Some of the unreported whales were sold to large-type whalers while others were processed at small-type shore stations. The magnitude of under-reporting between 1961 and 1972 was in the order of 50-100 whales per vessel per year, implying that in the roughly 178 vessel-years in this period, the capture of many thousands of sperm whales went unreported. Misreporting by large-type whalers started before WWII, and the magnitude increased in the 1950s-1980s. The nature of the misreporting was more complicated, being motivated initially by size limits and later by catch limits.

The author recommended several studies that would allow improved understanding of life history, population dynamics, body length distribution, and sex ratios of the catches, especially if additional records can be located. Estimating total removals is possible with existing information, although additional geographical and seasonal stratification would be desirable.

SC/55/O22 reviewed previous sperm whale demographic and assessment models and suggested what approaches are the most promising. The author noted that these models have been some of the most complicated ever used to manage living resources, and connects that complexity with the complicated life history and social structure of sperm whales. The limitations in implementing such models have not been lack of model structure, but rather have been the quality and quantity of information used to parameterise them, and lack of understanding of geographic population structure. A major problem has been the reliance on fishery-dependent data.

For demographic models, there are a number of difficulties with estimating natural mortality, calving rates and geographic population structure from fishery-dependent data. Several types of fishery-independent data are now being collected, and other methods are rapidly being developed.

For assessment models, the previous dependence on fishing efficiency data has not proven productive, and alternate approaches are needed. Whitehead and Planck (2002) is identified as a potentially productive approach that is the most likely to provide a meaningful assessment of sperm whale numbers. However, four steps are needed to expand that work: (1) identification of true population structure; (2) accurate estimates of abundance; (3) expanded line transect or mark recapture abundance estimates worldwide; and (4) improved estimation of demographic rates, especially maximum rate of population growth. To expand on this modelling approach will require coordinated data gathering efforts and development of Bayesian models to deal with data and model uncertainty.

Project descriptions

Descriptions of two current field studies of sperm whales were available, and are interesting both in terms of what is being attempted, especially in the methods being used as well as being developed.

SC/55/O15 reviewed an ongoing multi-year study of sperm whales in the northern Gulf of Mexico. Sperm whales have been seen year-round in waters greater than 200m, with clearly identified areas of concentration. Minimum density and abundance estimates have been obtained from sightings surveys. The scope of the research expanded in 2000 from abundance and distribution to include habitat and genetics, biopsy sampling, satellite tagging and short-term acoustic monitoring.

Preliminary results from the expanded study indicate that some whales show small-scale site fidelity, and that there may be haplotype differences between the Gulf and the Atlantic. One satellite tagged whale moved into the southern Gulf of Mexico, where sperm whales are known to occur.

SC/55/O17 reviewed an in-progress five-year field study of sperm whales focusing on establishing sample archives and baseline data on levels and potential effects of synthetic contaminants. In addition, tissue and acoustic samples are being collected, along with collection of potential prey species in samples of regurgitation and faeces. The overall sampling programme will utilise tropical samples from males to infer contaminants levels in polar seas and from females to infer samples from tropical seas.

Sample collection methods were described, including a novel acoustic data logger that has been developed to monitor whale sounds at depth. Also, a non-lethal dosing

protocol using skin biopsy slices has been used to investigate the inducibility of cetacean cytochrome P450 1A1.

Over 700 skin and blubber biopsies have been collected to date. Acoustic detections are made in real time using an acoustic array and logged. A comprehensive analysis of all samples is planned to ensure maximum information is obtained.

SC/55/O12 and SC/55/O18 included brief descriptions of ongoing and planned studies. These included a description of the *Voyage of the Odyssey* (see also SC/55/O17), expansion of the geographic coverage of the coda-clan analysis into the North Atlantic, analysis of movements from photo-identification data in the eastern central Pacific, and several genetic studies based on a worldwide genetic dataset being assembled.

Other project descriptions that are needed include: (1) SOSUS passive acoustic arrays; (2) acoustic and sighting surveys reviewed by Whitehead and Planck (2002); (3) IWC Scientific Committee fishery dependent data analyses and modelling from the mid-1960s to mid-1980s; and (4) sperm whale acoustic and sightings distributions from the west of Ireland.

Other information available

SC/55/O11 described seasonal observations of sperm whales off Peru between 1995 and 2002, raising questions about previous reports highlighting concern over sperm whales in this area and in Ecuador. The author identified an urgent need for further cetacean oriented surveys in the Southeast Pacific Ocean.

SC/55/O24 identified the possible threat to recovering sperm whales in this region due to its reliance on the Humboldt Current squid, which is subject to a developing fishery.

SC/55/O20 demonstrated the potential use of foetal length records to identify regional seasonality of breeding of sperm whales, with potential application to determining breeding structure.

During discussions, Fortuna and Lauriano summarised recent information on sperm whales in the Mediterranean. They noted that the IUCN had identified sperm whales as vulnerable, and more recently ACCOBAMS has listed a basin-wide Mediterranean sperm whale survey as an action item. They noted that in the 1980s and 1990s there have been contemporaneous declines in reported bycatches and a marked drop in apparent density of sperm whales in the southeastern Tyrrhenian Sea.

