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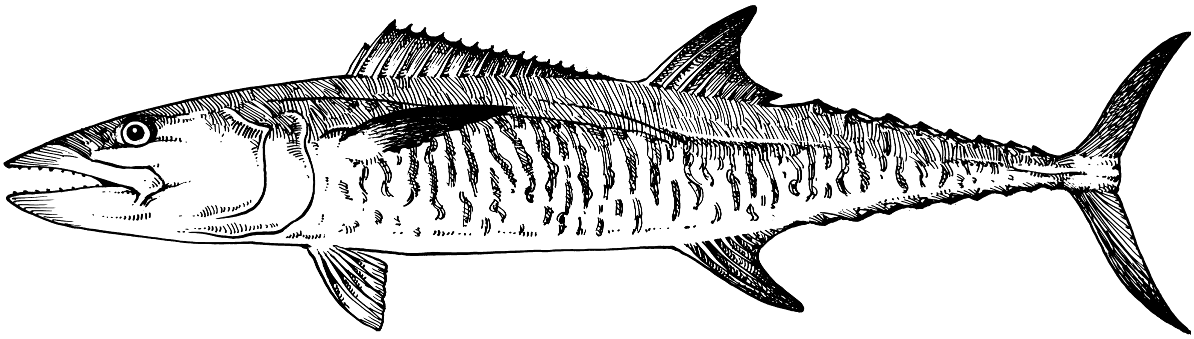
Monitoring Requirements for the Management of Spanish Mackerel (*Scomberomorus commerson*) in Queensland



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Summary and Recommendations

Spanish mackerel is an important commercial and recreational species with a total Queensland annual catch of approximately 1100-1500 tonnes. Recent research has divided the fishery into at least 3 stocks; an east coast stock that provides more than 85% of the total Queensland catch as well as stocks in the Torres Strait and the Gulf of Carpentaria. On the Queensland east coast, catches are virtually identical (in terms of total weight) between recreational and commercial sectors with the largest commercial landing coming from the Lucinda area on the north coast, whereas most of the recreational catch is taken from the south.

The current stock assessment for the east-coast Spanish mackerel fishery utilises an age-based population model that requires inputs on commercial and recreational total catches as well as representative catch age structures. These data currently come from a range of sources but rely heavily on the CFISH and RFISH databases as well as fishery dependent length and age data collected from the commercial sector by the Queensland Fisheries Service (QFS) through its Long Term Monitoring Program (LTMP). The LTMP sampling strategy has changed slightly since it began in 1999 but has essentially involved collecting fishery dependent samples of Spanish mackerel lengths and ages from the commercial sector at Lucinda during the spring/summer spawning period. There has also been sampling in the Torres Strait (although this has now ceased) and some preliminary sampling in the Gulf of Carpentaria.

Theoretically, sampling the spawning population at one point in time and space is a sound monitoring strategy providing that the entire exploitable stock is available on the spawning grounds each year. If a proportion of the stock is unavailable to be sampled (there are a variety of possible reasons why this is the case) then the single age structured sample may not be representative of the total catch, and if used in the stock model may provide biased assessments. Models and data presented in this report (as well as previous information) have shown that there is significant variation in Spanish mackerel length frequencies between sectors, gear types, spatially and even temporally and thus a single sample will not be representative of the entire catch.

The largest source of variation in fish lengths from the catches was between sectors with the commercial sector being more size selective than the recreational sector. This being the case, the current monitoring strategy is providing biased data on Spanish mackerel fish lengths and ages. In addition, from a long term monitoring point of view, management changes in the future may alter the selectivity patterns of either sector and may also change the proportion of the catch landed by each sector both regionally and temporally. This is another important consideration for spatial and sector resolution to the fishery dependent sampling.

Power analysis on the LTMP and CRC Reef Spanish mackerel length data (Tobin and Mapleston 2003) showed that about 60 catches (on average 4-5 fish per catch), from a number of different fishers (approximately 250 fish), from each of the commercial and recreational fishing sectors from four regions are required to detect a 5 cm change in average fish length. If there is the need to detect regional or sectorial differences in catches then this level of sampling is required.

Results from the catch re-sampling analysis suggest that the minimum monitoring requirement for the east coast stock is 40 - 60 random catches (250-300 fish) from both the

recreational and commercial fisheries in both the Townsville and the southern Queensland regions (a total annual sample of 1000 - 1200 fish). While it is recognised that some commercial catches can be in excess of 100 fish it is important to sample a small number of fish from many catches rather than sampling large numbers of fish from only a few catches. This would at least result in a representative sample of mackerel lengths (assuming the sampled population collected by the CRC Reef and LTMP is representative). Although it would still not allow any ability to detect full regional or sector differences in catch characteristics. For the latter to be possible about 60 catches will need to be sampled for each sampling unit (sector and region). It is not necessary to sample otoliths from each sector providing that the size structure of the sample of fish from which the otoliths are removed is the same as that of the catch but it is recommended that 300 otoliths be collected both in the north and south (total 600 otoliths). The current strategy of sampling only commercial catches resulted in poor accuracy and precision in estimating the length frequency for the total Spanish mackerel fished population.

In order to sample the recreational fishery adequately in the southern region the data will most likely be required to be collected over several months as it is logistically difficult to sample large numbers of recreational catches over a relatively short time period. Given the rapid growth rate of the species and problems with otolith interpretation this will require the derivation of an algorithm to assign fish to particular age classes based on "birthday", age and sampling month.

The collection of otolith samples for ageing during the spring also creates problems of otolith edge interpretation, as this is the time that the growth check becomes visible in otoliths. Errors in edge interpretation can cause an error of one year in assigned age. As the bulk of the fishery is made up of only 2 or 3 age classes, errors here can have a dramatic impact on accuracy of derived age structures that feed into the assessment models. Given the variation in growth between the sexes it may also be beneficial to use two growth curves in assessment models. If this were pursued then it would be necessary to double the number of otoliths collected (from 600 to 1200), as this would enable the derivation of separate catch age frequencies for each sex. Other areas where additional research could increase the precision of model outputs could be in the area of natural mortality as well as estimates of fecundity. Models are particularly sensitive to variations in natural mortality and the current estimate is not based on empirical methods.

The sampling strategy analysis demonstrated that considerable resources are required to adequately sample the east coast stock. Given that there are at least two other stocks currently fished in Queensland jurisdictional waters it is obvious that similar resources may need to be devoted to adequately monitor these stocks. At present the state of knowledge of the northern stocks is poor and the actual status of the Gulf and Torres Strait stocks is uncertain. There may be more than one stock in the Gulf and stock boundaries of the Torres Strait stock are uncertain. Before a sampling and monitoring strategy can be adequately formulated for these northern stocks it will be necessary to obtain better information on the stock structure of the northern stocks as well as obtaining more general biological information from these northern areas. There is clearly the need for further research in these areas although it is doubtful whether this should be included in the monitoring of the mackerel fishery as a whole at this stage given the relatively small size of these fisheries, the lack of biological data and the additional resources required to adequately collect data for monitoring and stock assessment.

The use of simulation modelling testing a combination of conventional tag-recapture and genetic mark-recapture has been investigated for this species and may prove to be a more cost effective assessment technique than age based stock models (Buckworth and Martell 2002; Simon Hoyle pers comm.) in the long term. At this stage the techniques have not yet been fully developed for Spanish mackerel but once the results of the "GENETAG" project are completely analysed, the costs and benefits of tagging versus fishery dependent assessment methods can be better compared. This should be an area of research that is closely monitored by the QFS Assessment and Monitoring team, as there is potential for significant cost savings in the future.

Introduction

The narrow-barred Spanish mackerel (*Scomberomorus commerson*) is an important commercial and recreational species fished along the continental shelf of the entire Queensland coast and has been recognised as a priority species for management and future assessment and monitoring. There have been numerous research studies (See Reference List) on the species that have provided a good understanding of its basic biology and ecology (at least in parts of its' range where studies by Geoff McPherson during the 1970's and 1980's in particular documented key features of the east coast stock). More recently there have been studies that have shown that in Queensland waters the species is composed of at least three distinct genetic stocks. There is uncertainty about the nature of the stock structure of fish in the Gulf of Carpentaria, Torres Straits and in the area north of Cairns. Despite this uncertainty about the stock identity of the northern stocks, the east coast stock is believed to be a unit stock (Ovenden *et al*. submitted). This is also the stock that has been the most thoroughly researched as well as contributing the majority of the Queensland catch in both the commercial and recreational sectors. Despite this, the Gulf of Carpentaria catch has been increasing in recent years and is also now becoming an important component of the total catch.

One of the features of all these stocks is that they are administered by at least two jurisdictions - Gulf of Carpentaria (NT and Qld), Torres Straits (Commonwealth and Qld), East coast stock (NSW and Qld). In the Gulf of Carpentaria, the Northern Territory government has been active in Spanish mackerel research for many years (R. Buckworth pers. comm.) while Queensland has been involved in research of the east coast stock since the 1970's (McPherson 1981, McPherson 1992 and others). New South Wales at present considers Spanish mackerel a low priority species for research and monitoring (Dennis Reid pers. comm.) as it is a relatively small commercial fishery (<30 tonne) and thus Queensland is responsible for the vast majority of the catch of the east coast stock.

Subsequent to a workshop that reviewed the stock assessment and monitoring data requirements for many of Queenslands' fisheries (Dichmont *et al*. 1999), Spanish mackerel was identified as a priority species for assessment and monitoring. A number of recent stock assessments (Welch *et al.* 2002, Hoyle 2002) have highlighted the need for precautionary management of these stocks. These assessments have used a range of data and models but are reliant to a large extent on data collected as part of the QFS Long Term Monitoring Program and it thus vital that the data collected by this program is unbiased and relevant to the requirements of the stock assessment models. This program basically collects fisheries dependent commercial size and age structures from the Lucinda region in north Queensland during the spring/summer spawning period.

