FINAL REPORT

PROJECT TITLE: Feasibility Study Into the Establishment of a Permanent Regional Fish-Ageing Centre in One of the BCLME Countries.

PROJECT NUMBER: LMR/CF/03/01

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EXECUTIVE SUMMARY

This report documents a study aimed at assessing the need for and feasibility of establishing a centralised fish age determination facility in one of the BCLME countries (Angola, Namibia and South Africa). The contracted investigators were also tasked with making recommendations for the terms of reference, structure (both administrative and infrastructural) and location of the facility, as well as evaluating the costs associated with the establishment and operation of the facility. The approach adopted during this study was to identify, through broad consultation with relevant personnel, the age data required by the national fisheries management authorities in each country, as well as the current capacity for age determination in each of the three countries (including human resources, infrastructure and financial commitments). This information was then used to establish whether or not the current capacity for age determination in each country is sufficient to fulfil the age data requirements in the long term, and hence whether or not a central age determination facility is required in the Benguela region.

Current age data requirements for IIM in Angola comprise approximately 1 750 age determinations from 7 species per annum, all data to be obtained from analyses of sagittal otoliths. The requirements for NatMIRC (Namibia) and MCM (South Africa) are considerably more extensive, comprising 23 and 47 species respectively, with data being obtained from a variety of different hard structures, including otoliths, vertebrae, fin rays and statoliths. Several of the species are (or will be) assessed at intervals of between 3 months and 10 years, reducing the number of data that are required within any given year. However, different methods of preparation and analysis of the samples are employed, involving different time and labour constraints. In order to quantify the age data requirements in a meaningful manner, they were expressed in terms of the number of working days (man-days) that would be required for a well-trained, experienced researcher to generate the required data (including a quality control component).

The results of this assessment indicated that generating the necessary age data for Angola, Namibia and South Africa required about 148, 312 and 1 219 man-days respectively. Human resources at IIM and NatMIRC are potentially sufficient to fulfil the age data requirements at present, provided adequate training is supplied. Human resources for age determination at MCM are presently completely inadequate, even if currently vacant age determination positions are filled. In terms of space (buildings), resources at NatMIRC are sufficient, and to a lesser extent, sufficient at IIM as well. This is not the case at MCM where space for age determination is insufficient. Equipment and technical support is sufficient in all three institutions, although both IIM and NatMIRC have limited access to specialised technical support. The availability of specialised materials is limited in Namibia, and almost non-existent in Angola.

It was concluded that Angola and Namibia have sufficient overall capacity to generate the required age data, although training of personnel is urgently required to realise this capacity. South Africa, in contrast, will not be able to generate the required age data, and this situation is unlikely to be rectified in the foreseeable future. Considering the history of age determination in the Benguela region over the past few decades, and specifically the dramatic staff fluctuations that have occurred, it was concluded that the implementation of a centralised age determination facility in the region is imperative if fisheries management authorities are to have access to the consistent age data that are required for stock assessment purposes in the long term.

Recommendations regarding the structure and function of an age determination centre appropriate for the Benguela region, as well as an evaluation of the costs of implementation and long-term operation of the centre are provided in the report. Key recommendations are:

- The activities of the centre should be, at least in the short- to mid-term, restricted to the processing and analysis of samples of those species that are of commercial importance in the region, and therefore require assessment and management by the national fisheries management authorities in each country.
- The centre should be responsible for the production of all age data required by the national authorities in the three countries, and this service should ultimately be paid for by each country on a non-profit, “cost-per-otolith” basis.
- The centre should not be owned by any particular country or institution, but should rather by a joint venture between the three countries that falls under the administrative umbrella of BENEFIT, BCLME or the future Benguela Commission.
- In an attempt to minimise the costs of establishing the centre (specifically rental costs), it is recommended that the centre be located at one of the three national fisheries research institutions. At present, NatMIRC represents the most favourable option because of space availability. Although MCM would be more suitable in terms of access to specialised facilities and supplies, there is currently no space within MCM suitable for the centre.

An evaluation of the costs associated with establishing the centre indicated that an initial outlay of ZAR 1 135 300 is required for capital equipment and materials. In the long-term, equipment maintenance and materials are anticipated to cost in the region of ZAR 280 000 per annum. In terms of employment of staff, costs are estimated to be as follows

- First 6 months (establishing the centre and training) ZAR 675 000
- The following year (continued training) ZAR 1 640 000
- Long-term per annum (subject to inflation compensation) ZAR 1 510 000

It is anticipated that the centre would attain full operational status within 1.5 to 2 years after being established. Annual operating costs would be recovered from the national fisheries management authorities through provision of reliable age data by the centre.

BACKGROUND

Benguela Current Large Marine Ecosystem (BCLME) Programme is a multi-sectoral regional initiative by Angola, Namibia and South Africa whose objective is to facilitate the integrated management, sustainable development and protection of this unique eastern boundary current upwelling ecosystem. It is funded by the Global Environmental Facility (GEF) under its International Water portfolio and is implemented by the United Nations Development Programme (UNDP) with the United Nations Office for Project Services (BENEFIT) as executing agency. The three member countries provide further financial and in-kind contributions.

Joint assessment of shared commercially important fish resources is the key requirement for the sustainable management of these resources. This is recognised in the Strategic Action Program (SAP) signed by the Ministers of the three countries responsible for fisheries and ocean governance. The use of reliable ageing data in stock assessment models is an essential and basic element of this. Currently, age determination procedures for exploited species are inadequate. The *status quo* is a major shortcoming in the stock assessment of the shared commercial species hake, sardine and horse mackerel, and therefore requires urgent attention. Further, BCLME countries have no sufficiently developed capacity (human, institutional, infrastructural) required to support meaningful stock assessments, particularly in respect of the validation of age determination methods being employed. In addition, the methods of collection of ageing data by the researchers from three countries are not standardised, making comparisons of the results difficult. A call for a regional centre dedicated to fish age determination was made 6 years ago by former Marine and Coastal Management scientist Dr. M. Kerstan, but the potential implementation of such a centre has not been explored. Considering the current situation with regard to fish age determination in the region, it has been recognised that a centralised age determination facility may well be the most suitable option for addressing this limitation. The project described in this report represents an initiative by BCLME to assess the feasibility of establishing such a centralised age determination facility in the Benguela region.

OBJECTIVES

The specific objective of this project is to assess the feasibility of establishing a regional ageing centre in the BCLME countries including an assessment of needs and an assessment of the financial and infrastructure implications.

SCOPE:

- Investigate the needs and the justification of establishing a regional ageing centre in the BCLME countries
- Identify appropriate resources (materials, financial, human, infrastructural) necessary for the implementation and long-term operation of such a centre (assuming it is feasible)
- Assess the most appropriate location of the centre
- Consider how the centre will be administered, including the terms of reference for the centre and issues related to ownership.

It should be emphasized that this assessment of the need for a regional ageing centre is restricted by the national requirements for age data in the region. Only the important, commercially exploited fish species that are managed by the relevant departments in the national governments of the three countries, and for which age data are a critical requirement for representative stock assessment procedures on which management decisions should be based are therefore considered in this study.

APPROACH

The approach and work plan was divided into two components, each component directed at answering the two key questions inherent in the Terms of Reference of this project, namely:

a). How beneficial is a central fish age determination centre for the BCLME region?

To answer this question, each of the national institutions was investigated with the intention of:

i. Identifying the age data (prioritised) that are currently required by the institutions for effective stock assessment purposes (as well as projected future requirements). Specifically: species, number of age data required, sampling intervals, required levels of accuracy and precision.

ii. Establishing whether or not the institutions are currently in a position to provide this data by assessing the current capacity for routine age determination in the region, in particular numbers and experience of staff, equipment status, access to specialized equipment and facilities, technical support, and present financial commitment of the national government authorities to sustain the present number of staff members presently involved in age determination.

iii. If the institutions are currently in a position to provide this data, it will be established whether or not this situation is likely to continue in the long term (considering problems experienced in the past).

iv. If the institutions are not in a position to provide this data, it will be established whether or not the required age data are sufficiently important (in terms of sustainable utilization of the exploited fish resources) to justify the expense of establishing a regional ageing centre capable of generating these data.

b). If a regional age determination centre is required, how should it be structured and administered?

This second key question aims at a set of recommendations for an age determination centre model appropriate for the region. A visit to an international regional ageing facility that is partially or fully self-sustaining, was considered to be essential for this purpose. The Central Ageing Facility in Victoria, Australia, was identified as to be such a facility. A comparison (in terms of both funding and administration) is made with other facilities that are governmental or semi-privately funded in order to explore the most suitable option for the Benguela region.

ASSESSMENTS AND RECOMMENDATIONS

1. DATA COLLECTION

Information was collected by consultation with relevant staff members from four different institutions:

- Instituto de Investigação Marinha (IIM) in Luanda, Angola,
- National Marine Information and Research Centre (NatMIRC) in Swakopmund, Namibia,
- Marine and Coastal Management (MCM) in Cape Town, South Africa,
- Central Ageing Facility (CAF), Queenscliff, Australia

A unified approach was adopted to ensure that the data would be both meaningful and comparable. For this purpose, Dr. Kerstan developed a “Facility Assessment Questionnaire” (see Appendix 1) that was distributed to all investigators to be used as a template for the data collection phase. The completed Facility Assessment Questionnaires (FAQs) for each institution (MS Word documents), as well as a spreadsheet summary of the age data requirements of each institution (MS Excel file “AgeDataRequirements.xls”) accompany this report in electronic format. Because the Central Ageing Facility in Queenscliff, Australia is used as a model for a self-sustaining, regional age determination centre, information felt to be of relevance is presented in the next section (section 2) before attention is directed to the Benguela region (section 3).

2. THE CENTRAL AGEING FACILITY, AUSTRALIA: REPORT OF A VISIT BY M.D. DURHOLTZ.

2.1. Rationale:

The BCLME/BENEFIT project LMR/CF/03/01 has two primary objectives. The first of these is to establish whether or not a centralised fish age determination centre is required in the Benguela region. If such a centre is required, the second objective of the project is to make a recommendation regarding the structure (in terms of infrastructure and administration) and mandate of the centre. In order to satisfy the latter objective, it was felt that a visit to an international facility tasked with routine, production age determination would be highly beneficial. The Central Ageing Facility (CAF) in Victoria, Australia, was identified as being an appropriate model for obtaining information relevant to this objective. The primary reason for this identification was that the CAF is essentially a self-sustaining facility that routinely processes and analyses in excess of 20 000 otoliths each year, generating age data for more than 20 species of fishes. Further, CAF has been in operation since 1991, indicating that the facility does provide a valuable service, and has been cost-effective in the long term. This section documents the fact-finding visit to CAF by Dr. M.D. Durholtz on 28 and 29 October 2003, presenting information that is felt to be of relevance to the implementation of a centralised age determination facility in the Benguela.

2.2. History of CAF:

Prior to the establishment of CAF, fish age determination procedures in Australia were relatively fragmented, with one or two researchers in various laboratories involved in fish ageing. In several cases, different researchers in different laboratories were ageing the same species of fish with little or no collaboration or sharing of expertise. When staff fluctuations occurred, there was little or no “overlap” or continuity, with substantial loss of expertise and knowledge. In view of Australia’s extensive fisheries, the lack of cohesive age determination programmes to provide age data fundamental to stock assessment (and subsequent management) was identified as a serious shortcoming.

Dr. David Smith (currently director of MAFRI in Queenscliff, Victoria) lobbied extensively for the establishment of a centralised age determination facility where expertise and knowledge could be consolidated, retained and efficiently used. The federal fishery management body (Australian Fishery Management Authority, AFMA) recognised the value of such a facility, and the funding was made available for the establishment of CAF. The question then arose as to where to situate CAF and how to administer the facility. Because Dr. David Smith, by then director of MAFRI in Victoria, had been largely responsible for the concept of CAF, the decision was made to establish CAF at the Queenscliff branch of MAFRI, Dr. Smith agreeing to oversee the implementation of the facility. CAF was established in 1991. Construction of a new MAFRI complex is currently underway in Queenscliff, and it is expected that the new institute will be completed by mid-2004.