A proposed In-depth Assessment process

The Working Group noted the rapid development of new research methods that are allowing a substantial increase in our understanding of this species, the existence of several major field programmes around the world, and the strong scientific as well as conservation interest in this species. The Working Group recognised that considerable new information would need to be collected using several of the developing methodologies before it would be productive to conduct an In-depth Assessment. Further, it recognised that while there is considerable interest, the priority for work on this species would likely be lower within the SC for the next several years.

To begin work toward an In-depth Assessment, the Working Group recommended that the most useful approach would be to conduct an In-depth Assessment planning workshop. The expectation would be that this workshop would identify the key new methodological developments, identify critical tests of these methods that would be needed and describe how these might be conducted, especially using combinations of new methods simultaneously. Further, the workshop would endeavor to identify relevant spatial scales for conducting regional field studies that would answer key uncertainties identified in the review of information that an In-depth Assessment would eventually have to address. Successful completion of an In-depth Assessment would depend on appropriate field studies and analyses being completed, perhaps over a period of several years.

The major steps in this process would be:

(1) Contract with someone familiar with the IWC assessment process to summarise the current information available on sperm whales[1].
(2) Conduct an In-depth Assessment Planning Workshop according to the draft agenda below to review methods and identify geographic focus and needed field studies.
(3) Encourage coordinated fieldwork to address information needs in geographic areas of focus.
(4) Conduct In-depth Assessment.

The major thrust of the workshop would be a review of methods for each of the topics required for conducting an assessment, review of existing and future information sources and needs, and development of recommendations for field programmes (a draft agenda is given in Appendix 2).

The information summary can be conducted immediately. The In-depth Assessment Planning Workshop would likely be best conducted in the autumn of 2004. Coordinated fieldwork would occur following that, and may require 2-3 years. Thus the In-Depth Assessment could be completed no sooner than 2007 or 2008.

Feasibility

The group anticipates that increasing interest in pelagic ecosystems and the role of top predators in them, along with increasing accessibility due to development of new methods, will encourage funding for key aspects of the In-depth Assessment process outlined. For example, several substantial field projects are described above, both at regional levels and more generally. In addition, the Census of Marine Life sponsored by the Alfred E. Sloan Foundation has a strong component on historical issues, especially 18^{th}-19^{th} century whaling. The SC itself has been working toward completing 20^{th} century catch data for several years. There are concerns about the status of sperm whales in several areas, including the degree of recovery from previous whaling both globally (Whitehead and Planck, 2002) and regionally, as well as increasing concern about cetacean-fisheries interactions and the effects of acoustics on odontocetes. While there is no assurance of funding for such an ambitious undertaking, there are possibilities that the working group judged worth pursuing.

Budget and Venue

Costs for initiating this process include a contract for a review of assessment related information and travel costs for the In-depth Assessment Planning Workshop (covering of travel costs for roughly half of the anticipated 25-30 workshop participants). The group identified the success of several recent workshops that began with a public symposium followed by a smaller workshop, and suggested

[1] A useful starting point would be Whitehead (2003).

that such an approach would require a total of 4-5 days. Several potential locations were identified, including sites in the Caribbean, the Mediterranean and at the New Bedford Whaling Museum in Massachusetts, USA, as well as conducting it in conjunction with another meeting such as the European Cetacean Society.

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Appendix 1

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Appendix 2

DRAFT AGENDA FOR A WORKSHOP TO DEVELOP AN IN-DEPTH ASSESSMENT OF SPERM WHALES

Terms of Reference:

(1) Identify and evaluate key new methodological developments, identify critical tests of these methods that would be needed and describe how these might be conducted, especially using combinations of new methods simultaneously.
(2) Identify relevant spatial scales and formulate plans for conducting regional field studies that would answer key uncertainties that an In-depth Assessment would eventually have to address.
(3) Develop a research programme that would be necessary and sufficient as a basis for an In-depth Assessment of the status of sperm whales, including identifying research coordinating and funding mechanisms.

Draft Agenda:

1. Election of Chair and appointment of rapporteurs
2. Review terms of reference, agenda and available documentation
3. Review of methods for:
   - 3.1 Population structure and movements
     - 3.1.1 Tagging
     - 3.1.2 Genetic (sources of samples: e.g. teeth, biopsy, skin, faeces)
     - 3.1.3 Acoustic
   - 3.2 Abundance and distribution
     - 3.2.1 Sighting and acoustic surveys
     - 3.2.2 Individual identification: photographic, genetics
     - 3.2.3 Genetic diversity
   - 3.3 Life history
     - 3.3.1 Age determination
     - 3.3.2 Vital rates
     - 3.3.3 Social structure
   - 3.4 Population ecology
   - 3.5 Modelling
   - 3.6 Catch history
     - 3.6.1 Post-1920
     - 3.6.2 Pre-1920
   - 3.7 Field use of methods in combination

4. Identification of major information sources
   - 4.1 Review field programmes and data sources
     - 4.1.1 Previous
     - 4.1.2 Current and planned
   - 4.2 Review of previous and planned analyses
     - 4.2.1 Fishery-data-dependent
     - 4.2.2 Fishery-independent
     - 4.2.3 Combined
5. Identification of major field studies and data re-analysis projects
   - 5.1 Necessary spatial scales
   - 5.2 Candidate field study areas
   - 5.3 Data re-analysis projects
6. Determining approaches for implementing the research programme
   - 6.1 Identify agencies with potential interest
   - 6.2 Identify cooperative research projects that could attract funding
   - 6.3 Identify research coordination mechanisms
7. Review and finalise report