Another recent study (Tobin and Mapleston 2003) has provided highly relevant data for evaluating sampling strategies for fishery dependent assessment of the east coast Spanish mackerel resource. That study identified both fishing sector and coastal region as the two most important sources of variation in mackerel catch characteristics. The commercial fishing sector landed a more size selective component of the east coast Spanish mackerel resource than the recreational fishery. Commercial fishers target specific size classes in response to marketing considerations and seek to maximise their economic returns from fishing. Recreational fishers on the other hand target mackerel opportunistically and consequently, the landed catches of the recreational fishing sector tend to be more diverse in length and age structure. They also noted that regional size and age structure of commercial catches were stable between regions relative to the variable nature of the recreational catch characteristics between the same regions.

This present report examines the data that has been collected to date, that is used to monitor and manage the stocks of Spanish mackerel throughout Queensland using the current assessment models. In particular the sampling strategy of the QFS long term monitoring program is reviewed and recommendations are presented for cost effective future monitoring options. The report also provides comments on other logistic, sampling analysis issues for this fishery. Readers are also advised to consult Tobin and Mapleston (2003) for details of recent regional size and age structured catch information, descriptions of fishing methods and other biological characteristics as this present report only summarises much of that detail. Throughout this report we have defined a catch as a daily commercial fishing "activity" as logged into the CFISH system. Likewise a recreational catch is a daily catch per angler.

Regional descriptions used in Spanish mackerel monitoring and management

Perusal of many of the documents describing catches of Spanish mackerel have highlighted several different conventions defining regional boundaries used to describe catches and management arrangements. This can be confusing when individual reports refer to common region names but not common geographic areas. Throughout this report we have used the definitions of Tobin and Mapleston (2003) that divide the east coast stock into zones of roughly 2° (120nm) width. This differs from the usual regions specified by the QFS Condition and Trend reporting (See Figure 1). Confusion may be created because the line of latitude (18.5°S) that divides the Northern Wet Region (Cairns) from the Northern Dry Region (Townsville) essentially passes through the Lucinda region where the bulk of the Spanish mackerel catch is taken. This means that in some descriptions the "Cairns region" has the bulk of the Spanish mackerel catch whereas by other definitions it is the "Townsville region".

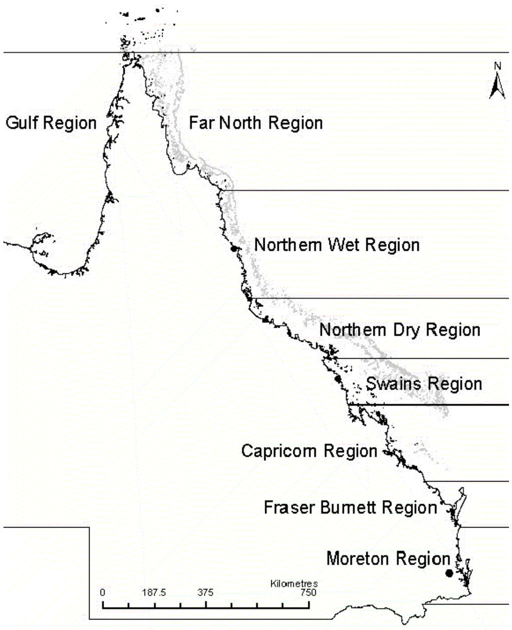

Figure 1 Descriptions commonly used for fishing regions by QFS for management and monitoring purposes.

It is important that future documents dealing with the assessment and monitoring of the Spanish mackerel resource either specify regional boundaries as latitudinal data or at least specify regions as accurately and unambiguously as possible.

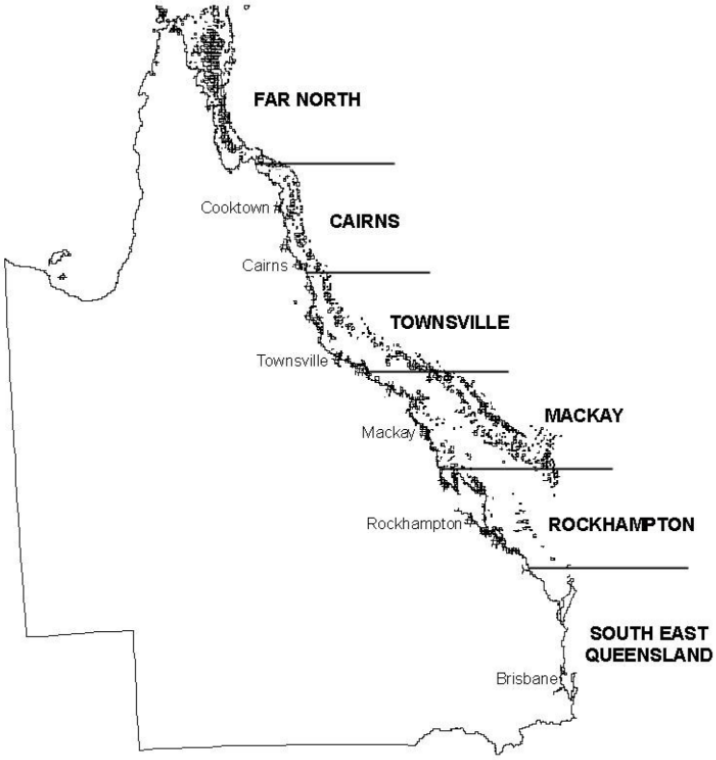

Figure 2 Areas used to describe Spanish mackerel catches by Tobin and Mapleston 2003

Spanish mackerel stock structure

Recent work conducted on the genetic identity of narrow barred Spanish mackerel has relevance to the design of a cost efficient monitoring program. Ovenden *et al.* (submitted to MFWR) have confirmed that the east coast stock is a separate stock from the northern and western Australian populations. That study was however unable to make definitive statements about the genetic identity of either the Gulf of Carpentaria or the Torres Straits stocks of Spanish mackerel, so there is still uncertainty about the number of mackerel stocks in this northern region. Further research to improve the understanding of the stock structure of northern Australian Spanish mackerels is therefore required. The research showed that the Torres Strait population was unlikely to be part of the northwest Australian stock and is likely to be a discrete stock. It was hypothesised that periods of isolation when lowered sea level caused a land bridge to separate east and west caused this isolation, and the Torres Strait population was experiencing little or no gene flow from neighbouring populations. The boundary separating the Torres Strait and eastern stocks is also unknown.

The Queensland east coast stock of Spanish mackerel displays a strong migratory behaviour that allows fishers to predict and target schools of fish move through, or temporarily reside in, particular regions along the Queensland east coast. In contrast the Northern stocks are believed to be less migratory and subject more to localised over exploitation and depletion.

QFS long term monitoring program

The current QFS monitoring program has been in operation since 1999 and was initially based on a fishery dependent survey of the commercial catch. This involved measuring a sample of fish from the commercial catch during the spawning season October/November in the Lucinda area of North Queensland with otoliths also being collected since 2001. In addition fish were measured and sampled for otoliths in Torres Straits for three years from 2000 to 2002 but this program was discontinued in 2003. Some preliminary sampling of Gulf of Carpentaria fish also commenced in 2003 with length information and some otoliths being collected from a sample of commercial Gulf line fishers (Neil Gribble, pers. comm.). Up until 2003 the samples from the Lucinda area were collected exclusively from commercial fishers who predominantly fished using wire, a technique described by McPherson (2002) as being selective for smaller mackerel and therefore under representing the larger mackerel that are likely present on the fishing grounds during sampling. In 2003 additional samples were sought from both recreational anglers as well as other commercial line fishers who use gear virtually identical to that of recreational anglers (line fishing).

The program currently samples as many catches from the commercial sector as possible during a 7-10 day sampling program with no spatial or temporal replication, and in the past no samples from the recreational sector. In the past this has meant the sampling of between 20 and 50 catches.

Stock assessment models and parameters used for Spanish mackerel fishery management

O'Neill and McPherson (2000) have described the requirements for stock assessment of Queensland Spanish mackerel noting that Dr Carl Walters recommended a target reference point of F~0.5 M (that is, fishing mortality should be half that of natural mortality) as a safe long term sustainable harvest rate level. It was also recommended that the aim of the stock assessment for this fishery should be to estimate and manage on the level of fishing mortality (i.e. fishing effort) rather than stock biomass (i.e. using quotas).

There have been two recent assessments conducted on the Spanish mackerel fishery. These assessments (Welsh *et al*. 2002) used the same base stock model as described by O'Neill and McPherson 2003. This age-structured model was originally developed by Rik Buckworth and Dr Carl Walters for use on the Northern Territory Spanish mackerel fishery. The model is similar to a Virtual Population Analysis (VPA) model, but allows for missing age data for some years where catch data is available. The model estimates the age structure of the fishery, and predicts future stock size trends, as a function of fishing mortality (F). Due to the use of age structured catch data the model is highly dependent on the accuracy and precision of the ageing data. The model also assumes equal exploitation rates on all recruited age classes. In order to continue to use these models age structured data will be required at regular intervals and it is important for these data to be representative of the entire fished stock.

As the monitoring data is meant to feed into stock models it is important to appreciate the parameters used in these models. While an analysis of the model sensitivity and response to data bias is beyond the scope of this report there are several points that are relevant to a discussion of the data collected by the QFS LTMP. The parameters used in the current model are shown in Table 1

Table 1 Input parameters for the age-structured model, as derived from Welch et al. (2002).