2.3. CAF ADMINISTRATION AND FUNDING:

Subsequent to the establishment of CAF, the administration of the facility has fallen under the MAFRI (Marine and Freshwater Institute) umbrella. MAFRI currently falls within the Department of Primary Industries of the Victoria State Government. Although MAFRI became a corporation in 1996, it was subsequently drawn back into the state government, but still operates largely as a business, having an annual operational budget of A$ 10.5 million. Although State and Commonwealth provide for 45% and 22% of MAFRI funding respectively, the balance is sourced from external contracts. The Queenscliff (marine) branch of MAFRI currently employs 85 staff members, and runs 7 programmes. CAF falls within the Offshore Fisheries Programme, and operates as a largely self-sustaining facility. All funds are generated through routine age determination. Approximately 25% of the funds generated by CAF operations are ceded to MAFRI to fund support services (e.g. the library, LAN server and IT support). However, MAFRI also represents a financial buffer for CAF, having some capacity to cover CAF operations when insufficient income from external contracts is generated by the facility.

When CAF was first established, two sources of funding were made available to assist in the development of the facility. The national fisheries research and development body (currently the Fisheries Research and Development Corporation) provided the funds for the purchase of equipment. In addition, AFMA provided sufficient funds to employ researchers and cover operating costs for an 18-month period. Subsequently, AFMA has committed to further support of the facility by ensuring that the provision of all age data requirements for the management of the South East Fishery (SEF) in Australia are contracted to CAF. Funds generated through SEF age determination (11 species, approximately 11 000 otoliths per annum) currently cover approximately 45% of the facility's operational costs. The balance of the operational costs is obtained from "external" contracts. These include age determination for CSIRO (Commonwealth Scientific and Industrial Research Organisation), other marine research facilities and programmes in Australia as well as international contracts such as orange roughy ageing for New Zealand and a multi-species age determination project for Saudi Arabia. Currently, CAF processes and analyses a total of between 20 000 and 25 000 otoliths from about 20 different species of fish per annum.

2.4. CAF INFRASTRUCTURE:

2.4.1. Staff:

CAF currently employs 6 staff members:

Position	Qualification	Duties	Experience
Director	Completing Ph.D.	Administration, marketing, scientific leadership, writing of reports, periodic age determination when required.	10 years age determination of tropical fish species
Head Technician		Processing, preparation and analysis of otoliths when required, preliminary data analysis. Equipment maintenance. Leading and supporting research.	13 years of routine age determination of 25 fish species
Senior Technician	B.Sc.	Processing, preparation and analysis of otoliths, preliminary data analysis, preparation of reports.	10 years of routine age determination of 25 fish species
Senior Technician	B.Sc.	Processing, preparation and analysis of otoliths, preliminary data analysis, preparation of reports.	7 years of routine age determination of 20 species.
Junior Technician	B.Sc. (Hons.)	Processing, preparation and analysis of otoliths, preliminary data analysis.	2 years of routine age determination of 10 species
Junior Technician	B.Sc. (Hons.)	Processing, preparation and analysis of otoliths, preliminary data analysis.	1 year of routine age determination of 2 species

Only three members are permanently employed at present (Head and Senior Technicians), while three are employed on a contractual basis (Director and two Junior Technicians). That several members are employed on contract reflects the MAFRI policy that all new employees are first employed on contract for a three-year period before they can fill a permanent position. Inter-personal relationships within the facility are excellent, staff members continuously consulting with each other at all levels. According to the Director and other members of MAFRI, the success of CAF can be largely attributed to the extensive staff co-operation and interaction that has induced a stimulating work environment in CAF, fostering the retention of experienced personnel within the unit. The levels of expertise and enthusiasm displayed by all staff members both contribute to, and are a result of this favourable work environment.

2.4.2. Buildings:

At present, CAF has full access to a dedicated age determination laboratory of approximate dimensions 8m x 4m, and an adjoining storage area of approximately 2.5m x 2m. This laboratory has sufficient space for 5 workstations with extra bench space for storage of samples in the process of being prepared and analysed. CAF staff members also have shared access to three other laboratories. The first, adjoining the dedicated age determination laboratory, is used for weighing of otoliths and has an additional workstation for compound microscope work. The second laboratory, equipped with a fume cabinet and extraction system is used for resin work (i.e. embedding of otoliths). The third laboratory is a wet laboratory containing the otolith saw used for sectioning of otolith samples. One office is dedicated to the director of CAF, while a guest office is available in the Institute. Facilities shared by all members of the Institute include a library, conference room, kitchen/tearoom, several workshops and storerooms. A car park is also available at no cost. At present, sufficient space is available for all of CAF's activities. The only negative (which is minor), is that the wet laboratory is spatially separated from the main, age determination laboratory. In the new institute currently under construction, however, the space allocated to CAF is not fragmented at all, all laboratories and offices adjoining in each other. The new ageing laboratory (11m by 8m) will have sufficient space for 6 or 7 workstations and a compactus for storage of samples. The preparation laboratory will be 5m by 3m, and the weighing room will be 3m by 3m in size. Space in an adjoining wet laboratory is available for the otolith saw.

2.4.3. Equipment and Materials:

CAF own 4 dissecting microscopes (Wild MC3), each equipped with a phototube, as well as 2 analytical microscopes equipped with phototubes, one of which has fluorescent capabilities (filters for OTC, alizarin and lipofuscin). All microscopes are equipped with transmitted light sources, and 5 incident light sources are also available. All microscopes are cleaned and serviced once per annum. The facility owns 5 image analysis systems (IAS); these include 4 CCD colour video cameras mounted onto each of the dissecting microscopes (and which can also be mounted on to the fluorescent analytical microscope) that are interfaced to personal computers via colour frame grabbers, as well as a digital still camera for low light intensity work that is mounted on an analytical microscope and is interfaced to a PC with special image analysis software for lipofuscin analysis. The image analysis software used by the facility is "OPTIMATE", a module of "OPTIMAS" that has been customized (macros and file options) specifically for CAF operations. Data collected during routine CAF activities are automatically saved in Excel worksheets using DDE (dynamic data exchange). The personal computers used by CAF are all leased through the Department of Primary Industries (from which IT support is available 24 hours per day), and are periodically upgraded. All PCs are networked through the MAFRI LAN, facilitating data collection and storage. All files stored on the server are backed up daily. An additional workstation (dissecting microscope, IAS and PC) will be available when CAF moves to the new institute. The facility owns a microbalance that is interfaced to a PC, facilitating the semi-automatic collection of otolith weight data (otoliths are routinely weighed during processing).

CAF has two otolith saws (with several spare blades), as well as sufficient silicone moulds and resin (clear polyester casting resin) for the embedding of otoliths. A drying oven is available for accelerating resin polymerisation. Although CAF does not burn otoliths, an oven capable of temperatures sufficient for this purpose is available within the institute. All other consumables (otolith saw blades, resin, stationery, storage boxes, microscope slides and cover slips etc) are readily available.

2.5. CAF OPERATIONS AND PROCEDURES:

2.5.1. Activities:

The primary activities of CAF are routine age determination of up to 25 fish species from otolith analysis. Analyses of fin rays or dorsal spines are also routinely conducted, as are daily age determination of squid from statoliths. Some work on scales is also done, but this is primarily Fourier transformation analysis for stock discrimination studies (North American salmon research group). The facility has also recently been employing lipofuscin technology to estimate the age of octopus and giant crab.

2.5.2. Costing:

Whenever tendering for an age determination contract, CAF first considers the species involved, and specifically the processing and analytical procedures that are required to generate representative age data. Given knowledge of the time required to complete the specific processing and analytical procedures, CAF can then estimate the time required for a researcher to complete the processing and analysis of the samples. The cost of employing the researcher (i.e. salary) is expressed as an hourly rate (assuming 1 824 working hours per annum) that is used to calculate the cost of employing the researcher for the time taken to complete the sample. An additional 10 to 25% of this total is added to cover materials and running costs (equipment etc), depending on the size and nature of the sample, as well as data quality control procedures (see below). On average, CAF charges about A$ 16.00 per otolith, although this varies depending on the difficulty associated with preparing and analysing the material.

2.5.3. Sample Processing, Preparation and Analysis:

All otoliths are sent to CAF, usually in paper envelopes. Once the otoliths arrive at CAF, they are registered on the CAF database (MS Access); each otolith is given a unique, 9 digit reference number of the form SSS_BBB_NNN, where SSS = species code, BBB = batch number and NNN = otolith number. The otoliths are then weighed (the data automatically downloaded into an ASCII text file that is subsequently imported into the database) and embedded in clear polyester casting resin. To increase efficiency, the otoliths are embedded in rows so that up to 5 otoliths can be sectioned with the otolith saw simultaneously. This process is, however, species dependent. Orange roughy otoliths, for example, are individually embedded and sectioned. Four sections are taken from each specimen to ensure that at least one specimen will include the primordium of the otolith. The sections (with a descriptive label) are then mounted on microscope slides with resin and cover slipped for later analysis.

Otolith analysis is conducted using the IAS. A colour image of the specimen is viewed within "OPTIMATE" on the PC monitor. The size of the image is automatically calibrated within "OPTIMATE". Annuli, supernumerary growth features and other zones are manually marked along an axis extending from the primordium to the edge of the otolith. The software automatically counts the various features, measures the distance between them and downloads the results into an Excel worksheet using a dynamic data exchange (DDE) protocol. During the analysis, the reader also enters a subjective rating of the readability of the otolith on a scale of 1 to 5. All files are archived on the LAN server and backed up daily. In most cases, all otolith samples are archived and stored at CAF (with the exception of those where the clients require that the material be returned to them).

2.5.4. Quality Control:

When a batch of otoliths arrives at CAF, the technician tasked with analysing the material first retrieves an earlier batch of the same species (and from the same geographical location if possible) from storage, and re-reads a random sub-sample of at least 100 otoliths. Results are compared to the original estimates and an index of average percent error (APE) calculated. If the APE is not satisfactory (> 5%), the process is repeated until the reader achieves a satisfactory level of precision. The new batch is then analysed. A minimum of 25% of the new batch is re-read (in the case of small samples < 200 otoliths, the entire batch is re-read), and the index of APE is calculated. A regression of first on second readings is also conducted, with statistical testing of the intercept (a=0) and slope (b=1) of the model. If the precision of the readings is not satisfactory, the process is repeated until suitably precise age estimates are obtained. All this information is included in the final report submitted to the clients. An additional measure implemented by CAF is the use of otolith exchange programmes. Samples are exchanged between CAF and other researchers (such as CSIRO in Tasmania and NIWA in New Zealand) to ensure that the readers within the various institutions are generating comparable results. CAF is also in the process of generating reference collections for the species routinely analysed by the facility. This material will be separately stored and archived, facilitating the "re-calibration" of readers when new material is sent to CAF.

2.6. KEY FACTORS CONTRIBUTING TO THE SUCCESSFUL ESTABLISHMENT AND CONTINUED OPERATION OF CAF IN THE LONG TERM:

- The initial funding boost described above was critical to the successful establishment and early operation of CAF. Apart from the availability of funds to purchase the required equipment and materials, sufficient funds to employ good staff for a reasonable period was probably the primary factor contributing to CAF's success during the early period. Considering that a certain amount of time is required for such a facility to become known within the field, it is critical that there is a funding source for the initial period during which not many contracts will be forthcoming. The ongoing commitment of AFMA to use CAF for analyses of otoliths from the South East Fishery contributes substantially to CAF's long-term continuation.
- Staff: This is probably the single most important factor contributing to CAF's success. Age determination requires very specialized skills and inherent talents, specifically the ability for consistent pattern recognition. This cannot be overemphasized. While researchers can be trained to a certain level, it is this pattern recognition ability that is fundamental to age determination. Considering further that routine age determination is not an intellectually stimulating activity, an enthusiasm for the task is an additional requirement if readers are to be retained. CAF has been very fortunate in that it has managed to obtain and retain several researchers who display very high pattern recognition abilities, as well as an enthusiasm for the task that generates an exceptionally rare, stimulating work environment. It is unlikely that these researchers would have continued routine age determination if they had been working in isolation. Because these researchers are working as a group in close proximity to each other, the combination of specialized skills, good inter-personal relationships and continual exchange of ideas and expertise within the group contributes to the stimulating work environment. It is extremely unlikely that the same levels of commitment and enthusiasm would have been retained if the researchers had been operating in isolation.
- The centralization of these age determination skills is a key factor in CAF's success. When new species are being analysed by the facility, the collective expertise of the group facilitates efficient and reliable analyses of the material.
- Computing: The efficient database, network and good technical support enjoyed by CAF is vital to efficient data handling and archiving. Due to the large amounts of data generated during production age determination, efficient archiving of data is critical. The ability to rapidly search for, identify and extract relevant data is crucial.
- Storage and archiving of samples: Sufficient space for storage of otoliths is critical. Considering that most of the samples are retained by CAF (CAF currently has over 300 000 otolith samples in storage), space for the storage of this material is required. Further, the samples have to be efficiently archived. The major reason for this is that if during routine age

determination data start displaying differences in growth for example, effective quality control protocols require that previous samples be re-analysed to ensure that the differences are real, rather than a function of reader drift. The ability to rapidly identify which samples should be re-read, and then extract these samples from storage greatly improve overall efficiency. Implicit in this is the appropriate archiving of reference collections.