Parameter	**Sexes combined**
L_∞ (asymptotic mean length)	141.25 cm
K (growth rate)	0.2 year^{-1}
t_0 (theoretical age at length 0)	-1.97 years
Minimum legal size (FL)	68 cm
Age at full recruitment	2 years
a (length weight parameter)	0.000013 kg.cm^{-3}
b (length weight parameter)	2.9
M (natural mortality)	0.34 yr^{-1}
Length at maturity (FL)	79 cm
Fecundity	76539 eggs/kg
Beverton-Holt-a (stock recruitment parameter)	0.00000327 recruitment / egg
Beverton-Holt-b	5.333 x 10^{-9} eggs^{-1}
r_{max} (max reproductive rate at low population size)	5.00 replacement spawners / spawner

Much of these data were sourced from McPherson (1992) and McPherson (1993). Growth is modelled according to the von Bertalanffy growth curve, where L_∞ is the asymptotic length, K is the growth constant (also known as the Brody growth coefficient), and t_0 is the hypothetical age at which individuals have zero length. None of the current models differentiate growth between sexes, despite the fact that growth has been demonstrated to vary sexually (females are larger and faster growing). The Beverton and Holt recruitment steepness parameter (rmax) was based on parameters derived from Scombrid species (Myres *et al*. 1999)

Where fecundity has been used in models it has been set at the mean number of hydrated oocytes per gram of ovary in immediately pre-spawning fish with no allowances made for relative differences in spawning frequency for different age or size classes.

Models are always highly sensitive to natural mortality and in this case M was estimated using Hoenig's estimator (Hoenig 1983). It should be noted that this method is often criticised as being highly inaccurate for many species.

In some models the lack of catch data for the period between 1982 and 1987 was accommodated by setting the annual catch for this time at 575t. This was the average of 1979-81 fish board data and 1988-90 QFISH data. Such an assumption allows a continuous time series of data available for the analysis but is based on the possibly flawed assumption that the catch trend from 1982 to 1987 was stable.

All of the recent assessments of the fishery have highlighted the need for more age-structured data to improve the reliability of model outputs. Prior to this current review Welch *et al*. 2002 recommended that the recreational catch should be sampled in addition to or instead of commercial sampling. Hoyle per comm. also noted that it was important to collect size and age-structured data from a number of regions along the East Coast of Queensland from both the commercial and recreational fishing sectors.

A tag-recapture program is also being considered for this species to provide reliable estimates of annual exploitation rates (reliable if a high reporting rate of tagged fish recaptures were achieved). But, before this can be achieved significant advances must be made to achieve high tagging intensity and low mortality rate tagging over short periods. Traditional tagging may become more effective if NT and Qld fisheries can reduce tag loss/mortality rates with the use of an alternate tag style currently being trialled. This work is essential for validating the current stock assessment model.

Data sources used in stock assessment of the Spanish mackerel fishery

Other than the QFS monitoring data there are currently several data sources which can be used in the assessment and monitoring of Spanish mackerel in Queensland. These are summarised below.

1. Annual commercial catch and effort data from the QFISH data system from 1988 for both the east coast and the Gulf of Carpentaria. There is uncertainty about the large catch of "unspecified mackerel" that has not been allocated to a particular species within the CFISH database. There have been several approaches for allocating a proportion of this category to Spanish mackerel. These have traditionally been allocated based on regional ratios of Spanish mackerel to other species where species identification has been specified. These issues are discussed in more detail later in this report.

2. Annual Queensland Fish Board (QFB) records from 1970 to 1981. Like the QFISH data these data suffer from a lack of a clear definition of each of the mackerel species and in this case it is difficult to formulate decision rules for allocating the catch into species groups. These data also do not take into account landings taken outside the Queensland Fishing Boundary that were assigned to the Fish Board in Brisbane or other regional QFB depots.

3. Commercial size and age structured data from north Queensland for 1977 and 1978 (Geoff McPherson's data). This is a research data set that contains size and age data largely collected from the commercial fishing sector in North Queensland and is believed to be an unbiased sample of the commercial age structure during the two sampling years of the project.

4. Data collected from RFISH recreational catch and effort surveys during 1997, 1999 and 2001. These surveys contain data on Spanish mackerel catches throughout Queensland based on diary records of a sample of recreational anglers. Again, there is some uncertainty about the species identification in many of the records as a high proportion of catches are recorded as "mackerel" only and are not assigned to a particular species.

5. Results of CRC/QDPI FRDC project (No. 2001/109) on Spanish Mackerel (Tobin and Mapleston 2003). This project collected size and age structured data from commercial and recreational Spanish mackerel fishers from 4 regions south of Cairns to the Queensland/New South Wales border.

6. Data from the QFS LTMP project which has been collecting size and some age structured data from the mackerel fishery off Townsville and in the Torres Straits. These data are collected during only one month of the year (October), which is the time when mackerel are "aggregating" to spawn in waters off Townsville.

The CRC dataset (5) and that of the QFS LTMP data (6) form the basis of sampling strategy discussion of the present report.

Gulf of Carpentaria Spanish mackerel stocks.

Despite the fact that CFISH data indicate a relatively stable catch in the Gulf of Carpentaria (Figure 3) the effort on all mackerel species in the Gulf is believed to be increasing as a result of increased net fishing as well as hook and line. There is currently little information about the selectivity of each of these gears nor is there any information on the general biology of the Gulf Spanish mackerel stocks (apart from some information from the Northern Territory) but should monitoring of this fishery be considered an issue then it will be important to monitor the catch from both fishing methods in a similar manner to the monitoring of the recreational and commercial fishery on the east coast. It is important that future research continues to collect information from the Gulf fishery, particularly given the importance of the Northern Territory Spanish mackerel fishery and the fact that the stock is being fished by two state jurisdictions, each with different management arrangements. Queensland managers have previously highlighted the need for a management strategy evaluation of the Gulf of Carpentaria Spanish mackerel stocks (Mark Elmer, pers. comm.). Given the lack of basic biological information about this stock, any assessment of the fishery would most likely be imprecise and inaccurate. We will show in later sections of this report that in order to have sufficient power to detect change in size structure of the east coast fishery considerable resources are needed. It is reasonable to assume that a similar situation exists with the Gulf of Carpentaria stocks of Spanish mackerel. Unlike the east coast stock where we have a significant amount of data to model the fishery the Gulf of Carpentaria stock is data poor and considerable uncertainly surrounds it.

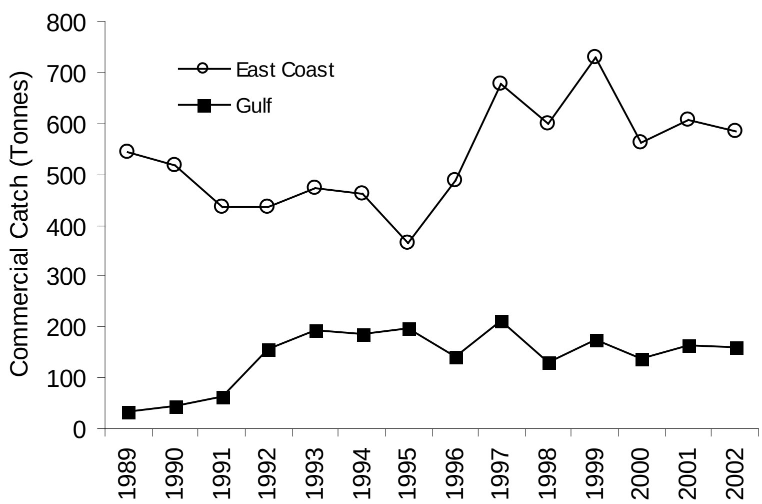

Figure 3 Change in commercial catch of Spanish mackerel on the east coast and in the Gulf of Carpentaria.

Buckworth *et al* (2003) noted that adult Spanish mackerel from Northern Australia do not undertake lengthy seasonal migrations (in contrast to the east coast stock) but show a high degree of site attachment. They warn that the combination of the schooling habit of Spanish mackerel with a meta-population structure renders stocks highly susceptible to localised and serial depletions. For this reason alone the fishery requires ongoing research.

Northern Territory scientists have also been involved in research into the Spanish mackerel fishery during the last 10 years. As mentioned earlier NT fishers are catching a part of the same stock fished by Queensland fishers in the Gulf of Carpentaria. O'Neill and McPherson (2000) note the following features relevant to the assessment and management of the NT mackerel stocks. (1) The NT stock is probably still recovering from high exploitation from Taiwanese gill net fishing, which took large catches of small fish up until the mid 1980's, (2) Sustainable yield estimates are about 300-500t per year, depending on what the recreational sector is assumed to be catching at present. If the recreational catch is low the sustainable yield is about 300t per year. If the recreational catch is high, then the sustainable yield is about 500t per year. The NT argue that recreational fishers should be treated in the same way as the commercial sector in terms of management and (4) allocation of the 300-500t catch quota between fishing sectors is a major issue for NT fisheries managers.

These features add to the uncertainty in assessing and monitoring the shared Gulf of Carpentaria stock(s) that form a part of the NT commercial and recreational fisheries.

Features of the Queensland CFISH and RFISH Spanish mackerel data and catch size structure

Much of the detailed analysis of the Queensland commercial (CFISH) and recreational (RFISH) catch and effort data can be found in Tobin and Mapleston (2003) but it is important to note the following features of these data that are pertinent to designing a representative and cost effective fishery dependent sampling strategy.

There are significant regional differences in catches between the two sectors (Figure 4 and Tobin and Mapleston, 2003). While the majority of the commercial catch is taken off Ingham (Townsville Region) most of the recreational catch is taken in the southern part of the state. In addition, the selectivity patterns of both sectors differ regionally with the commercial fishery having a smaller size variance compared to the recreational fishery (Tobin and Mapleston 2003). These issues are addressed more fully in later sections of this report.

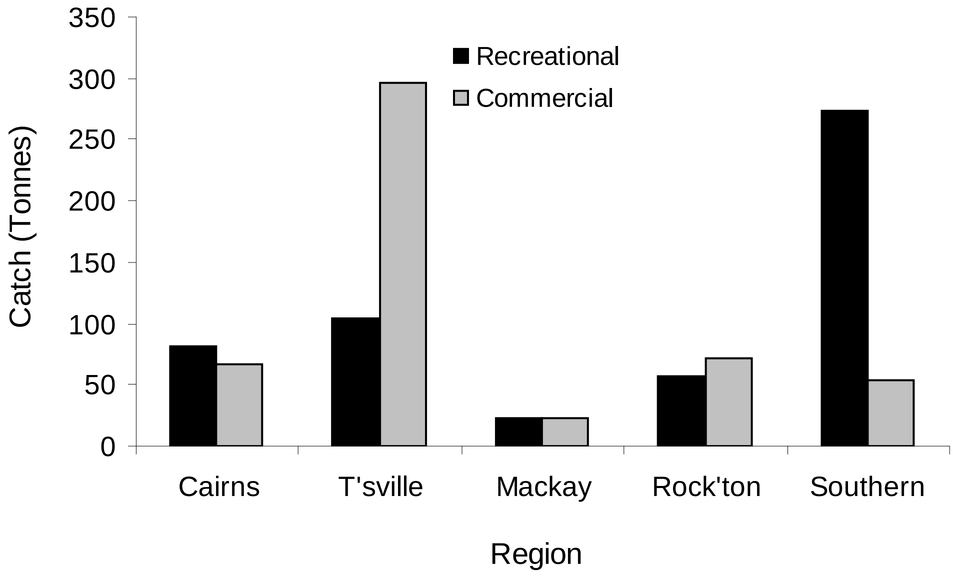

Figure 4 Recreational and commercial catch of Spanish mackerel in 5 regions along the east coast of Queensland during 2001.

The current monitoring strategy of targeting the commercial fishery off Ingham has potential biasing effects due to the under-representation of recreational catches from southern Queensland. This is not necessarily a problem if the catch size and age structures do not differ regionally. However, because mackerel are a highly migratory species and there is evidence of different regional selectivity's for the recreational sector in particular means that a single regional sample from one sector may be flawed.

Future management changes that cause a change in the proportion of the catch taken by each sector or region could further be a complicating factor if there is no spatial or temporal resolution to the data used for assessment purposes. Without samples from different regions and sectors, any change detected from the LTMP data could be misinterpreted and possibly incorrectly attributed to fishing mortality when it may equally be due to different regional patterns of fishing mortality.

Optimising the LTMP sampling strategy for the East Coast Spanish mackerel stock

At present there is only sufficient information to enable a sampling evaluation and power analysis of the east coast Spanish mackerel stock as this is the only stock which has sufficient catch and size data collected from both sectors over a broad spatial scale and over a number of years. The following section describes methods used to determine an optimal sampling strategy for this stock and presents the results of analyses that can be used to design a cost effective monitoring program for the stock.

Methods of Evaluation

1. Random Effects Modelling

The size frequency data collected by the DPI LTMP and the Townsville Reef CRC (6689 fish in total) were analysed using a linear random effects model ((Montgomery 1997);

(GENSTAT 2002)). The analysis facilitated the estimation of the variance components. That is, a linear model with random effects which partitions the variance in the data into components. Random effects are those factors that can be treated to represent a random selection from the overall population. For example, the Spanish mackerel size frequency data originated from 119 different commercial and recreational fishing catches, a possible random selection from the total number of catches between 2000 and 2003 inclusive. Like generalised linear models, random effects models can be used to analyse unbalanced data sets. But unlike generalised linear models, they can also measure more than one source of variation in the data thus providing an estimate of the variance components associated with the random terms in the model. The linear random effects model is applicable here because it can be used to obtain information on sources and sizes of variability in the Spanish mackerel data sets. This is of particular interest where the relative size of different sources of variability must be assessed to design a more effective sampling strategy for Spanish mackerel.

The analysis used a linear random effects model assuming normally distributed errors. The response variable was based on the individual fish lengths and the findings are pertinent to both average fish lengths and frequency distributions. The data were stratified into four regions along the east coast of Queensland: 1) Townsville, 2) Mackay, 3) Rockhampton, and 4) South East Queensland, based on the area definitions used by Tobin and Mapleston (2003) (Figure 2). Calender years were used to define the annual cycle of the fishery. The fishing months were analysed as nested factors within each year. This recognised that the months in one year were not identical to the months in other years (months are typically assumed identical between years when coded as fixed main effects). Two other model factors were used to complete the models and analyses. One model used the fishing sectors (commercial and recreational) and the fishing gears (line or wire) to define sources of variation in fish sizes. The other model used the unique fishing group identifiers in the databases to define sources of variation in fish sizes between fishing groups, fishing sectors and fishing gears. The fishing sector, gear and group identifiers could not be modelled together due to aliasing, that is, their coding explained similar sources of variation in the data.

The statistical software package Genstat 6 (2002) was used to carry out the analyses and provide estimates of the variance components. No transformations on the data were required and the standardised residuals were normally distributed with no pattern when plotted against their fitted values. Definition of the two models were as follows:

(a) First Model

Response Variate: Fish Fork Length

Fixed model component: Constant
Random model components: year / month + region + sector + gear

- Calender years – 2000 to 2003.
- Fishing Months – January to December.
- Fishing regions – Townsville, Mackay, Rockhampton, and SE Qld.
- Fishing sector – recreational or commercial.
- Fishing gear – line (rod and reel) or wire.

(a) Second Model

Response Variate: Fish Fork Length

Fixed model component: Constant
Random model components: year / month + region + fishing group id

- Calender Years – 2000 to 2003.
- Fishing Months – January to December.
- Fishing regions – Townsville, Mackay, Rockhampton, and SE Qld.
- Fisher groups – 119 different recreational and commercial fishing groups.

2. Power analysis

The main considerations in designing a monitoring scheme for Spanish mackerel are whether the fish collected and measured are representative and whether they are able to show true changes, or trends, in fish age or length. In stock assessment, changes in age-structure or length frequency typically highlight patterns in recruitment, fishing mortality, and fishing gear selectivity. In order to model these patterns, a long time-series of representative data are needed. The ability to detect true changes in Spanish mackerel age or length frequencies, e.g. due to the effect of increasing fishing mortality, which occurs over and above the amount of variation that the natural population exhibit can be quantified through power analysis. In statistics the term power refers to the ability to detect a true increasing or decreasing trend. Several factors affect power, such as the number of catches sampled, variability of the samples, and magnitude of the difference or trend to be detected. Designs with small samples sizes and high variability will have low power. If the size of the difference or trend is small compared with the natural population variability it will be difficult to detect.

Accurate monitoring of Spanish mackerel fish lengths and ages requires an appropriate number of catches, fishing regions, seasons, and years sampled to be able to detect a trend. All these considerations can be related to power analysis. Calculating the power of detecting trends in fish length or age structures is difficult and requires estimates of the variance. Spanish mackerel monitoring has now been under taken for four years and this data provides us with an estimate of the variance. An excel worksheet for power analysis of specified means was used to determine the power for a given scenario of mean fish sizes between regions (O'Neill and Thompson 1998). A range of possible sample sizes (number of catches and fish) were tested for anticipated mean fish sizes. The power was calculated using an estimate of variance from the random effects models.

3. Sampling Analysis

A randomisation program was developed in (MATLAB 2002) to evaluate possible monitoring strategies for Spanish mackerel. The simulation used four sources of Spanish mackerel data 1) the DPI LTMP fish length frequencies collected in November 2001 and 2002, 2) the Reef CRC fish length frequencies collected between July 2001 and January 2003, 3) the 2002 commercial catches from the CFISH database and 4) the 1999 RFISH database of recreational catches. Descriptions of these data are provided in the results section and elsewhere in this report. The data were structured to examine a stratified sampling program consisting of eight strata defined by two fishing sectors (commercial and recreational) and four regions (Townsville, Mackay, Rockhampton, and SE Qld).

The randomisation program followed a series of steps to construct/simulate 1) the actual Spanish mackerel fish-length frequency distributions and 2) the fish-length frequency distributions as determined by the monitoring sampling protocols. The results from the program compared the frequency distributions to evaluate the accuracy of monitoring both fishing sectors and the four fishing regions. The numbers of catches examined for monitoring each stratum were 10, 30, 50, 70, and 90 catches. Table 1 and Figure 5 outline the program's sampling algorithm. A least squares (*ls*) measure was used as a simple statistic to quantify the accuracy of monitoring fish-length frequencies:

$$ls = \sum_{j=1}^{\max size}\left(sampledLF_j - actualLF_j\right)^2$$

where *j* were centimetre length classes and max size was the largest fish in the data (160cm). Note the accuracy of constructing fish age distributions was not assessed in this report. Further data to differentiate fish sex and aging errors are required. The current Matlab program can be easily modified to evaluate fish age distributions. Nevertheless, the issue of differentiating fish sex and aging errors is a post monitoring concern. If the fish-length frequency distributions are monitored accurately, then this will lead to accurate monitoring of fish age distributions (given the fish are aged with reasonable accuracy).

Table 2 Algorithm for constructing fish-length frequencies in each stratum.