3. ASSESSMENT OF THE NEED FOR A CENTRALISED AGE DETERMINATION CENTRE IN THE BENGUELA REGION

This assessment attempts to establish whether or not the requirements for fish age data identified by each of the national institutions can be fulfilled by the current capacity for age determination in the region (i.e. human resources, infrastructure, technical support). Although it is relatively simple to quantify both age data requirements and capacity, relating the two aspects is not a clear-cut issue. From the data requirements perspective, species will differ in terms of the difficulties associated with the collection, preparation and analysis of the samples. The time and effort required to obtain the relevant data is therefore not reflected in the number of data required in each case. Further complications are that the frequency with which age data is required for the various species varies considerably (every ten years in many cases), and for several species there is uncertainty concerning the number of data required. This makes it difficult to quantify the number of data per annum (which is perhaps the most useful way of quantifying and assessing data requirements). In an attempt to resolve these difficulties, the assessments described in section 3.1 below attempt to categorise each species in terms of the difficulties associated with the preparation and analysis of the samples, and then quantify the time and effort required by a well trained, experienced researcher to generate the age data for each category. Where uncertainty concerning the number of data required (and/or the reporting frequency) exists, we have assumed likely values for the purposes of this assessment. It should therefore be noted that the requirements discussed in the following section are not exact. We do feel, however, that the assessment provides a realistic estimate of current age data requirements, and hence the capacity that is needed to fulfil them.

Quantifying and assessing the infrastructural components of capacity (buildings, equipment etc) is a simple task, but this is not the case with regard to human resources. This is because the level of expertise (and to a certain extent, experience) of an individual is not a factor that can be readily quantified. Individuals vary in terms of their technical skills, a factor that will impact on the time required to prepare samples, and more importantly, on the success rate and quality of the resultant preparations. Adequate training in the technical aspects can resolve this problem, but this does not apply to the analytical component, specifically the analytical skills of the individual. Age determination of this nature requires an inherent talent that is perhaps best described as “pattern recognition ability” - an innate ability to consistently identify the features that are used to estimate age. Further, in view of the rather monotonous nature of routine age determination, enthusiasm and a genuine interest in the work is a fundamental requirement. If the researcher or technician does not display these attributes, the impacts on the data that are generated will be profound. Consequently, the only reasonable means of assessing the human resources component is through examination of the performance of the personnel over an extended time period. In view of the drastic lack of personnel currently dedicated to age determination in the Benguela region (see section 3.2), such an assessment cannot be reasonably made at present.

3.1. CURRENT SCIENTIFIC REQUIREMENTS FOR AGE DATA IN THE BENGUELA REGION

The age data requirements for each of the three countries in the Benguela region are summarized in Tables 3 to 8 below. The species list has been limited to those that are considered to be either critical (these data are required immediately) or important (data that although not critically needed at the moment are likely to become critical within the next 1 to 2 years). With one exception, the data that are required are year classes or age groups (reported as age length keys) for use in stock assessment models (specifically age structured production models, yield per recruit models or yield per spawner models). The only exception is that of chokka squid in South Africa, where the data required are daily ages for use in hatch-date analyses and growth modelling.

In order to assess these requirements in a meaningful manner, it is useful to express them in terms of the time that would be required by a well trained, experienced staff member to generate the data. To accomplish this, two factors were quantified and categorised accordingly. The first factor, "Preparation", refers to the time required to prepare the samples for analysis. In Tables 3, 5 and 7, it is apparent that 5 basic "categories" of preparation methods are involved. These categories are summarized in Table 1. Each category involves one or more stages of processing. The time to process 500 specimens during each stage was estimated, and the total for each category was computed to generate an estimate of the preparation time expressed as "man-days per 500 specimens", the 500 referring to the number of structures (otoliths, vertebrae etc) involved. This conversion factor could then be used to estimate the time that would be required to prepare the given number of specimens for each species.

Registration ("Reg", Table 1), involves sorting specimens, assigning unique reference numbers and entering support data (biological and catch information etc). This is a process that is common to all samples processed for age determination purposes. We feel that up to 250 specimens can be registered during a normal working day, irrespective of the species. A technique that is employed by all three institutions to enhance the structural features of interest in certain species is the burning of specimens (usually otoliths). All three institutions have access to laboratory ovens capable of the temperatures required for this purpose. It was therefore assumed that with adequate organization and access to sufficient burning trays, up to 500 specimens can be burnt over an 8-hour period (1 working day). In many cases, samples are embedded in clear polyester resin, either to enhance features (for example, sardine and anchovy otoliths are embedded in resin with a black background to enhance contrast), or to facilitate handling and provide support to the structures during subsequent treatment (i.e. slicing or sectioning). From previous experience of the investigators, up to 5 days may be required to embed 500 specimens.

Table 1: Estimated time of sample preparation (man-days per 500 specimens) for each of the five preparation categories ("Prep. Cat.").

Prep. Cat.	Description	Reg.	Burn	Embed	Slice	TOTAL
A	No preparation	2	-	-	-	**2**
B	Embed only	2	-	5	-	**7**
C	Embed + slice and mount	2	-	5	2.5	**9.5**
D	Burn + embed + slice and mount	2	1	5	2.5	**10.5**
E	Embed + section, mount and polish	2	-	5	25	**32**

Once the specimens are embedded in resin, most species require that the structures be sliced, generating a thin section of the specimen in which the features of interest are clearly visible, unobstructed by surface irregularities. This is accomplished using an otolith saw. At CAF, a single-blade saw is used, and several sequential cuts are made through the specimen to ensure that at least one of the slices will be from the correct central location in the structure (*i.e.* through the nucleus in the case of otoliths). Another approach is to use a multi-blade saw, where a single cut can generate several parallel slices, one of which is precisely located. The slices are then mounted on microscope slides for subsequent viewing and analysis. With sufficient training and experience, it is reasonable to assume that a well-trained staff member can slice up to 200 specimens during a normal working day (*i.e.* 2.5 days for 500 samples). This figure will vary, depending on the size of the specimens and potential difficulties in correctly locating the slice(s) in the whole specimens, but on average, 200 per day is a reasonable slicing and mounting rate.

The final category in Table 1 (category E) refers to squid statoliths. Although the process appears to be the same as that of category C, the difference lies in the method of slicing. Because of their small size (generally less than 2 mm long), squid statoliths (embedded in resin) cannot be sliced using an otolith saw, but rather have to be sectioned by means of manual grinding and polishing. This is a very time-consuming and labour intensive process, with frequent checks on progress having to be made by microscopic examination. The time taken to generate the sections is consequently an order of magnitude longer than for other species. Based on the previous experience of Dr. Durholtz, about 20 statoliths can be sectioned during a normal working day, hence the 25 days per 500 in Table 1.

The second factor that was considered in terms of generating the required age data was "Analysis". This involves the visual examination, interpretation and counting of the features being used to estimate age. In some species (e.g. sole), the annual growth zones (AGZ's) being used to estimate age are relatively clear and can be rapidly interpreted and counted. In other species (e.g. orange roughy) difficulties in the interpretation and subsequent counting of AGZ's are inherent. This may be a function of the clarity of the features being used to estimate age (which varies considerably between species), and/or a function of the number of false features. The species listed in Tables 3, 5 and 7 were therefore broadly categorised in terms of the likely difficulties associated with interpretation and counting of features (i.e. "readability"). The time taken to generate age data for a set of 500 samples was then estimated for each category (see Table 2), this value then being used to compute the time required to analyse (read) the number of samples required for each species.

Table 2: Estimated time (man-days) required for one reading of 500 specimens for each of the four "analysis" categories.

Analysis Category	Readability	Time Requirement
1	Easy	2.5
2	Moderate	10
3	Difficult	20
4	Very Difficult	25

The species listed in Tables 3, 5 and 7 were then categorised according to the associated preparation and analysis methodology. For example, sole otoliths require no preparation at all (category A in Table 1), and are relatively simple to analyse (category 1 in Table 2), and are therefore designated category A1. In contrast, otoliths of the *Sardinella* and horse mackerel species are prepared by burning, embedding in resin and slicing them with a multi-blade otolith saw (category D in Table 1). However, *Sardinella* otoliths are moderately difficult to analyse (category 2 in Table 2), while those of horse mackerel are difficult (category 3 in Table 2) because of a longer life span and difficulties in interpreting the annual growth zones. *Sardinella* is therefore assigned to category D2, while horse mackerel are designated as category D3.

An additional factor we have included in the estimates of time requirements is that of data quality control, and specifically the re-reading of a subset of each batch of samples for the purposes of assessing the levels of precision and bias associated with the age determinations. We have assumed that two further replicate readings of a subset of about 50% of each batch of samples would be a reasonable and useful protocol. In accordance with this assumption, the analysis time for each category of species computed using the conversion factors in Table 2 are increased by 100%. A final component that is common to all samples and categories is that of reporting. Once the age data have been collected, a report containing a description of the material, a synthesis of the results (and an age length key in most cases) as well as the associated statistics (assessment of bias and precision etc) has to be compiled and submitted for each batch of samples that is analysed. This process is likely to involve a period of about 3 working days irrespective of the number of samples within each batch, and we have consequently factored a 3 day reporting period for each batch into the overall time requirements.

It should be emphasised that the figures presented below exclude two aspects of routine age determination. The first is a technical aspect, specifically preparation success rate. This refers to the proportion of the samples that after preparation are damaged, destroyed or otherwise unreadable. Although partially a function of the nature of the samples themselves (species vary in the clarity of the features being used, and there are also intraspecific differences influenced by geographical/environmental and age/size related effects), success rate is primarily a function of the technical difficulties associated with the method employed for each species and the expertise of the person doing the preparation. For example, a success rate of between 50 and 70% can be expected during the preparation of squid statoliths by a well trained, experienced researcher. This implies that in order to generate the required number of age data, the overall sample size would have to be increased by a factor of between 30 and 50% to account for the statoliths that would be destroyed or damaged during preparation. For the majority of the species listed below, no information regarding success rate of the method is available. The reason for this is that no rigorous assessment of the method and the level of technical expertise of the researcher are possible, either because a method has yet be developed, or because no researcher is currently appointed for this purpose.

The second aspect of routine age determination that is excluded from the assessments below is a quality control aspect, specifically the periodic “re-calibration” of readers. In a situation where readers are routinely analysing a number of different species, it is a generally accepted practice that the readers periodically reanalyse a set of specimens (usually a reference collection) to assess potential “drift” (bias) in their interpretation of the structures. For example, CAF recently experienced a situation where the growth rates of a certain species appeared to be displaying a gradual change over a period of several years. When the reader re-analysed a set of otoliths that had been read several years previously, it was apparent that the criteria the reader was employing had changed over time, with concomitant impacts on the data that the reader was generating. The perceived change in growth rate was consequently not a biological feature, but rather a function of the error in the age data. To avoid errors of this nature, periodic reader “re-calibration” is an essential process. This process will increase the number of data that a reader generates per annum, but the increase will not be reflected in the regional age data requirements that are presented in the following sections.

3.1.1. Angola (Instituto de Investigaçaõ Marinha, IIM):

Age data requirements for the management of marine fisheries in Angola are relatively few at present. Only 7 species are currently of importance in terms of age data for stock assessments (Table 3). These include two species each of Sardinellas, horse mackerel and a demersal sparid (Dentex), as well as another demersal species (Pandora). Samples are currently obtained from annual research surveys using a stratified random sampling approach. All species are (or will be) assessed once per annum using age structured production models.

Table 3: Summary of age data required by IIM for management of marine fish resources in Angola. O = otolith. Ann. ALK = annual age length key.