1.	Organise all possible catches (number of fish) into vector **V**.
2.	Organise available fish lengths (cm) in a matrix **M,** where the rows separate individual fish lengths and the columns separate different catches.
3.	Select *n* catches at random without replacement from **V** e.g. 30 catches
4.	Select *n* catches at random with replacement from **M**.
5.	Using the data from step 4, select fish lengths at random with replacement from each catch (column) to create fish lengths for each catch in step 3.
6.	Repeat steps three to four for all catches in **V** to simulate the actual fish-length frequency.
7.	Calculate statistical measures to compare the monitoring and actual fish-length frequencies.
8.	Repeat steps three to five 1000 times to obtain a large number of variations in the data sets.
9.	Data sets from each stratum were combined using appropriate weights (total catches).
10.	Calculate 5% and 95% percentiles on the 1000 variations of fish-length frequencies and statistical measures.

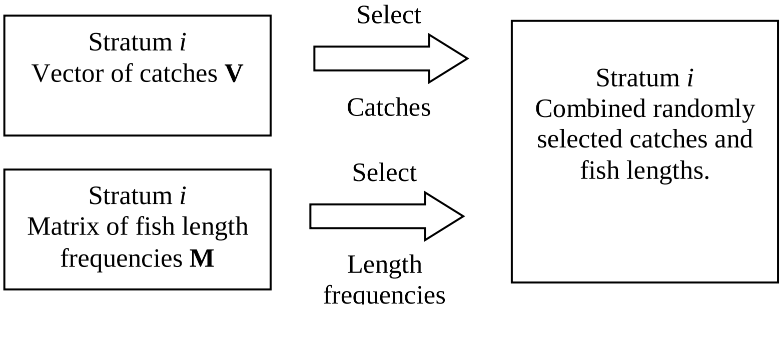

Figure 5 Flow diagram illustrating the randomisation approach. Also note the detailed steps in Table 2.

Data used in the Sampling Analysis

Table 3 shows the combined number of catches and fish measured by the DPI and the Reef CRC. Note that the fish measured by the DPI were from only commercial fishers operating in the Townsville region using wire-trolling gear. The fish measured by the Reef CRC were from commercial and recreational fishers using line-gears from all regions. These data were structured into eight strata defined by two fishing sectors and four regions.

Table 3 The combined number of Spanish mackerel catches and length frequencies collect by the DPI and the Reef CRC.

Region	Commercial		Recreational	
	No. Catches	No. Fish	No. Catches	No. Fish
Townsville	53	2771	46	227
Mackay	15	115	12	65
Rockhampton	83	962	15	67
South East Qld	33	284	28	76

The number of commercial and the estimated number of recreational Spanish mackerel catches are shown in Table 4. The number of recreational angler catches of Spanish mackerel was calculated by dividing the estimates of total catch (Table 5) by the average catch rates (Table 6). The size of the recreational catch was derived using the total harvest estimates in 1999 of 56,000 Spanish mackerel and 73,400 unspecified mackerel (Higgs 2001). The percentage 19.1% of unspecified mackerel was allocated to Spanish mackerel by summing across the RFISH scaling factors or weights (w_kept database field) (Table 5). An average fish weight of 8kgs was used to approximate the total Spanish mackerel harvest (t). The all-mackerel weights consisted of the species school, grey, salmon, shark, spotted and Spanish. The recreational catches from Cairns were combined with Townsville's for the analysis. The number of fish in each commercial catch was calculated by dividing the Spanish mackerel catches in kilograms by the average fish weights (rounding the fractions of fish upwards) (Table 7). For the purpose of this report commercial unspecified mackerel were not disaggregated into Spanish mackerel. A detailed binary regression analysis is required for this exercise and warranted in future stock assessments. The ratio of east coast commercial unspecified (54 t) to Spanish mackerel (520 t) was 10% in the 2002 year. Disaggregating 54 t of unspecified mackerel into the species school, grey, salmon, shark, spotted and Spanish would have little influence on the results.

Table 4 The number of commercial and recreational Spanish mackerel catches used in the analysis (data sources: 2002 commercial logbooks and 1999 RFISH).

Region	Commercial	Recreational
Townsville	2344	12953
Mackay	865	2010
Rockhampton	1454	3524
South East Qld	1210	15456

Table 5 The weights used to disaggregate the 1999 RFISH harvests into Spanish mackerel (SPM) by region.

Region	Spanish Mackerel Weights	SPM Weights as a Proportion	All Mackerel Weights	SPM Harvest (No. Fish)	Selected Unspecified Mackerel Harvest (No. Fish)	Total Harvest (No. Fish)	Total Harvest (t)
Far North	1919.12	0.031	2220.12	1724	431	2155	17
Cairns	9028.52	0.145	31800.25	8111	2029	10140	81
Townsville	11594.1	0.186	63894.45	10415	2605	13020	104
Mackay	2527.69	0.041	37366.24	2271	568	2839	23
Rockhampton	6392.74	0.103	39801.76	5743	1436	7179	57
SE. Qld	30434.86	0.488	145986.1	27340	6838	34178	273
Unknown	441	0.007	5607.917	396	99	495	4
Total	**62338.03**	**1**	**326676.8**	**56000**	**14006**	**70006**	**560**

Table 6 Recreational anglers average Spanish mackerel catch rates (data source: RFISH 1999).

Region	Spanish Mackerel Average Catch Rates (no. fish)
Townsville	1.79
Mackay	1.41
Rockhampton	2.04
South East Qld	2.21

Table 7 Average fish weights by region used to convert the 2002 commercial Spanish mackerel catch (kgs) to numbers of fish (data source: Reef CRC).

Region	Spanish Mackerel Average Fish Weights (kgs)
Townsville	7.7
Mackay	8.1
Rockhampton	8.2
South East Qld	7.8

Results

Random Effects Modelling

The random effects modelling showed significant variation in Spanish mackerel lengths between fishing groups, gear types, regions and months (Table 8). Of the two models, the second suggested more variation and highlighted the importance to sample many fishing groups within each region. These two sources of variation represented 58% of the variation in the data. The first model highlighted the importance of sampling both commercial and recreational catches and the major gear types of line and wire fishing; together these sources represented about 25% of the variance. It should also be noted that the temporal variations in fish sizes were also significant (10% of the variance in model 1). This suggests that samples need to be collected from both recreational and commercial sectors and it is preferable to collect samples over a temporal scale that allows an assessment of this variation.

Table 8 The estimated variance components of the Spanish mackerel length data.

Random Effects Term	Variance Component	Percent of Total Error
Model 1		
Year	8.7	4
Year/month	22.9	10
Region	5.6	3
Sector	18.1	8
Gear	7.4	3
Residual	160.7	72
Model 2		
Year	25.8	6
Year/month	16.2	4
Region	63	16
Fishing Groups	171.3	42
Residual	127.8	32

Power Analysis

The power results were dependent on the amount of variance and the monitoring target for measuring change in average fish size (Table 9 and Figure 6). The variance components calculated in the second model should be taken as a conservative measure as the model more truthfully captured the variation in fish lengths taken between fishing groups. Powers larger than 0.8 were used to suggest appropriate sample sizes, due to these powers being more effective in detecting change with 95% confidence (Thomas 1994). The results indicated that a 5 cm change in average fish size (e.g. from 100cm to 95cm) would likely to be detectable if about 60 catches, consisting of about 250 fish, were sampled from each of the eight strata (two sectors and four regions). In comparison, the results indicated that a 10 cm change in average fish size would likely to be detectable if about 25 catches, consisting of about 100 fish, were sampled from each of the strata. Slightly improved powers would be achieved if sample sizes were optimally allocated according to total catches in each region.

In summary, the random effects modelling and the power analysis show the importance to monitor Spanish mackerel lengths and ages every year, with samples collected spatially across the regions from both commercial and recreational fishing sectors. The current DPI monitoring sampling has low power, but this will improve considerably when samples are collected from more fishers and regions. Generally for trend detection more sampling units, that is sample more catches, is preferred than to increase sampling the number of fish with only a few fishers and catches. If more Spanish mackerel are measured from many different catches, the variation in fish lengths between fishing groups can be removed from the trend detection. Strategies to reduce variances are to have strict guidelines on when, where and how sampling should be undertaken. More catches measured within each region will decrease the within–region variance.

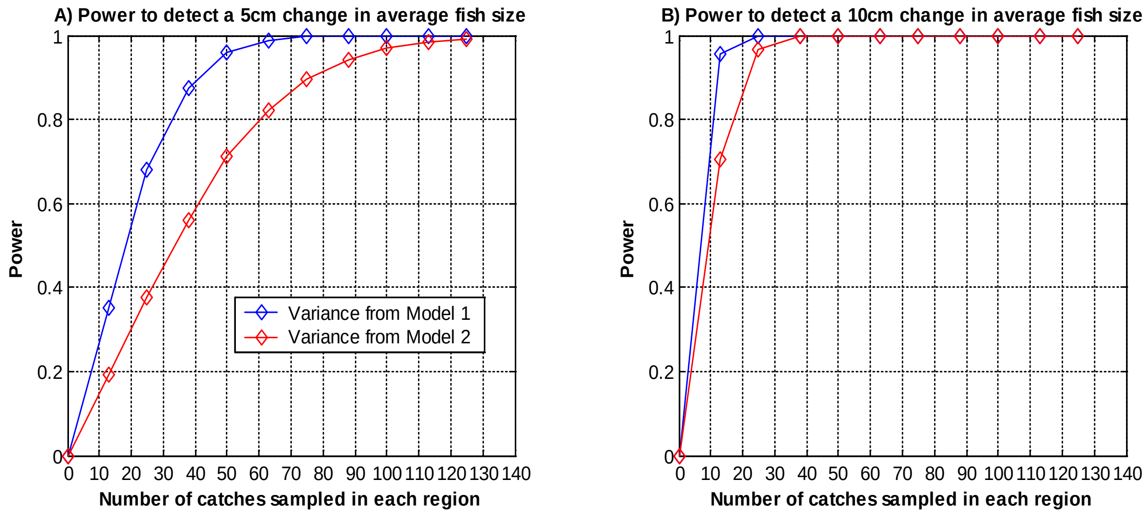

Figure 6 Power to detect A) a 5cm change in average fish length and B) a 10cm change in average fish length for Spanish mackerel. The sample sizes (number of catches) relate to each fishing sector and region. Powers of larger than 0.8 are generally considered to be effective for detecting change. The results are tabulated below (Table 9).

Table 9 The powers to detect a 5cm or 10cm change in average Spanish mackerel length. The sample sizes (number of catches) relate to each fishing sector and region. Each Spanish mackerel catch was assumed to average about 4 fish, as calculated from the data.

Sample Size Number of Catches (assumed 4 fish per catch)	Sample Size Number of Fish	Power **5cm change** Var ≈ Model 1	Power **10 cm change** Var ≈ Model 1	Power **5cm change** Var ≈ Model 2	Power **10 cm change** Var ≈ Model 2
0	0	0	0	0	0
13	50	0.353	0.955	0.191	0.704
25	100	0.679	1	0.377	0.968
38	150	0.874	1	0.56	0.998
50	200	0.958	1	0.711	1
63	250	0.988	1	0.822	1
75	300	0.997	1	0.896	1
88	350	0.999	1	0.942	1
100	400	1	1	0.969	1
113	450	1	1	0.984	1
125	500	1	1	0.992	1

Sampling Analysis

As expected, smaller least squares were obtained when more catches were sampled, indicating higher accuracy in evaluating the Spanish mackerel length frequency distributions. Commercial samples are also generally estimated with a higher degree of confidence than those obtained from the recreational sector. This is a result of the greater size variation in mackerel caught by the recreational sector, a result already highlighted by Tobin and Mapleston (2003). Samples from the recreational sector from SE Queensland also had a higher variance than other regions and sectors again due to a larger variation in size of fish landed.

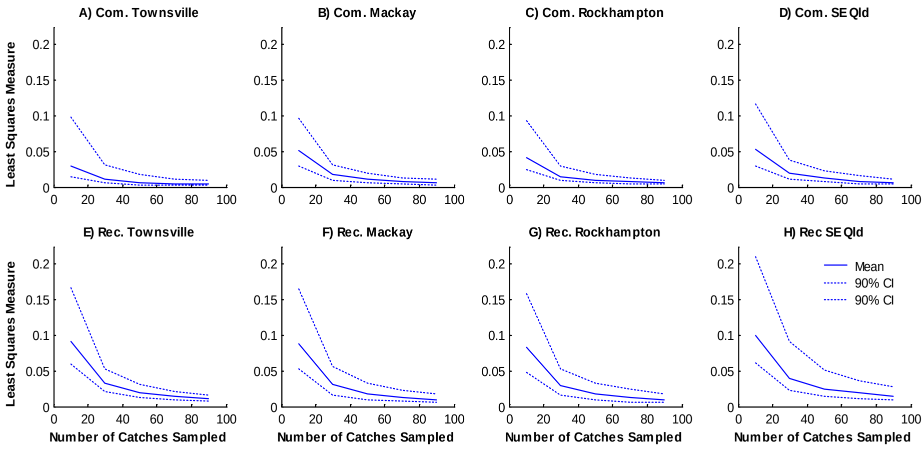

Figure 7 The average least square measures (dotted lines 90% confidence intervals) from monitoring numbers of different catches in each stratum (two fishing sectors: com – commercial and rec- recreational; four regions: Townsville, Mackay, Rockhampton and SE Qld).

Once again the model estimated the average size of mackerel from the commercial samples from Townsville with the greatest confidence (Figure 8). The plots also show smaller confidence intervals when more catches are sampled, indicating higher accuracy in estimating average fish length.

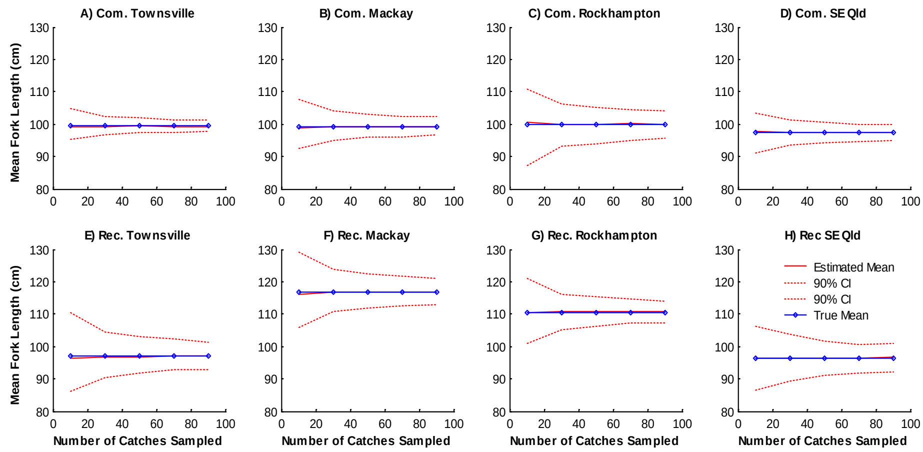

Figure 8 The comparison of actual (blue line) and estimated (red line) mean Spanish mackerel lengths (red dotted lines 90% confidence intervals). The comparison is shown for monitoring numbers of different catches in each stratum (two fishing sectors: com – commercial and rec- recreational; four regions: Townsville, Mackay, Rockhampton and SE Qld).

When the actual size data is re-sampled the resultant length frequency plots (Figure 9) show greater monitoring accuracy and smaller confidence intervals when more catches are sampled, and that sampling just one fishing sector and region cannot represent the overall fishery length frequency distributions. More than 30 catches are required to be sampled from each fishing sector and region before the sampled data starts to approximate the actual observed distributions.

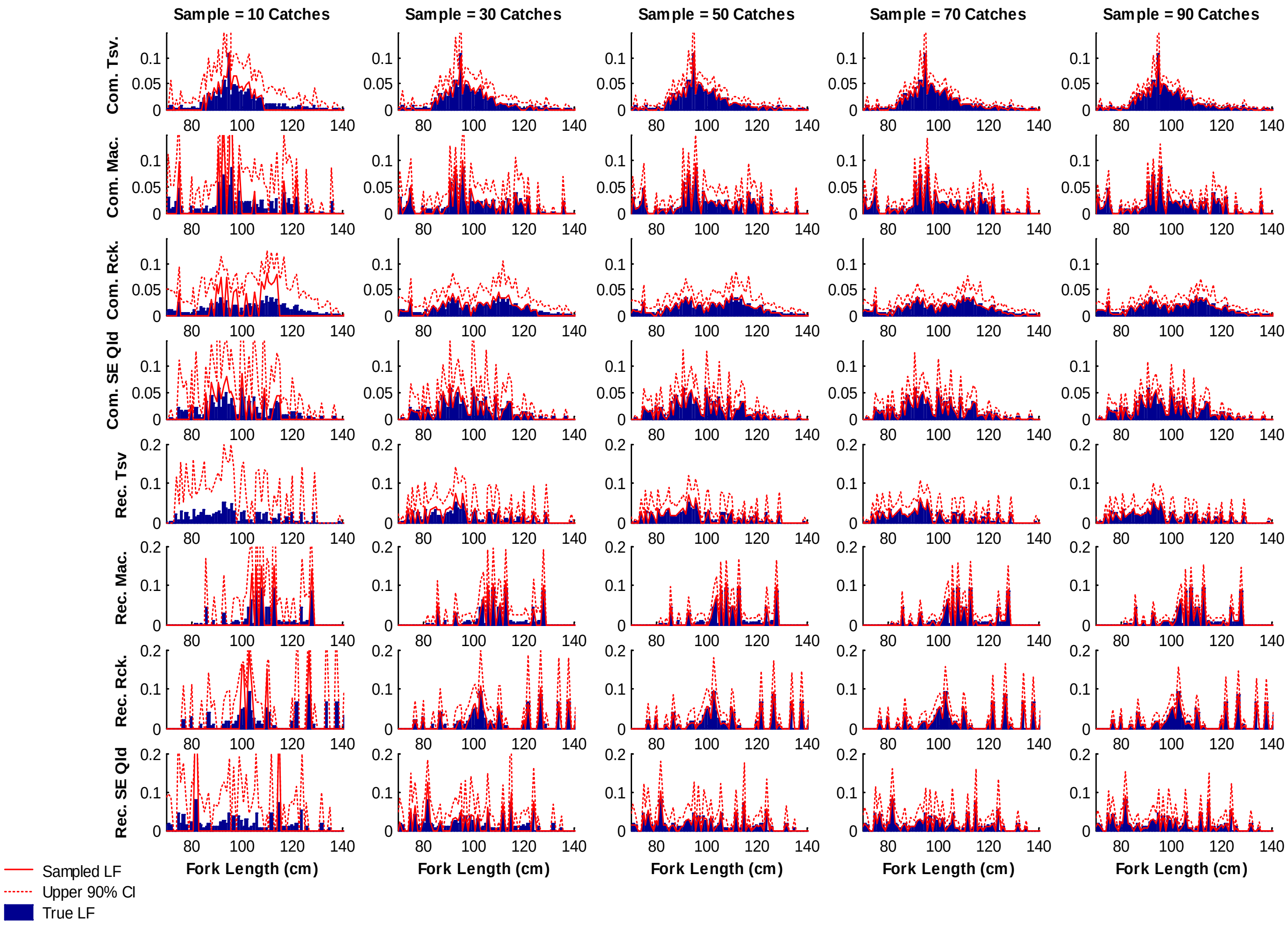

Figure 9 The comparison of actual overall fishery (blue) and estimated for each strata (red) Spanish mackerel length frequencies (scaled as proportions; red dotted lines are the upper 90% confidence intervals). The five columns of plots show the accuracy of monitoring a number of different catches in each stratum. The rows of plots relate to the eight strata (two fishing sectors: com – commercial and rec-recreational; four regions: Townsville, Mackay, Rockhampton and SE Qld).