Species	**Structure**	**Report**	**No. per report**	**No. per annum**	**Preparation and Analysis**	**Category**
Trachurus trecae (Cunene horse mackerel)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D3**
Trachurus capensis (Cape horse mackerel)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D3**
Sardinella auritus (Sardinella)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D2**
Sardinella maderensis (Sardinella)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D2**
Pagellus bellottii (Pandora)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D2**
Dentex macropthalmus (Sea bream)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D2**
Dentex angolensis (Sea bream)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D2**

The age data required are year classes or age groups, and will be used to construct annual age length keys (ALKs) for each species. Age determination of all species involves the visual examination of presumed annual growth zones in the sagittal otoliths, and all samples are prepared using the burn-and-slice method. Analysis is by means of visual examination using a dissecting microscope. A minimum of 5 estimates per 1 cm length class are currently required for all 7 species (although it is likely that this will prove to be insufficient), generating about 250 age estimates for each species and an annual total of 1 750 age estimates. Note that this latter value does not include the extra two readings of a random subset of 50% of the samples (the quality control component), but this aspect is factored into the time requirement presented in Table 4. All of the required samples fall into categories D2 or D3 (see Tables 1 and 2). Using the conversion factors in Tables 1 and 2, the estimated time required to process and analyse the samples is presented in Table 4, as is the time needed to complete the associated reports.

Table 4: Estimated time (man-days) needed by one researcher to generate the annual age data requirements of IIM. Estimates for each category are computed from the conversion factors in Tables 1 and 2, and are subdivided into the time required to prepare ("Prep"), analyse ("Read") and conduct 2 re-reads of 50% of the sample ("QC"). The number of required reports and the time to produce them are indicated in the "Reports" column.

Category	No. of Data	Days to complete sample			Reports		Total
		Prep	Read	QC	No.	Days	
D2 Sardinellas*, Pandora, Dentex*	1250	26	25	25	5	15	**91**
D3 Horse mackerel	500	10.5	20	20	2	6	**56.5**
						TOTAL	**147.5**

These figures indicate that one well-trained, experienced researcher provided with suitable equipment, could fulfil the age data requirements (including the reports) for Angola within approximately 150 working days. It should be noted, however, that IIM is planning to implement monthly sampling of commercial catches, a measure that will increase the number of samples and consequently the time required to generate the age data. As noted above, these figures do not account for success rate or periodic "recalibration" of the reader, both of which are expected to increase the number of structures that have to be prepared and analysed.

3.1.2. Namibia (National Marine Information and Research Centre, NatMIRC):

Namibia's age data requirements (Table 5) are considerably more extensive than those of Angola, with NatMIRC currently aiming at age data for 23 species. As was the case with Angolan requirements, the age data required by Namibia are all age groups or year classes, reported in the form of age length keys. All age determination is conducted by visual examination of annual growth zones in the various structures. In several cases (e.g. sole, kingklip, the elasmobranchs), the frequencies with which age data are required (as well as the number of age data) have yet to be established. In these cases, likely report frequencies and associated numbers of data are assumed (Table 5). No preparation method has been developed for several of the species. It is likely, however, that the "embed and slice" method will be used for these species, and the following discussion assumes that this will be the case. Also apparent in Table 5 is that for several species (e.g. monk, orange roughy, the large pelagics), stock assessments (and associated age data reporting) occur at intervals of longer than 1 year (up to every tenth year in some instances).

Table 5: Summary of age data required by NatMIRC for management of marine fish resources in Namibia. Values in italics indicate uncertainty regarding reporting frequency and the number of data required per report. O = otolith, I = illicium, V = vertebra.

Species	**Structure**	**Report**	**No. per report**	**No. per annum**	**Preparation and Analysis**	**Category**
Merluccius capensis (Cape hake, shallow)	O	Ann. ALK	730	730	Burnt, embedded, sliced, viewed with dissecting microscope.	**D2**
Merluccius paradoxus (Cape hake, deep)	O	Ann. ALK	610	610	Burnt, embedded, sliced, viewed with dissecting microscope.	**D2**
Austroglossus microlepus (Sole)	O	Ann. ALK	*250*	*250*	No preparation, viewed whole with dissecting microscope.	**A1**
Trachurus capensis (Cape horse mackerel)	O	Ann. ALK	250	250	Burnt, embedded, sliced, viewed with dissecting microscope	**D3**
Sardinops sagax (Sardine)	O	Ann. ALK	100	100	Embedded, viewed whole with dissecting microscope.	**B2**
Engraulis encrasicolus (Cape anchovy)	O	Ann. ALK	60	60	Embedded, viewed whole with dissecting microscope.	**B2**
Cerntrophosus granulosus (Gulper)	O	Ann. ALK	250	250	No method as yet (embed and slice?)	**C2**
Thyrsites atun (Snoek)	O	Ann. ALK	250	250	Embedded, sliced, viewed with dissecting microscope	**C2**
Centroscymnus coelolepsis (Portuguese dogfish)	V	Ann. ALK	250	250	No method as yet (embed and slice?)	**C2**
Nothorynchus cepedianus (Sevengill cow shark)	V	Ann. ALK	250	250	No method as yet (embed and slice?)	**C2**
Triakis megalopterus (Spotted gully shark)	V	Ann. ALK	250	250	No method as yet (embed and slice?)	**C2**
Mustelus mustelus (Smooth hound shark)	V	Ann. ALK	250	250	No method as yet (embed and slice?)	**C2**
Genypterus capensis (Kingklip)	O	Ann. ALK	300	300	No method as yet (embed and slice?)	**C2**
Lophius vomerinus (Monk)	I	2 yr ALK	200	100	Embedded, sliced and viewed with dissection microscope	**C2**
Lophius vailanti (Monk)	I	2 yr ALK	200	100	Embedded, sliced and viewed with dissection microscope	**C2**
Hoplostethus atlanticus (Orange roughy)	O	10 yr ALK	400	40	Embedded, sliced and viewed with dissection microscope	**C3**
Argyrosomus inodorus (Kob)	O	10 yr ALK	250	25	Embedded, sliced and viewed with dissection microscope	**C2**
Coracinus capensis (Galjoen)	O	10 yr ALK	250	25	Embedded, sliced and viewed with dissection microscope	**C2**
Lithognathus aureti (West coast steenbras)	O	10 yr ALK	250	25	Embedded, sliced and viewed with dissection microscope	**C2**
Diplodus sargus (Blacktail)	O	10 yr ALK	200	20	Embedded, sliced and viewed with dissection microscope	**C2**
Carcharhinus brachyurus (Bronze whaler)	V	10 yr ALK	100	10	No method as yet (embed and slice?)	**C2**
Isurus oxyrinchus (Shortfin mako)	V	10 yr ALK	200	20	No method as yet (embed and slice?)	**C2**
Prionace glauca (Blue shark)	V	10 yr ALK	200	20	No method as yet (embed and slice?)	**C2**

It is reasonable to assume that in these cases, assessments (and production of the age data) will be staggered over alternating years to minimise the data that would be required in any given year. Consequently, age data for only one of these species would have to be generated every year, equivalent to about 250 age estimates per annum for these species (although this figure is variable, considering that 400 age estimates are required for orange roughy, but only 100 for bronze whaler). The data requirements expressed as the time required to prepare and analyse the samples are summarized in Table 6. The result shows that a well-trained, well-equipped, experienced researcher could generate the age data required by MFMR each year in about 312 working days.

Table 6: Estimated time (man-days) needed by one researcher to generate the annual age data requirements of NatMIRC. Estimates for each category are computed from the conversion factors in Tables 1 and 2, and are subdivided into the time required to prepare ("Prep"), analyse ("Read") and conduct 2 re-reads of 50% of the sample ("QC"). The number of required reports and the time to produce them are indicated in the "Reports" column.

Category	No. of Data	Days to complete sample			Reports		Total
		Prep	Read	QC	No.	Days	
A1 Sole	250	1	1.3	1.3	1	3	**6.6**
B2 Sardine, anchovy	160	2.2	3.2	3.2	2	6	**14.6**
C2 Large pelagics, monk, kingklip	2 145	40.8	42.9	42.9	2	6	**132.6**
C3 Orange roughy	400	7.6	16	16	1	3	**42.6**
D2 Hakes	1340	28	26.8	26.8	2	6	**87.6**
D3 Horse mackerel	250	5.3	10	10	1	3	**28.3**
						TOTAL	**312**

3.1.3. South Africa (Marine and Coastal Management, MCM):

Critical age data required for the assessment of South African fish stocks currently encompass 47 species, 36 of which are line fish species (Table 7). With one exception (squid), the age data required are age group or year class assignments obtained from visual examination of annual growth zones in the various structures, and are reported as age length keys. In the case of chokka squid (*Loligo vulgaris reynaudii*) age data are required with a daily resolution. These data are obtained from counts of daily increments that occur in the statoliths of this species.

The frequency of reporting varies considerably among the different species. In the commercially important (and heavily exploited) demersal and small pelagic species, stock assessments (and underlying age data) are required quarterly (i.e. every 3 months). Annual age length keys are required for squid and the scombrid species, while the remaining species (primarily line fish) are assessed at intervals of between 3 and 10 years.

Table 7: Summary of age data required by MCM for management of marine fish resources in South Africa. Values in italics indicate uncertainty regarding reporting frequency or the number of data required per report. O = otolith, I = illicium, S = statolith, R = dorsal fin spine, V = vertebra.

Species	**Structure**	**Report**	**No. per report**	**No. per annum**	**Preparation and Analysis**	**Category**
Merluccius capensis (Cape hake, shallow)	O	3 mo ALK	500	2000	No preparation, viewed whole with dissecting microscope	**A2**
Merluccius paradoxus (Cape hake, deep)	O	3 mo ALK	500	2000	No preparation, viewed whole with dissecting microscope	**A2**
Lophius vomerinus (Monk)	I	3 mo ALK	500	2000	Embedded, sliced, viewed with dissecting microscope.	**C2**
Austroglossus microlepus (Sole)	O	3 mo ALK	250	1000	No preparation, viewed whole with dissecting microscope.	**A1**
Genypterus capensis (Kingklip)	O	3 mo ALK	500	2000	No method as yet (embed and slice?)	**C2**
Trachurus capensis (Cape horse mackerel)	O	3 mo ALK	500	2000	Burnt, embedded, sliced, viewed with dissecting microscope	**D3**
Sardinops sagax (Sardine)	O	3 mo ALK	250	1000	Embedded with black background, viewed with dissecting microscope.	**B2**
Engraulis encrasicolus (Cape anchovy)	O	3 mo ALK	250	1000	Embedded with black background, viewed with dissecting microscope.	**B2**
Loligo vulgaris reynaudii (Chokka squid)	S	Ann. ALK	1000	1000	Embedded, sectioned, viewed with analytical microscope	**E4**
Thunnus alalunga (Albacore)	R	Ann. ALK	500	500	Embedded, sliced, viewed with dissecting microscope.	**C2**
Thunnus spp (Tuna)	R	Ann. ALK	500	500	Embedded, sliced, viewed with dissecting microscope.	**C2**
Sarpa salpa (Strepie)	O	3 yr ALK	200	67	Embedded, sliced, viewed with dissecting microscope.	**C2**
Thyrsites atun (Snoek)	O	5 yr ALK	500	100	Embedded, sliced, viewed with dissecting microscope.	**C2**
Seriola lalandii (Yellowtail)	O	5 yr ALK	500	100	Embedded, sliced, viewed with dissecting microscope.	**C2**
Atractoscion aequidens (Geelbek)	O	5 yr ALK	500	100	Embedded, sliced, viewed with dissecting microscope.	**C2**
Pachymetopon blochii (Hottentot)	O	5 yr ALK	200	40	Embedded, sliced, viewed with dissecting microscope.	**C2**
Chrysoblephus puniceus (Slinger)	O	5 yr ALK	200	40	Embedded, sliced, viewed with dissecting microscope.	**C2**
Lichia amia (Garrick)	O	5 yr ALK	300	60	Embedded, sliced, viewed with dissecting microscope.	**C2**
Pomatomus saltatrix (Elf)	O	5 yr ALK	250	50	Embedded, sliced, viewed with dissecting microscope.	**C2**
Liza richardsonii (Mullet)	O	5 yr ALK	200	40	Embedded, sliced, viewed with dissecting microscope.	**C2**
Oplegnathus conwayii (Cape knife jaw)	O	5 yr ALK	250	50	Embedded, sliced, viewed with dissecting microscope.	**C2**
Pterogymnus laniarius (Panga)	O	8 yr ALK	200	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Rhabdosargus sarba (Natal stumpnose)	O	8 yr ALK	200	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Argyrosomus inodorus (Kob)	O	10 yr ALK	500	50	Embedded, sliced, viewed with dissecting microscope.	**C2**
Argyrozona argyrozona (Carpenter)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Chrysoblephus laticeps (Red Roman)	O	10 yr ALK	200	20	Embedded, sliced, viewed with dissecting microscope.	**C2**

Table 7: Summary of age data required by MCM for management of marine fish resources in South Africa. Values in italics indicate uncertainty regarding reporting frequency or the number of data required per report. O = otolith, I = illicium, S = statolith, R = dorsal fin spine, V = vertebra.

Species	**Structure**	**Report**	**No. per report**	**No. per annum**	**Preparation and Analysis**	**Category**
Cheimerius nufar (Soldier)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Rhabdosargus globiceps (White stumpnose)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Epinephelus spp. (Rock cod)	O	10 yr ALK	200	20	Embedded, sliced, viewed with dissecting microscope.	**C2**
Petrus rupestris (Red steenbras)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Coracinus capensis (Galjoen)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Chrysoblephus oristiceps (Dageraad)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Polysteganus undulosus (Seventy-four)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Lithognathus lithognathus (White steenbras)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Cymatoceps nasutus (Poenskop)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Sparodon durbanensis (White musselcracker)	O	10 yr ALK	300	30	Embedded, sliced, viewed with dissecting microscope.	**C2**
Diplodus sargus (Blacktail)	O	10 yr ALK	200	20	Embedded, sliced, viewed with dissecting microscope.	**C2**
Galeorhinus galeus (Soupfin shark)	V	10 yr ALK	*250*	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Carcharhinus brachyurus (Bronze whaler)	V	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Carcharhinus obscurus (Dusky shark)	V	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Chrysoblephus gibbiceps (Red stumpnose)	O	*10 yr ALK*	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Pachymetopon grande (Bronze bream)	O	10 yr ALK	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Chrysoblephus anglicus (Englishman)	O	*10 yr ALK*	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Polysteganus praeorbitalis (Scotsman)	O	*10 yr ALK*	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
(Belman)	O	*10 yr ALK*	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Callorhynchus capensis (St. Joseph shark)	V	*10 yr ALK*	250	25	Embedded, sliced, viewed with dissecting microscope.	**C2**
Rhabdosargus holubi (Cape stumpnose)	O	*10 yr ALK*	200	20	Embedded, sliced, viewed with dissecting microscope.	**C2**

The line fish protocol adopted by MCM requires that a particular species falling within the line fish category only be assessed at intervals corresponding to half of the life span of the fish, and every ten years when the life span exceeds 20 years. This implies that a staggered protocol could be adopted, limiting the number of age data that have to be generated within a particular year (as was described for Namibia in section 3.1.2 above). If such an approach were to be adopted, only between 3 and 6 line fish species would have to be assessed in any given year, with an average of 1 300 (and a maximum of about 1 800) age data having to be generated per annum.

The age data requirements listed in Table 7 are summarized in Table 8, expressed in terms of the estimated time that would be required to fulfil these requirements. The assessment suggests that almost 1 220 working days would be required for a well-trained, experienced researcher to complete the analyses and provide MCM with it's annual age data requirements (including accompanying analyses of precision and bias and a report of the results). Alternatively, five researchers sharing the workload could complete the analyses in about 244 working days.

Table 8: Estimated time (number of working days) needed by one researcher to generate the annual age data requirements of MCM. Estimates for each category are computed from the conversion factors in Tables 1 and 2, and are subdivided into the time required to prepare ("Prep"), analyse ("Read") and conduct 2 re-reads of 25% of the sample ("QC"). The number of required reports and the time to produce them are indicated in the "Reports" column.

Category	No. of data	Days to complete sample			Reports		Total
		Prep	Read	QC	No.	Days	
A1 Sole	1 000	4	5	5	4	12	**26**
A2 Hakes	4 000	8	80	80	8	24	**192**
B2 Sardine, anchovy	2 000	28	40	40	8	24	**132**
C2 Monk, kingklip, tunas, line fish	6 307	120	126	126	16	48	**420**
D3 Horse mackerel	2 000	110	80	80	4	12	**282**
E4 Squid	1 000	64	50	50	1	3	**167**
						TOTAL	**1 219**

3.2. CURRENT CAPACITY FOR AGE DETERMINATION IN THE BENGUELA REGION.

3.2.1. Angola (Instituto de Investigaçaõ Marinha Ministerios dos Piescas e Ambiente, IIM):

When IIM was founded, five staff members where allocated to age determination, and an external (French) consultant was employed to provide training. A laboratory, a reading room and three offices were available to the age determination unit. IIM has, however, experienced a dramatic decrease in capacity for age determination. Loss of experienced staff and deterioration of equipment is the primary reason for this, presumably resulting from the extended conflict in Angola over the past few decades. At present, the age determination unit no longer exists. All age determination falls within the activities of the pelagic section at IIM, with only one scientist and one technician involved with age determination, both on a part-time basis. No staff members are dedicated to full-time age determination. Some work has been conducted on otoliths of Cunene horse mackerel, as well as limited age determination of Pandora and the two *Dentex* species using scales. The scientist has had some training in the reading of hake otoliths, as well as the preparation and analysis of horse mackerel otoliths. While some technical support (6 technicians) is available (primarily for collection of samples and supporting data), all of these staff members have other duties. One technician employed on a part-time basis periodically services age determination equipment.

Space for age determination activities is available in a laboratory and an adjoining room, but this space is shared with other members of the institute. The availability of suitable, working equipment is at present very limited. This obstacle has been addressed, however. The required equipment (a stereomicroscope equipped with a colour video camera and monitor, a laboratory oven capable of temperatures up to 375^{o}C and an otolith saw equipped with blades) has been purchased and is in the process of being imported into Angola. The equipment should be available for use in early 2004. Factors identified as critical to improving age determination capacity in Angola is the ability to appoint sufficient numbers of staff with relevant experience, funding to refurbish the age determination laboratory, and finally training in the use and maintenance of the new equipment, as well as in general age determination methodology. An additional obstacle is the availability of materials (resin, microscope slides, bulbs and other consumables). These materials are not readily available within Angola and have to be imported at great expense, a process that often involves a considerable period of time.

With regard to quality control, apart from limited validation of the method employed for Cape horse mackerel, no validation of the method for the other species has been conducted. Reference otolith collections are being generated for the two horse mackerel species, but no collections of this nature are available for the other species. No known-age material is available for any of the species.

3.2.2. Namibia (National Marine Information and Research Centre, NatMIRC):

NatMIRC (the National Marine Information and Research Centre of the Ministry of Fisheries and Marine Resources) in Swakopmund, Namibia was founded in 1994, but it was only in 1998 that a researcher dedicated to fish age determination was appointed. Prior to this, age determination in Namibia was fragmented, with different scientists being sporadically involved in the age determination of different species. With the appointment of the age determination researcher in 1998, a laboratory and equipment dedicated to fish age determination were made available. Subsequently, there has been some staff turnover, with extended periods where no age determination work is conducted due to lack of personnel. At present, one researcher (M.Sc. qualification) is permanently employed for fish age determination (primarily hake and horse mackerel). This researcher is also expected to conduct sampling during routine research surveys, although some support (5 technical and 4 scientific staff members) in this area is available. A second full-time position for a technical assistant dedicated to age determination has recently been filled. The researcher has experience in daily age determination of anchovy, and has recently been trained in age determination of horse mackerel, while the technical assistant has had no training or experience in routine age determination at all. The training process is, however, ongoing through various BENEFIT programmes aimed at enhancing age determination capacity in the region. One senior scientific staff member is involved in data evaluation and analysis, while several technical staff members are involved in age determination on a part-time basis. The technicians are not, however, adequately trained in age determination methods, although the BENEFIT programmes mentioned above are aiming to address this issue. A technician who was periodically involved in the age determination of various large pelagic species (line fish) over a ten-year period has subsequently transferred to another section. An additional technician is involved with periodic servicing of age determination equipment. NatMIRC therefore represents the largest pool of human resources for age determination in the region, employed at an annual cost of some ZAR 300 000. Two junior scientists (1 dedicated), 1 head technician, 2 senior and 5 junior technicians (1 dedicated) comprise a resource of expertise that can be utilized or trained immediately. Considering normal staff cooperation as a possible indicator of interactive training efficiency, the potential for successful training should also be highest at NatMIRC.

In terms of infrastructure, a large, well-equipped laboratory is dedicated to fish age determination, and space (storage and bench space) is available in a second laboratory shared with other demersal section users. Some space in a third laboratory (large pelagics laboratory) is also periodically used for age determination purposes. The main laboratory is equipped with a fume cabinet for embedding of otoliths in resin, and has space for wet work (slicing of samples with otolith saws). Two offices are available to the unit. Storage space is limited however. Social areas (tea rooms), a well-stocked library and workshops are shared with other users in the institute.

Capacity in terms of equipment appears to be satisfactory. Six dissection microscopes are dedicated to age determination, although at least 4 of these require servicing. One dissection microscope is equipped with a colour video camera interfaced to a personal computer. Image analysis software is available on this PC. Two other PC's are available to the unit, both linked to a LAN and the World Wide Web. The unit also has access to two analytical microscopes.

Two otolith saws (one fixed, one portable) with 6 spare blades are in working order, as are a drying oven and a burning oven. In general, the equipment is in working order, although poorly maintained during periods when no age determination personnel were appointed. Most consumables are generally readily available, with the exception of specialised equipment such as otolith saw blades, microscope bulbs and chemicals. These materials have to be imported from South Africa or other countries, a usually lengthy process (in one instance, 9 months elapsed between the ordering and delivery of new otolith saw blades). Although the unit does have access to an electron microscope, this is situated in Windhoek, approximately 4.5 hours away from the institute.

The lack of trained staff, resulting primarily from drastic staff turnover has been identified as a major obstacle to the efficient functioning of the unit. The work environment is also not particularly stimulating, the researcher(s) often working in isolation with no rewards for good work done, particularly in terms of relatively low salaries. In terms of data quality control, age determination of only one of the hake species (*Merluccius capensis*) has been validated. Age determination of sardine has been validated in South Africa, but not in for the Namibian population. A validation study on South African Cape horse mackerel (*Trachurus trachurus capensis*) is nearing completion, and the results may be applicable to the Namibian stock, but this would require corroboration. No known-age samples are available for any of the species listed in Table 5. An otolith reference collection is in the process of being generated for Cape horse mackerel, but no such collections are available for any of the other species.

3.2.3. South Africa (Marine and Coastal Management, MCM):

At present, MCM has no clearly defined age determination unit or any staff dedicated to age determination. Permanent positions for a researcher and a technician dedicated to age determination of offshore species (primarily pelagics) have been advertised, and should be filled by 2004. At present, the only age determination activities being conducted at MCM are routine reading of hake otoliths by one researcher (who is currently filling a management position and unlikely to be in a position to continue with routine age determination in the future) and one technician at an estimated annual financial share of ZAR 30 000 (10% of NatMIRC). Both of these staff members have other duties. The two full-time positions dedicated to age determination (currently vacant) represent a further annual financial share of approximately ZAR 250 000. Two technicians and 3 auxiliary staff members conduct routine collection and preparation of otoliths of pelagics, but no reading of these otoliths is occurring at present. No staff capacity for routine age determination of squid or the line fish species exists, and it is unlikely that this will be rectified in the near future (although the funds to out-source squid age determination have recently been made available). Ten technicians are involved in sampling (at sea and in ports), while an additional two technicians are responsible for equipment maintenance.

In terms of equipment and materials dedicated to routine age determination, there does appear to be sufficient capacity available within MCM. Three dissecting microscopes equipped with image analysis systems are available, as well as one analytical microscope equipped with a video camera and monitor. A second analytical microscope with fluorescent capabilities (filters for OTC and a mercury lamp) is available but requires servicing. A third analytical microscope equipped with fluorescent capabilities and a video camera for squid statolith work is on order, and should be available for use by 2004. Two otolith saws equipped with diamond blades are in working order, as are two ovens capable of temperatures between 250°C and 350°C. Ready access to a well equipped research aquarium greatly simplifies any supporting validation work that has to be conducted (within the limitations of available staff), while access to advanced electron microscope equipment (Electron Microscopy Unit, University of Cape Town) as well as microprobe technology (National Accelerator Centre, Stellenbosch) is also available. Consumables and chemicals are readily available from local companies specializing in scientific supplies. Further, both inshore and offshore sections do have sufficient support capacity in terms of sampling (otolith collection, preservation and archiving), and the implementation of various observer programmes for commercial catches will add to this capacity.

A lack of capacity is, however, evident in terms of laboratory and office space dedicated to age determination. Although a laboratory has been allocated for this purpose, it is currently not equipped and no funds are currently available to refurbish the laboratory. There is not sufficient space in the laboratory for both preparation and analysis of specimens. Further, no offices for staff dedicated to age determination are available, although a request for two offices will be made to the Director: Research and Development by the end of October 2003.