Monitoring just commercial catches in all regions (Figure 10) results in only limited accuracy in estimating the actual length frequency. The plots again show greater monitoring accuracy and smaller confidence intervals when more catches are sampled. Sampling just one fishing sector (even in all regions) cannot represent the overall catch-fish-length distributions.

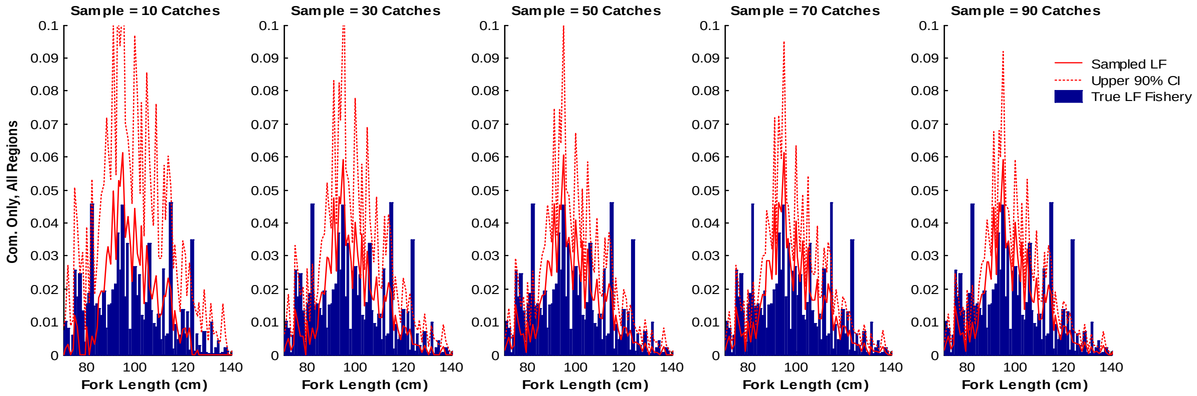

Figure 10 The comparison of actual (blue) and estimated (red) Spanish mackerel length frequencies for the fishery (scaled as proportions; red dotted lines are the upper 90% confidence intervals). Sample sizes relate to commercial catches from each region

By monitoring both commercial and recreational catches in Townsville and SE Qld only (the high catch regions), reasonable accuracy is achieved in estimating the actual overall fishery length frequency (Figure 11). Sampling both fishing sectors in only the high catch regions of Townsville and SE Qld can thus reasonably represent the overall fish-length distributions.

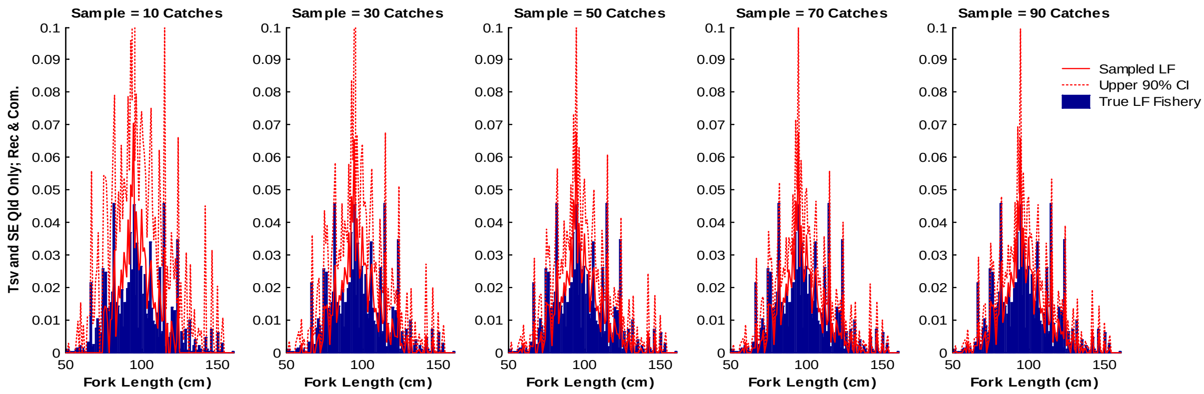

Figure 11 The comparison of actual (blue) and estimated (red) Spanish mackerel length frequencies for the fishery (scaled as proportions; red dotted lines are the upper 90% confidence intervals). Sample sizes relate to each commercial and recreational sector and two regions.

When a sampling strategy is used that involves sampling both the recreational and commercial length frequencies (Figure 12) of mackerel from the two main regions (Townsville and SE Queensland) a similar pattern is seen to that of the individual regions. The plot shows smaller least squares when more catches are sampled, indicating higher accuracy in evaluating Spanish mackerel fish-length frequency distributions. These results suggest that a minimum of 40 catches from each sector and region is required to reasonably represent the overall length frequencies from all regions and sectors. It needs to be stressed that these catches need to be random and from both sectors and regions.

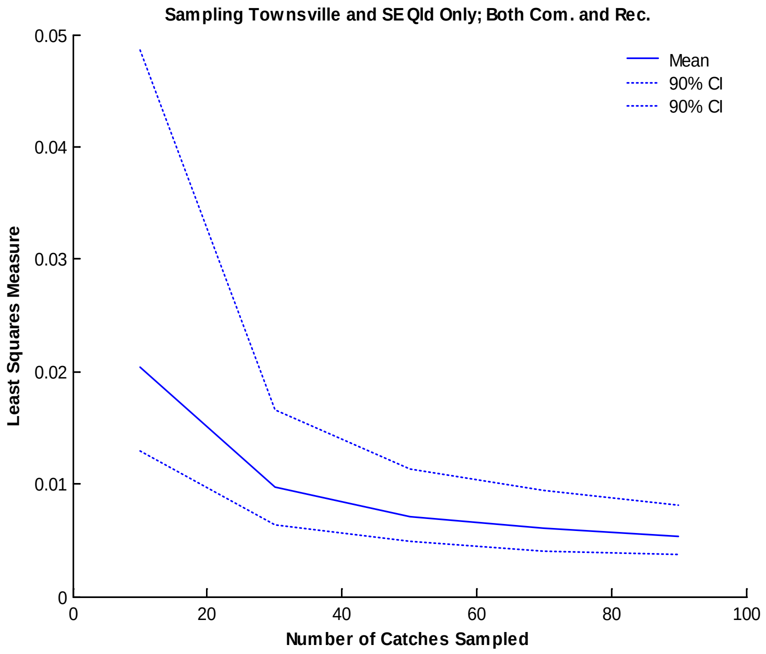

Figure 12 The average least square measures (dotted lines 90% confidence intervals) for monitoring between 10 and 90 catches from each commercial and recreational sector in Townsville and SE Qld.

Discussion

Before a monitoring strategy can be devised the aims of that strategy need to be carefully understood. There is a major difference in a strategy that seeks to just monitor the "health" of a stock on a long term basis compared with a strategy that seeks to collect information that can be utilised in stock assessment or management strategy evaluation models. The current LTMP strategy of sampling the spawning population may fulfil the first requirement but it is inadequate for stock assessment models.

The sampling strategy analysis has demonstrated that it is essential to sample both the recreational and commercial catch of Spanish mackerel and that at least some spatial resolution to the data is required. While there was also significant temporal variation to the fish length frequencies, this variation was relatively minor compared to the effects of sector and region. Any monitoring or assessment program that has no sectorial, spatial or temporal resolution of the data is fundamentally flawed when it has been demonstrated that there are significant differences in the catches among these sampling units. We recommend the sampling of about 250-300 fish for length measurement from both the recreational and commercial sectors from the Townsville and SE Queensland regions. That is a total sample of 1000 –1200 fish. It is also important that the samples of each sector and region come from a minimum of 30 catches. It is acknowledged that some commercial catches of over 100 fish can be measured at times from the Townsville Region but it is important that many catches are sampled rather than sampling large numbers of fish from only a few fishers catches. Logistically this will probably mean that more fish are measured from the Townsville region since on some sampling days it may be possible to measure 300 fish from only say 4 commercial catches. It is recognised that this places an additional workload on the field staff but the analysis shows that many sampling units are needed, as there is considerable variation among fishers in catch size structure.

Because length and age structures of fish caught in the commercial and recreational sectors from southern Queensland are similar (Tobin and Mapleston 2004) it may not be necessary (for current stock assessment purposes) to collect large samples from each sector in the south. However, we would still recommend that samples from southern Queensland be collected from both sectors as future management changes can alter the catch share between the sectors. This may see a shift in targeting strategies (influencing the size of fish taken) by the commercial sector in particular as they seek to maximise their economic returns. A two region/two sector balanced design sampling strategy allows for better future resolution of data and allows future sources of catch variation to be better understood and incorporated into models.

The fact that Tobin and Mapleston (2003) found little difference in the size structure between commercial and recreational catch size and age structures in southern Queensland provided further support that it may not necessary to sample 250 – 300 fish from each sector for otolith analysis.