While MCM has never had a discrete age determination unit, dedicated personnel were allocated to age determination, specifically of pelagics (sardine and anchovy), hake and sole. Sporadic, part-time age determination of various species has been conducted, either as part of research activities of various staff members, or as part of research conducted by students during postgraduate studies. Over time, however, loss of experienced staff and changing priorities has negatively influenced the production of age data for stock assessment purposes. Difficulties with appointing personnel with relevant experience have hampered efforts to address this lack.

In terms of quality control measures, age determination methods for several of the species listed in Table 7 have been validated either directly (squid, sardine, anchovy, carpenter, red roman, poenskop, bronze bream, Natal stumpnose, blacktail) or indirectly (horse mackerel, snoek, yellowtail, kob, hottentot, panga, white stumpnose, galjoen, dageraad, white steenbras, belman, elf, white musselcracker, strepie). Age determination methods for the remaining species still have to be validated. While otolith collections for many of the species are available, they are distributed through several different institutions within South Africa, and it is unknown as to whether these collections include known-age material or otoliths fulfilling the requirements for a reference collection. Because MCM has no dedicated age determination personnel at present, the issues of training and assessments of precision and bias are not relevant. These issues will have to be addressed when personnel are appointed.

3.3. AGE DATA REQUIREMENTS VERSUS CAPACITY.

3.3.1. Human Resources:

The age data requirements for the three countries in the Benguela region (discussed in section 3.1 and presented in Tables 3 to 8 above) are summarized in Table 9.

Table 9: Summary of human resources required to fulfil current age data requirements for each of the three countries in the Benguela region. Note: the human resources are restricted to personnel involved in age determination. Support and auxiliary staff members involved in sampling, preliminary specimen preparation and equipment maintenance are excluded. Italics indicate positions that are currently vacant.

Institution	Time required (man-days)	Researchers required	Researchers available	Sufficient?
IIM (Angola)	148	1	2 (both part-time)	Possibly
NatMIRC (Namibia)	312	2	2 (both full-time)	Yes
MCM (South Africa)	1 219	5	*2 (both full-time)* 2 (both part-time)	No

This assessment indicates that at present, only Namibia has sufficient human resources to generate the required age data for stock assessment purposes. It should be noted, however, that both dedicated age determination personnel at NatMIRC have limited experience of routine age determination, and further training is required if full capacity is to be realised. Further training is also required for the Angolan personnel, who have only had limited training in the age determination of horse mackerel. The only two staff members conducting any age determination activities at MCM have only been trained in age determination of hake, but it is likely that a new preparation technique will have to be employed for the two hake species in South Africa and the readers re-trained. It is probable that when the two dedicated age determination posts are filled, substantial training of these individuals would have to be provided before they are capable of routine age determination of the species required by MCM.

An aspect of the human resources component that cannot be quantified or measured is that of work satisfaction. In any institution, age determination researchers that are working on their own frequently feel isolated, a situation that generally leads to frustration and ultimately the resignation or transfer of the researcher. Considering that routine age determination can be a monotonous process if interpersonal discussion and scientific interaction are not possible, creating a stimulating work environment is very difficult when only one or two researchers are involved. Further contributing to this problem is that although the personnel are usually highly trained specialists, salaries are often felt to be inadequate and not representative of the skills inherent in the work. It is probably these factors that are primarily responsible for the continual staff turnover that has been a major problem in the Benguela region in recent years. Considering that all institutions are owned and administered by the state, filling of vacated posts invariably involves considerable time periods. Apart from an unspecified period when no age determination is conducted with a resultant accumulation of samples and lack of age data (as is currently the situation at MCM), this has serious implications with regard to loss of experience, skills and knowledge that are not transferred to the incoming staff members. The entire training and “re-calibration” procedures then have to be repeated, with a concomitant discontinuity in the data and changes in the data quality which may have profound impacts on the results of the stock assessments that are using the data.

3.3.2. Buildings:

In terms of space dedicated to age determination, MCM is presently the smallest in size ($10m^2$), followed by IIM ($25m^2$) and CAF ($40m^2$). NatMIRC offers the largest spatial opportunities for age determination activities ($180m^2$) and a financial share of ZAR 137 000 maintenance costs. In most institutions, the spatial facilities needed for age determination are largely shared with other research units Table 10). Only NatMIRC and CAF have laboratories and offices that are used exclusively by researchers assigned to age determination. Current availability of space for age determination would seem to be satisfactory in Namibia, potentially adequate in Angola but definitely not adequate in South Africa. The laboratory currently assigned to age determination at MCM is essentially a room (2m x 5m) separated from a larger laboratory (5m x 15m) that has been designated for ichthyoplankton work, and has sufficient space for two workstations, but no bench space for otolith saws or other equipment.

Table 10: Space allocation and daily use of offices and laboratories. Daily use of 8 hours is given in bold figures and space shared with other research units is indicated in italics. Figures from CAF are provided for comparative purposes.

Category	Institution			
	IIM	**NatMIRC**	**MCM**	**CAF**
Office	1	**1**	1	**1**
Guest room	-	-	-	*1*
Laboratory	*1*	**1** + *1*	*1*	**1** + *3*
Conference room	1	*1*	*2*	*1*
Tearoom	1	*2*	*1*	*1*
Workshop	1	*1*	-	*2*
Store	-	-	1	*2*
Car park	*1, free*	*1, free*	*1,ZAR 6/d.*	*1, free*
Overcapacities	NO	NO	NO	NO

3.3.3. Equipment:

Regarding equipment and its maintenance costs, IIM is least equipped to cope with its requirements regarding age data. Of the three research institutions of the BENEFIT/BCLME countries, MCM is best equipped to cope with MCM's requirements of age data (Table 11). No substantial data are available from the FAQs to realistically estimate the annual costs of service for the equipment. The service intervals range from one service in 6 years for microscopes at NatMIRC to necessary repairs in infrequent intervals at MCM. Microscope bulbs and saw blades are frequently replaced consumables and appear be readily available from NatMIRC funds. NatMIRC provides a detailed list of available consumables, which helps to estimate their annual acquisition costs. MCM resources presently appear large enough to ensure continuation of research without stressing its consumables' fund.

Acquisition of materials and specialised equipment and supplies is an area that can be a limitation in the region, particularly in the case of Angola, and to a lesser extent in Namibia. In most cases, these items are not available within Angola at all, and have to be imported at considerable cost. The more specialised items (e.g. otolith saw blades) are not available in Namibia either, and have to be imported from South Africa or elsewhere, again involving extra costs and frequently substantial time delays (examples are the recent nine month period that elapsed before otolith saw blades were delivered to NatMIRC and the current difficulties being experienced in importing age determination equipment into Angola).

Table 11: Dedicated age determination equipment within each institution, and current acquisition costs (in ZAR), modified from the FAQ forms according to the most relevant information. Compounded costs are indicated with an asterisk (*).

Equipment	IIM		NatMIRC		MCM		CAF
	No.	Costs	No.	Costs	No.	Costs	No.
Dissection microscope	1*	55 000*	6	90 000	4*		4
Analytical microscope			2	40 000	4	140 000	2
Video image analyser					3*	330 000*	4
Imaging software	1*		1	10 000	3*		5
Video/digital camera	1*		1	5 000	3*		5
Personal computers	?	?	2	20 000	3		
LAN server			1		1		1
System software			2	4 000	3*		6
Otolith saws (portable)	1	17 000	1	2 500	2	24 000	2
Otolith saws (fixed)			1	3 000			
Saw blades	2	4 000	6	21 900	?	?	2
Drying oven (-250º)				20 000	1	?	1
Drying oven (-350º)	1	20 000		20 000	1	20 000	
Staining chemicals					20	10 000	
Consumables				22 300			
Microbalance							1
Research vessel access	1		1		2		
Minimal acquisition costs		**96 000 +**		**258 700+**		**524 000+**	

3.3.4. Current Output:

The current annual age data output at IIM covers 4 long-lived fish species with a total of 326 otoliths and 626 scales being read. NatMIRC produced 400 readings in 2001 and 2002. 1,500 otoliths were burnt or sliced. Work on vertebrae is in the experimental phase. MCM recently generated 2,000 age data of 2 short-lived and 1 long-lived fish species. A fully operational age determination centre such as CAF, in comparison, processes between 20 and 25 long-lived species annually, comprising up to 25 000 otoliths, 2000 scales and fin rays, and up to 4,500 vertebrae. All of these hard structures are sliced, and the fin rays and vertebrae are, in addition, either burnt or stained.

3.3.5. Summary:

ANGOLA (Requirements = 148 man-days):

Human resources:	Possibly sufficient if adequate training is provided (training is an urgent requirement)
Laboratories and offices:	Possibly sufficient.
Equipment:	Presently insufficient, but should be rectified by early 2004.
Support:	Basic technical support is sufficient, specialised technical support is not. Materials and equipment difficult, expensive and time-consuming to import

Assessment: IIM does have the capacity to fulfil its current age data requirements provided suitable training is provided. Training is urgently required, as is supporting research (validation etc). Availability of materials and limited technical support is an obstacle.

NAMIBIA (Requirements = 312 man-days)

Human resources:	Sufficient (but further training is urgently required)
Laboratories and offices:	Sufficient
Equipment:	Sufficient
Support:	Basic technical support is sufficient, specialised technical support is partially sufficient. Specialised materials and equipment have to be imported.

Assessment: NatMIRC does have the capacity to fulfil to Namibia's current age data requirements, but training is urgently required, as is supporting research (validation etc).

SOUTH AFRICA (Requirements = 1 219 man-days)

Human resources:	Insufficient (even if two full-time posts are filled)
Laboratories and offices:	Insufficient
Equipment:	Sufficient
Support:	Basic and specialised technical support sufficient and immediately available. Materials and equipment are readily available.

Assessment: MCM cannot fulfil its age data requirements, and it is unlikely that it will be in a position to do so in the foreseeable future. Human resources are not available at present. There will be insufficient time to fulfil requirements even if vacant posts are filled. Current space availability is a serious constraint, and this unlikely to be rectified in the near future.

3.4. CONCLUSIONS

Only IIM and NatMIRC have sufficient capacity to generate their age data requirements. MCM does not have the manpower for this purpose, even if the two advertised age determination posts are filled. Previous experience has shown that staff fluctuations are the major obstacle to consistent age determination in the region. The primary reasons for these fluctuations appear to be working in isolation and salaries that do not reflect expertise. The effects of frequent staff fluctuations are continuous re-training of new personnel, loss of consistent age interpretation criteria and, thus, a serious impact on age data quality. There is also no transfer of knowledge and expertise. This has also impacted negatively on the development of historical age databases.

CAF shows that a dedicated age determination unit staffed with experienced personnel for more than 10 years is capable of processing more than 20 species of fish, producing more than 30 000 age determinations per annum. The working environment at CAF favours the retention of staff over long periods. Staff members do not work in isolation; they are stimulated by continuous interactions and discussions as well as their involvement in research projects. Knowledge and expertise are consolidated within the unit, facilitating rapid and efficient training of new staff members when staff fluctuations do occur. Data quality and continuity is consequently maintained.

The results of this assessment lead us to conclude that the implementation of a central age determination facility in the BENEFIT - BCLME region is imperative if fisheries management in the region is to have access to the consistent age data that are required for stock assessments in the long term. In the following section (section 4), we present our recommendations regarding the infrastructure, administration and operation of such a centre. We also provide recommendations on the location and terms of reference of the centre.

4. RECOMMENDATIONS FOR A CENTRAL FISH AGE DETERMINATION CENTRE IN THE BENGUELA REGION: BENFAC (BENGUELA FISH AGEING CENTRE)

4.1. TERMS OF REFERENCE.

- Supply age data requirements for the national fisheries management bodies/institutions in all 3 countries in the region (IIM Angola, MFMR Namibia and MCM SA).
- Age data should be only for those species that are subject to exploitation (commercial or otherwise) and therefore require stock assessment and management.
- Once fully operational, age data should be provided to the three national management institutions by the centre on a "cost-per-otolith" basis, the income then being used to finance the operation of the centre on a non-profit basis.
- Other age determination work for "external" sources could be conducted on a contractual basis, provided that this work would not infringe on or interfere with the primary clients (i.e. the three countries).
- Activities should not include sampling and collection of supporting data. Samples (otoliths, vertebrae etc) should be delivered to the Centre (with supporting data), and the Centre only responsible for preparation and analysis.
- The Centre should be responsible for ensuring that the quality of the age data is satisfactory, and should therefore provide supporting statistics and analyses quantifying the levels of accuracy and precision of the data.
- The Centre should be responsible for any validation work, but this should be conducted in collaboration with the respective institutions.
- The Centre is responsible for the training of staff and periodic "re-calibration", as well as developing reference collections etc.
- Following the preparation and analysis of each batch of samples, the Centre should produce a report documenting:
  - A summary of the material (samples) and a brief description of the methods employed
  - The age data (e.g. age length key)
  - Accompanying statistics regarding quality control (indices of precision and bias)
  - Comments (if necessary) concerning strengths and weaknesses of the data
  - Recommendations concerning future sampling, data collection etc

4.2. OWNERSHIP AND ADMINISTRATION.

We recommend that the centre should not be owned by any particular country or institution. It should be considered as a cooperative venture between the three countries, and should be administered under the umbrella of BENEFIT, BCLME or the proposed Benguela Commission.

The three countries in the region should be contractually obliged to ensure that all national age data requirements are ceded to the centre, and are paid for on a "cost-per-otolith" basis. The administering authority (BENEFIT, BCLME or the Benguela Commission) would be responsible for all invoicing, receipt of payments, purchasing, payment of salaries and distribution of reports generated by the centre. The administering authority should also be responsible for providing a scientific forum allowing for discussions of:

- The age data required from the centre over a given time period
- The costs of providing the age data
- Problems or inadequacies in data already produced by the centre
- Supporting research
- Appointments

Samples for processing should be delivered directly to the centre. The centre will then be responsible for providing the administering authority with a monthly report listing sample batches received, sample batches being processed and sample batches completed. Ideally, all completed specimens should be retained by the centre and stored. However, this material remains the property of the relevant institution, which is fully entitled to request the return of the material at any stage. In other words, the centre acts as custodian of the samples.

4.3. LOCATION.

Establishing the age determination centre outside of a pre-existing government institution would entail high rental costs. It is therefore recommended that the Centre should be located within one of the national marine science institutes. NatMIRC (Swakopmund, Namibia) currently offers the best spatial opportunities to establish the centre. Although Cape Town offers advantages such as the rapid supply of materials and specialised services, as well as access to the Electron Microscopy Unit (University of Cape Town), a microprobe (National Accelerator Centre) and the MCM research aquarium, there is insufficient space available within MCM to accommodate the Centre. The difficulties and expense associated with obtaining the required materials and specialised support in Angola precludes IIM as a potential location for the Centre.

4.4. INFRASTRUCTURE:

4.4.1. Staff

All staff members should be appointed and employed by the centre directly. While some research staff may be seconded to the centre by the various national institutions, this should be on a permanent basis (to avoid staff turnover and associated re-training etc). During the establishment of the Centre, external consultants (specialists) will have to be employed on a contractual basis to provide training, particularly for difficult species. The permanent staff structure should be as follows:

- **Scientific Director**

  Responsible for day-to-day management of the centre, ensuring that objectives are met, liasing with governments and other relevant authorities, marketing (in the long-term), reviewing reports prior to submission, database management. Minimum requirement for applicants should be a Ph.D. and at least 5 years' experience in fisheries science, ideally related to age determination. Experience in project management should also be a pre-requisite. The salary should be at the level of a Deputy Director in MCM (total package of approximately ZAR 250 000 p.a.).

- **Head technician**

  Responsible for day-to-day operation of the Centre: administration, ordering/buying of materials, ensuring that equipment maintenance protocols are adhered to, bookkeeping, scheduling of staff activities, archiving of samples and data and training. Minimum requirement for job applications should be a national Diploma or B.Sc. (Hons) with at least 3 years of job experience in the field of marine research, preferably age determination. The salary for this position should be at the level of Control Oceanographic Technician at MCM (total package of approximately ZAR 200 000 p.a.).

- **Scientists (2)**

  Permanently responsible for routine age determination, supporting research (validation etc), quality control and data analysis, writing of reports, database management and training. Minimum requirement applicants should be M.Sc. or higher with at least 3 years of experience in the field of marine research, and preferably age determination. The salaries for these positions should be at the level of a Specialist Scientist at MCM (total annual package of approximately ZAR 220 000 p.a.)

- **Technicians (6)**

  Permanently responsible for routine age determination, including preparation and analysis. Minimum requirement for applicants should be a Matric or equivalent. The salaries for these posts should be at the level of Junior Oceanographic Technician at MCM (total package approximately ZAR 72 000 p.a.) with a possibility of promotion to Senior Oceanographic Technician (total package approximately ZAR 150 000 p.a.).

4.4.2. Buildings:

- **Offices**

  Four (Director, head technician and scientists) offices with power and LAN points, telephones and furniture, including 1 fax machine

- **Age determination laboratory**

  Sufficient bench space for 10 workstations (minimum 2 meters bench space per workstation, preferably partitioned).

  Power points at each workstation (for PC, microscope, light sources, video camera)

  LAN point at each workstation

- **Resin laboratory**

  Two large fume cabinets, alternatively an effective extraction system for the entire laboratory.
  Approximately 5 meters of bench space.
  Sufficient shelves and cabinets for storage of materials.
  Drying ovens

- **Wet laboratory**

  Sufficient bench space for 3 otolith saws (approximately 2.5 meters for each).

  Water supply (with basins).

- **Store Room**

  Sufficient shelving space (a compactus is an alternative) for the storage of completed samples and reference collections.

4.4.3. Equipment and Materials

- **Microscopes**

  Dissecting microscopes - 9

  Analytical microscopes - 1

  Fluorescent microscopes - 1

  (All microscopes equipped with standardized phototubes and transmitted illumination).

- **Auxiliary equipment**

  Video cameras (colour) - 10

Digital still cameras (colour) - 2

Incident illumination - 9

- **Computing**

Desktop PCs - 11

Laptops - 3

LAN - 1

Printers - 4

Software - MS Office

Adobe Acrobat

Graphics (Corel/Photo Shop)

Sigma Plot

IAS (Optimas/ImagePro)

Statistics (Statistica)

- **Laboratory equipment**

Otolith saws - 3

Oven (350^{o}C) - 2

Fume Cabinet - 2

Microbalance - 1

- **Materials**

Resin (incl. accelerator)

Otolith saw blades

Latex/silicone (for embedding moulds)

Microscope slides (+ cover slips)

Mounting medium (DPX)

Forceps, scalpels

Stationary

- **Office equipment and furniture**

Telephones - 8

Fax - 1

Photocopier - 1

Desks - 4

Chairs - 13

Filing Cabinets – 4

Shelving

4.5. Implementation and Long-term Operation.

4.5.1. Initial Phase (Duration approximately 2 to 3 months):

- **Refurbishing of Laboratories and Offices**
  The initial phase requires the painting of walls of the allocated offices and laboratories, the acquisition and relocation of benches, plumbing and electrical wiring to provide enough power and LAN points. Desks and chairs will have to be bought if they cannot be taken over from existing or donated resources. Telephones and fax machines have to be purchased and installed. Fume cupboards for the resin work also need to be accommodated.
- **Appointment of Staff and External Consultants**
  It is anticipated that in the initial phase 2 consultants are needed to set up the facility and to train the new staff members. One consultant should be familiar with pelagic species and the other with long-lived and demersal fish. Consultancy periods should be flexible ranging from 6 to 12 months, depending on the availability of the consultants. Appointment of the consultants could be by open tender and awarded by the administrative authority. Permanent positions in the centre should be advertised and all staff should initially be appointed on a contract basis. To ensure aptitude and best performance, new staff members should initially be given a trial period of 6 months after which they and the employer can decide on the continuation of the employment. Staff member should be permanently employed only after 5 years of continuous service. The consultants should be involved in the interviews for the permanent positions.
- **Purchase of equipment and materials**
  The Scientific Director and Head Technician with input of Consultants should be responsible for all equipment and materials purchases, and should ensure that the equipment complies with international standards. All equipment and materials should be available before staff training starts.

4.5.2. Training Phase (Duration approximately 1.5 years):

Prior to the start of training (preferably during the foundation phase), the consultants should select suitable samples from available materials for not more than 4 representative species. We recommend that otoliths of sardine, one hake species, one horse mackerel species and one sparid species should be selected for training purposes. Training should continue for 6 months. After 6 months, the aptitude and gained expertise of the trainees should be assessed to decide on whether or not the contract should be continued. The total training phase for all technicians should not last longer than 1.5 years. Routine age determination may be initiated during this phase, but the clients should be made aware of any potential limitations in the data. During this phase the required protocols for sample registration, preparation, analysis, data quality control (including routine re-reading of specimens for "re-calibration" purposes) and reporting should be developed and set in place.

4.5.3. Operational Phase:

It is anticipated that the centre should be fully operational 1.5 years after being established, although this may extend to 2 years if difficulties with finding suitable technicians are encountered.

4.6. COSTS.

4.6.1. Initial Costs of Implementation:

Although the objective would be that the age determination centre would become self-sustaining in the long-term, it would be unrealistic to expect this to be realised within any period shorter than 2 years. It is therefore imperative that sufficient funding be available to cover the initial costs of implementation. These are summarized in Tables 12 and 13 below.

- **Equipment, furniture and consumables**

Table 12: Acquisition costs (ZAR) of equipment, furniture and consumables in the foundation phase of the age determination centre.

DESCRIPTION	QTY	UNIT PRICE	TOTAL
Dissecting microscope (with phototube, transmitted and incident illumination)	9	25 000	225 000
Analytical microscope (with phototube)	1	40 000	40 000
Fluorescent microscope (with phototube and filters for OTC	1	60 000	60 000

Table 12: Acquisition costs (ZAR) of equipment, furniture and consumables in the foundation phase of the age determination centre.

and ALC)			
Incident Illumination	9	2 500	22 500
Video cameras	10	5 000	50 000
Digital still cameras (high-resolution, low light)	2	15 000	30 000
PC	11	10 000	110 000
Server	1	20 000	20 000
Laptop	3	15 000	45 000
Printers	4	2 000	8 000
System software	1	5 000	5 000
Image analysis software (ImagePro)	1	40 000	40 000
Various software (word processing, statistical, graphics)			60 000
Otolith saw	3	15 000	45 000
Oven (350°C)	2	20 000	40 000
Fume cabinets	2	30 000	60 000
Microbalance	1	30 000	30 000
Materials and consumables			80 000
Telephones	8	400	1 200
Fax	1	4 000	4 000
Photocopier	1	120 000	120 000
Desks	4	2 000	8 000
Chairs	13	1 200	15 600
Filing cabinets	4	4 000	16 000
TOTAL			**1 135 300**

These costs have been estimated according to recently quoted prices in 2003. It would be reasonable to assume that these costs will increase by approximately 10% in 2004. Further, these costs assume that all required items have to be purchased by the centre. Cost could be defrayed if the member countries would be prepared to lend or donate their existing equipment (if suitable) to the Centre. The sponsor would have complete control over the sponsored items. The centre would carry costs of routine maintenance of these items. The donating institutions would be benefiting from this arrangement in that all age determination will be conducted by the centre, releasing staff members currently assigned to age determination within the institution. Furthermore, the sponsoring institutions would accelerate the initial, set-up phase.

- **Salaries**

  The issue of salaries is an important one, considering that a major justification for the implementation of the centre is to retain staff. Attractive salaries are an important component of this, and employees of the centre have to be provided with remuneration comparable with what they could earn in the private sector. Salaries of all employees should be subject to a performance-based schedule as follows:

During the initial training phase, all technicians and scientists will be employed on a 6-month probation; continued employment is subject to satisfactory performance, aptitude and attitude. The salary during this period should be 60% of the salary associated with permanent post. If the contract is continued, the employee should earn 80% of the final salary for the following 4.5 years. After 5 years, if the employee wishes to continue in the post, 100% of the salary will be payable, and the position would become permanent. The junior technicians would then be eligible for promotion to senior technician (with associated salary increase) if performance and aptitude warrants. Representative inflation compensation will have to be considered, and the salaries adjusted accordingly.

Consultants: Two specialists in age determination methodology for a period of between 6 and 18 months, with the contracts being reviewed at 6-month intervals. We feel a basic fee of about R 20 000 per month should be reasonable. The Centre should be responsible for accommodation and travel costs. The issue of leave during the consultancy would have to be addressed subject to the policy of the administrative authority.

Table 13: Estimated employment costs (ZAR) for the various phases of the establishment and long-term operation of the age determination centre.