LTMP ageing data

An additional problem with sampling during October/November relates to ageing the otolith samples collected at that time. Accurate and precise ageing is vital since current stock assessments are based on age based VPA. The fact that spring is commonly the time when bands are laid down creates a number of difficulties in interpretation as some animals may have a visible opaque edge whereas the bulk may have a translucent edge. Tobin and Mapleston (2003) clearly show this is the case for Spanish mackerel otoliths. It is a well-known fact that growth checks (opaque bands) become visible during different months for different ages (Francis *et al*. 1992), and this is even more noticeable when whole otoliths are being used rather than sectioned otoliths. That is, edge interpretation problems increase with age. It is vitally important that this edge interpretation problem be recognised in any ageing protocol, particularly if samples are to be obtained at different times of the year (such as would be the case if samples were collected from southern Queensland). The accuracy and precision of stock assessment model outputs would be greatly enhanced if an algorithm was developed (See Francis *et al*. 1992) which assigned ages in months rather than years and then allocated fish to an appropriate year class. Unless the ageing algorithm incorporates this information then ages can potentially be inaccurate by ±1 year. This amount of error is critical when the bulk of the catch consists of only 2 or 3 age classes because mis-assigned ages can cause dramatic impacts on model outputs.

Examination of the LTMP ageing database indicates that otolith edge interpretation data has been collected recently for some samples and it is vital that this continues in the future. It is recognised that if samples for ageing are always collected at the same time, ages can be adjusted when viewing otoliths by looking at the relative position of the edge and making an assessment based on this. However, if samples are collected at different times or if age structures shift there is considerable scope for error if "age" only is recorded rather than recording information on the number of bands and marginal increment. This allows different algorithms for assigning age classes to be tested in the future.

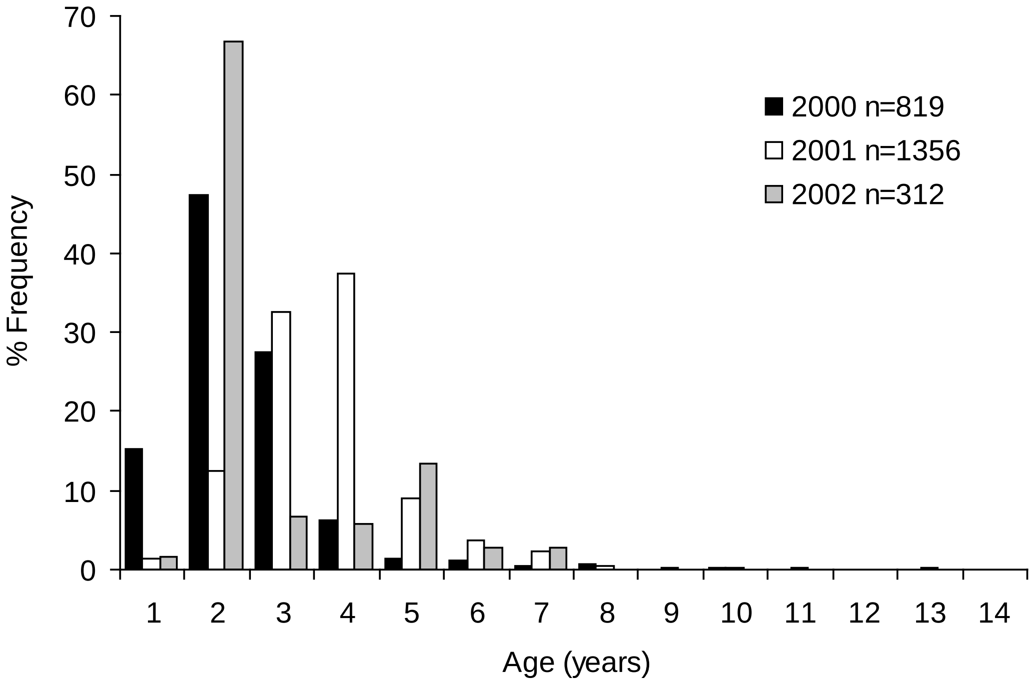

Figure 13 Age structures derived from raw age estimates from otoliths collected by the LTMP.

At present the monitoring program has collected considerable quantities of otoliths for age analysis (Figure 13). These data do not currently display any evidence of modal progression or strong age classes that can be followed in annual catch age structures. This observation is evidence of behavioural characteristics of the fishery that would suggest either (a) high exploitation, (b) different selectivity patterns, (c) parts of the population being unavailable for capture due to migration etc or (d) further evidence for an inadequate catch sampling regime.

Given that size is a poor predictor of age in this species it is important that the size distribution of the fish sampled for otoliths is identical to the size distribution of the sampled measured catch. Providing that sampling is truly random there is little need to collect large numbers of fish to measure and then resample from this for samples to age. Power analysis suggested 60 catches ~ 250 fish was an adequate sample size to detect a 5cm difference in length. For similar reasons we would also recommend the sampling of a total of 600 fish otoliths (sampled either proportionally or optimally allocated by size class) for construction of annual age length keys.

As well as being the sample suggested by the re-sampling analysis, this otolith sample size can also be derived based on rules used in NSW and NZ fisheries research organisations where the aim is to collect 20 otoliths for each size class. Given that 95% of the catch is between 70 and 130 cm in length this would divide the size frequency distribution into 30 x 2cm size classes (30 size classes x 20 fish = 600). Sampling approximately 300 fish from both the Townsville and south Queensland regions would be adequate to construct an age length key and would also allow some spatial resolution to the ageing data. This level of sampling is appropriate for incorporation of age data into current assessment models. If models were to incorporate separate growth curves for each sex it would also be beneficial to derive separate catch at age frequencies for each sex. This would require a doubling of the number of otoliths collected (eg 1200 otoliths) and also require determining the gender of each fish. Determining sex of fish may prove very difficult for the commercial fishery in the south as this is predominantly a whole fish export fishery and would therefore require purchase of fish for dissection and sex determination.

Sampling the recreational catch

While we have identified the importance of sampling the recreational catch the logistics of such a sampling strategy needs to be carefully evaluated and the costs fully understood. Sampling the recreational and commercial fishery at 4 locations over a 19-month period during the recently completed FRDC project only yielded 4,920 and 568 Spanish mackerel from the commercial and recreational fishing sectors respectively (Tobin and Mapleston 2003). To achieve this sample size (and subsequent analysis of otoliths and data) required 1.5 FTE's (full time staff).

There are several options that have been identified and used in other pelagic fisheries for collecting recreational catch information but all really suffer from an inability to sample as cost effectively as the commercial sector. Nevertheless in the case of Spanish mackerel it is essential that recreational sector be sampled. The following describes a number of possible options for collecting such information. It is not currently possible to estimate accurate costs of collecting a sample of fish from this sector.

Use RFISH diaries to collect mackerel size information. It is possible for recreational anglers to record the size of Spanish mackerel in diaries as part of the regular RFISH biennial diary survey. Such a strategy suffers from recall bias and a whole range of other errors and would also require a policy shift in terms of the design of the RFISH program. Discussions with staff involved in the RFISH program have also highlighted that such a strategy would be highly unlikely to be implemented given current budgetary and design constraints. Despite this it remains a sampling option should mackerel receive prioritisation in the future.

Charter boat diaries. Currently an index of size is recorded for Spanish mackerel taken by charter vessels in Queensland. Operators are required to record catch numbers and average weight and it may be possible for selected operators to collect additional information. We have not attempted to contact specific operators who target mackerel but based on the success of using charter operators to provide information on other species the use of this fleet may be an option. It would also need to be established whether the catches of this sector are truly representative of the broad recreational catch.

The current "size index" that is recorded in charter logs may be useful as a rough guide to broad scale changes in the size structure of the fishery but it lacks sufficient precision to enable it to be used in a stock assessment. It is only the additional voluntary information which some operators may supply that will be useful for stock assessment purposes.

Use specific anglers to keep and hold frames and other materials. This method has previously been used successfully to collect spotted and school mackerel samples from the recreational sector (Cameron and Begg 2002) and is probably also an option for Spanish mackerel. There are always keen recreational angler who are willing to assist by collecting biological information. This was also a method used by Reef CRC staff who used tackle stores as a collection point for recreational frames.

Examination of the RFISH data for 1997 and 1999 shows that over 80% of recreational angler Spanish mackerel catches are 3 fish or less. This means that considerable resources are required to sample the recreational sector. Given the low average catch of Spanish mackerel over 150 individual catches would need to be sampled before 300 fish were sampled.

In addition the length and aged based information can be obtained from fishing competitions such as the Fraser Island Fishing Competition. During the recently completed FRDC mackerel project Tobin and Mapleston (2003) obtained a large number of catch samples of mackerel from the Fraser Competition. This competition is particularly suitable for the collection of size information as well as otoliths because permit conditions require that fish frames are minced at a central location before the offal is dumped offshore. This means that fishers will return unwanted frames to a central facility for mincing enabling researchers to collect considerable biological information at a relatively small cost.

Collection of material from fishers returning from fishing trips. This is essentially an access point creel survey that relies on meeting fishers as they return to boat ramps after a fishing trip. This method is likely to be inappropriate in southern Queensland as creel survey studies (Ferrell and Sumpton 1997, Sumpton 2001) have shown that even during the mackerel season fewer than 20 Spanish mackerel will be sampled per person day at the most commonly used ramps in southern Queensland. While creel census may be an effective method of collecting data for a range of species it is not a feasible option for a single species study.

Other Options. In North Queensland large numbers of sugar mill workers fish for mackerel at times and it has been proposed to approach staff in mills for assistance with the collection of samples.

Acknowledgements

Jim Higgs is gratefully acknowledged for supplying catch data on the recreational and charter fishing sectors and Clare Bullock provided catch data for the commercial fishing sector. We are particularly grateful of staff from the Reef CRC particularly Amos Mapleston for providing data collected from a recently completed FRDC project. Both Darren Rose and Amos Mapleston assisted greatly by sharing their experiences in sampling Spanish mackerel. Discussions with other staff from the QFS Long Term Monitoring Program also provided an insight into some of the problems encountered when trying to obtain representative samples from both the commercial and recreational fishing sectors.

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