	First 6 months	**Following year**	**Years 1.5 to 5 (per annum)**	**Years 5+ (per annum)**
Director	75 000	200 000	200 000	250 000
Head Technician	66 000	176 000	176 000	220 000
Scientists (2)	132 000	352 000	352 000	440 000
Technicians (6)	180 000	480 000	480 000	600 000 +
Consultants (2)	240 000	480 000	-	-
TOTAL	**693 000**	**1 688 000**	**1 208 000**	**1 510 000 +**

4.6.2. Long-term Running Costs:

If the centre does fulfil its objective and become self-sustaining within 2 years, the costs listed below should be supported by the income generated from routine age determination by the centre.

- **Employment Costs**

  These would be the same as the total of the salaries listed in the column "Years 5+" in Table 13, with representative inflation compensation factored in on an annual basis.

- **Equipment Maintenance, Upgrades, Replacements and materials**

  Service contract for server and PC's and software upgrades = R 100 000 p.a.

  Annual replacements should not exceed 10% of the initial capital outlay on equipment

  Materials and consumables = R 50 000 p.a.

  An inflation compensation of approximately 10% per annum should be factored into these values.

APPENDIX 1: FACILITY ASSESSMENT QUESTIONNAIRE USED DURING DATA COLLECTION

IMPORTANT NOTICE

1. Note the currency you are reporting in. __________
2. Note name(s) title(s) and rank(s) of staff interviewed under "Reference".
3. Make any effort to get the complete information.
4. Try to obtain information as precise as possible.
5. Obtain copies of annual report(s) to support information.

SENSITIVE INFORMATION

The subsequent questions **may not be answered**. Therefore, assure the interview partner of strict privacy of the information provided and ascertain that no information is passed or leaked to competing institutions. Financial information should only pertain to the **AGE DETERMINATION UNIT**, if it is NOT an entire institution.

Name of institution: ______________________________

Name of Age Determination Unit: ______________________________

Address: ______________________________

____

____

Phones/Faxes: ____________/____________/____________

e-mails: ______________/______________

If available:

Annual Budget:	Government Funds:	___________	in %	__________
(2003)	Private Contractors:	___________	in %	__________
	Investment Funds:	___________	in %	__________
	Asset Returns:	___________	in %	__________
	Savings Plan Returns:	___________	in %	__________
	Total:	___________	in %	100

Annual Liabilities:	Insurances (Fire etc.):	___________
(2003)	Institutional Pension Fund:	___________
	Investments/ Savings Plan:	___________

Reference: ______________________________

I. CAPACITY

1. SIZE AND COST OF BUILDINGS

Size of age determination unit including any gardens, access roads, docking facilities or harbour access (m^2): ____________

Total area attributed / rented (m^2) to / by age determination: ____________

Estimated **m**onthly/**a**nnual costs of maintenance and rent: ____________

Reference: ____

2. OFFICE ALLOCATION

	No.	Space sufficient ? Yes	No	Utilization (hrs/day)
Offices	___	☐	☐	__
Guest offices/rooms	___	☐	☐	__
Laboratories	___	☐	☐	__
Permanent conference rooms	___	☐	☐	__
Social venues (kitchens, tearooms):	___	☐	☐	__
Workshops	___	☐	☐	__
Stores	___	☐	☐	__
Other	___	☐	☐	__

Are any rooms shared with other departments? ☐ ☐ __

State which ones and how their costs are shared.

____

____

Is a car park available or access to a car park shared? State costs. ________________________

Do overcapacities exist? If so, state where and what their costs and reasons are.

____

____

3. STAFF

Costs	No.	Costs per **m**onth / **a**nnum
Permanent staff working 8 hours/day:	___	___________
Permanent staff working 4 and 6 hours/day:	___	___________
Temporary staff working 8 hours/day:	___	___________
Temporary staff working 4 and 6 hours/day:	___	___________

Composition		
Permanent Scientific Staff (postdoc. qualifications):	___	___________
Permanent Scientific Staff (postgrad. qualifications):	___	___________
Temporary Scientific Staff (postdoc. qualifications):	___	___________
Temporary Scientific Staff (postgrad. qualifications):	___	___________
Permanent Technical Staff:	___	___________
Temporary Technical Staff:	___	___________
Auxiliary Technical Staff (short term, training):	___	___________
Secretaries and Workshop Personnel:	___	___________
Gardeners, Guards, Parking Attendants:	___	___________
External Experts:	___	___________

Staff Composition by Ranks

	No.		No.		No.
Director(s):	__	Assistant Director(s):	__	Senior Scientist(s):	__
Junior Scientist(s):	__	Postgraduate Student(s):	__	Student(s):	__
Head Technician(s):	__	Senior Technician(s):	__	Junior Technician(s):	__
Trainee(s):	__	Worker(s):	__	Guest Researcher(s):	__

Degree of Staff Cooperation

	Minimal	Acceptable	Normal	Excellent
Scientific – Scientific	☐	☐	☐	☐
Scientific – Technical	☐	☐	☐	☐
Technical - Technical	☐	☐	☐	☐
Social interactions (general)	☐	☐	☐	☐

Staff Assignment

Table 1. Numbers of staff assigned exclusively or occasionally to the various tasks of the unit.

	Scientific		Technical		Auxiliary	
Tasks	excl.	occ.	excl.	occ.	excl.	occ.
Age determination						
Technical preparations						
Preparation and determination						
Sampling						
Data collection (sea/port/lab)						
Staff (re-)training						
Data evaluation						
Innovative research						
Equipment maintenance						

Reference: ____

4. EQUIPMENT

Permanent Items		Costs	
	No.	at acquisition	of annual maintenance
Dissection microscopes	__	_________	_________
Analytical microscopes	__	_________	_________
Video image analysers	__	_________	_________
Imaging software	__	_________	_________
Video / digital cameras	__	_________	_________
Personal computers	__	_________	_________
LAN Server	__	_________	_________
System software	__	_________	_________
Otolith saws (portable)	__	_________	_________
Otolith saws (fixed)	__	_________	_________
Saw blades	__	_________	_________
Drying ovens (- 250º)	__	_________	_________

Burning ovens (- 350º)	__	_________	_________
Staining chemicals		_________	_________
Consumables (labs, offices, PCs)		_________	_________
Sea-going equipment		_________	_________
Electron microscope	__	_________	_________
Microprobe	__	_________	_________
Research vessel	__	_________	_________

Rented Items	No.	Costs **a**nnual / **m**onthly rent
Dissection microscopes	__	_________
Analytical microscopes	__	_________
Video image analysers	__	_________
Imaging software	__	_________
Video / digital cameras	__	_________
Personal computers	__	_________
Otolith saws (portable)	__	_________
Otolith saws (fixed)	__	_________
Drying ovens (- 250º)	__	_________
Burning ovens (- 350º)	__	_________
Electron microscope	__	_________
Microprobe	__	_________
Transportation (cars, trucks)	__	_________
Research vessel	__	_________

Equipment Maintenance

	No. of annual services	Repair only	Replacements Parts	Replacements Whole	How often?
Dissection microscopes	__	☐	☐	☐	____ / p.a.
Analytical microscopes	__	☐	☐	☐	____ / p.a.
Video image analysers	__	☐	☐	☐	____ / p.a.
Imaging software	__	☐	☐	☐	____ / p.a.
Video / digital camera	__	☐	☐	☐	____ / p.a.
Personal computers	__	☐	☐	☐	____ / p.a.
LAN Server	__	☐	☐	☐	____ / p.a.
System software	__	☐	☐	☐	____ / p.a.

Otolith saws (portable)	__	☐	☐	☐	____ / p.a.
Otolith saws (fixed)	__	☐	☐	☐	____ / p.a.
Saw blades	__			☐	____ / p.a.
Drying ovens (- 250º)	__	☐	☐	☐	____ / p.a.
Burning ovens (- 350º)	__	☐	☐	☐	____ / p.a.
Staining chemicals	__			☐	____ / p.a.
PCs	__	☐	☐	☐	____ / p.a.
Sea-going equipment	__	☐	☐	☐	____ / p.a.
Electron microscope	__	☐	☐	☐	____ / p.a.
Microprobe	__	☐	☐	☐	____ / p.a.
Research vessel	__	☐	☐	☐	____ / p.a.

Reference: ____

5. MATERIALS / CONSUMABLES

	Qty.	Costs	Readily available?
Resins	__	_________	☐ Yes ☐ No
Solvents	__	_________	☐ Yes ☐ No
Chemicals (list)	__	_________	☐ Yes ☐ No
	__	_________	☐ Yes ☐ No
Microscope bulbs	__	_________	☐ Yes ☐ No
Otolith saw blades	__	_________	☐ Yes ☐ No
Stationery (incl. Diskettes etc)	__	_________	☐ Yes ☐ No
Other materials (list)	__	_________	☐ Yes ☐ No
	__	_________	☐ Yes ☐ No
	__	_________	☐ Yes ☐ No
	__	_________	☐ Yes ☐ No

If materials are not readily available, state reason and usual delay period in obtaining these materials
____
____

II. CURRENT OUTPUT

1. ANNUAL STATISTICS

1.	Number of species processed	short-lived	____	long-lived	____
2.	Number of otoliths read		____		____
3.	Number of scales		____		____
4.	Number of fin rays		____		____
5.	Number of vertebrae		____		____
6.	Other ________________________________		____		____
7.	Number of otoliths	sliced	____		____
		burnt	____		____
		stained	____		____
8.	Number of fin rays / vertebrae sliced / stained		____		____
9.	Number of scales stained		____		____
10.	____		____		____
11.	____		____		____

Reference: ____

III. SPECIFIC REQUIREMENTS

(a separate copy of this table should be completed for each species)

SPECIES: **LONG LIVED?** (> 3 years): Yes / No **PRIORITY:** Critical / Important / Useful	 **LIFE STAGE:** Larvae / Juveniles / Adults **STATUS:** Permanent / Temporary
	DATA REQUIREMENTS
1. PURPOSE OF DATA: (e.g. age-structured stock assessment models, growth models)	
2. NATURE OF DATA: (e.g. year-class assignments, precise age ± 0.1 years, daily age)	
3. NATURE OF REPORTS: (e.g. age length key, stock age composition, growth curve)	
4. FREQUENCY OF REPORTS: (e.g. annual, biannual, monthly)	
5. MINIMUM NUMBER OF DATA: (also state size- or age-range that data should encompass)	
6. ACCURACY & PRECISION REQUIREMENTS:	
SAMPLING	
1. STRUCTURE: (e.g. otoliths, vertebrae, scales, fin rays)	
2. SOURCE: (e.g. pelagic/demersal research surveys, commercial catches, beach samples)	
3. FREQUENCY: (e.g. annual, monthly, weekly)	
4. STRATEGY: (e.g. random, stratified random by size class, stratified random by stratum)	

METHODOLOGY	
1. APPROACH: (e.g. visual examination of annual growth zones / daily increments, isotope analysis)	
2. ANALYSIS: (e.g. light microscopy, image analysis, SEM, microprobe)	
3. PREPARATION: (describe in brief, e.g. burn and slice, burn and break. Also mention if any stage is automated).	
DATA QUALITY CONTROL	
1. VALIDATION: (has the method been validated, how, when and by whom?)	
2. READER CALIBRATION: (how, when and by whom, is known-age material available?)	
3. ASSESSMENT OF PRECISION AND BIAS: (both within and among readers if more than one reader, do readers conduct replicate readings, how often, are reference collections / standards available?)	
4. TRAINING: - Has the reader(s) been trained in the method? - Is the level of training adequate? - How was the reader trained, and by whom?	
5. FURTHER COMMENTS:	

Reference: ____

IV. THE UNIT'S PAST AND FUTURE

1. What was the size (staff, offices, total budget) when the unit was founded?

____

____

____

____

____

2. What contributed most to the **e**xpansion / **d**ecline of the unit's capacity?

____

____

____

3. Did the duties change substantially with time? How did they change?

____

____

____

4. Are staff turnover rates a matter of concern?

____

____

____

5. Is the job climate conducive for improved efficiency and productivity?

____

____

6. Has the overall-expertise attracted private investors? If so, how?

____

____

____

____

____

7. Are the research vessels and their maintenance fully financed by government? If not, state other sources of funding.

____

8. What could be improved to accelerate the unit's performance. State in detail!

Reference: ____

Name of referee : __________________________________ Date : ________________

Copy of FAQ handed to : ____________________________________ on ________________

Signature of referee : …………………………………