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Can acoustic methods be used to assess the abundance of alfonsino in the SIOFA area?

The Southern Indian Ocean Deepsea Fishers Association (SIODFA)

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Abstract

A review of the potential of methods of acoustic stock assessment of SIOFA-area alfonsino targeted by SIODFA trawlers indicates that the logistical requirements to undertake such surveys could be satisfied.

i. Vessels are equipped with the required acoustic systems capable of executing quantitative echo integration surveys. There is a history of successful system calibration of fleet vessels and downloading of the acoustic records from members' acoustic systems if subsequent analysis is required.

ii. Vessel bridge officers are conversant with working with complex acoustic systems and have the technical skills to undertake quantitative acoustic surveys following pre-determined, or real-time survey designs.

However, to our knowledge, a valid determination of the backscattering cross section required to convert the recorded echo intensity to fish biomass has not yet been established for alfonsino. This may require, without guarantee of success:

iii. Careful field studies using stereo-camera and acoustic recording systems that are not part of a factory trawler's standard equipment.

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[2] Documents available only to members invited to closed sessions.

iv. Alternatively, analysis of the echo records from alfonsino obtained during, or in association with, fishing activities that may enable alfonsino backscattering cross section estimates to be obtained.

Of overriding importance are considerations of the behavioural characteristics of alfonsino: this indicates:

v. the bias in a population total estimate arising from the lack of knowledge as to the fraction of a/the alfonsino stock that is available/unavailable to an acoustic survey means that an abundance estimate based on an acoustic survey can only refer to an unknown, and probably small, fraction of the total stock. It is concluded that this renders acoustic surveying untenable as a method of determining alfonsino stock abundance.

vi. Fish flight from an approaching, or nearby, surveying vessel means that repeating transects to increase estimate precision may increase total error arising from increased bias caused by fish leaving the survey area during the period of the survey while transects are being replicated.

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March 2024

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1. INTRODUCTION

This document reviews factors that affect the results of acoustic surveys that could be used in an attempt to assess the abundance of an alfonsino stock(s). The potential use of acoustic surveys to assess the abundance of alfonsino has been mentioned at least at the last five SIOFA Scientific Committee meetings. However no formal assessment of the potential of the method (for alfonsino) has been undertaken. Informal reviews have been undertaken by SIODFA that expressed their view that estimates of stock abundance using acoustic methods were not possible for alfonsino populations. Thus, if correct, vessel time (≈ $70,000/day). should not be wasted on such endeavours.

This note assesses four factors involved in the execution of successful acoustic surveys in the situation encountered in the alfonsino fishery in the SIOFA area.

i. Presence on the respective factory trawlers of acoustic systems with sufficient and known pulse transmitting power that can be used in either echo count or echo integration modes and that record the echo information (echo intensity and time after transmit of the echo) in digital format that enables it to be retrieved for subsequent analysis.

ii. Capability of bridge officers to undertake prescribed acoustic surveys both the operation of the acoustic system and navigate the vessel along defined transects according to the survey design.

iii. Knowledge of the relation between the intensity of echoes measured at the vessels' transducer(s) and biomass of the fish that result in the echo intensity. This is given through knowledge of the acoustic backscattering cross section of the fish species, and is assumed to have a linear relation with biomass, and thus the fish aggregation size, commonly expressed by the decibel transformation – Target Strength –a base 10 logarithmic relation.

iv. A survey design that enables the survey results to be raised to give an estimate of the population total – the basis of all sample survey methodology.

2. ACOUSTIC SYSTEMS INSTALLED ON SIODFA FACTORY TRAWLERS

SIODFA trawlers are equipped with an array of acoustic systems (Table 1), primarily for detecting fish aggregations at great depths, i.e. > 500 m and manoeuvring with precision the fishing gear. The catch success of the vessels depends on the bridge officers' ability to operate these systems

effectively with optimal settings, not least to assist distinguishing the species identity of fish that are sonified.

The Simrad ES70-7CD is a split-beam transducer with a large bandwidth designed for fishery and research applications. The beamwidth is 7° at a nominal operational frequency of 70 kHz. The transducer has four separate sectors. SIODFA vessels operate with hull mounted transducers. A transmit power of up to 4 kW is possible. These vessels are also equipped with plotting systems that would enable pre-specified courses, i.e. survey transects to be followed by the bridge officers.

These specifications show that the SIODFA vessels targeting alfonsino have acoustic systems with the technical capacity to undertake quantitative acoustic surveys at the depths at which alfonsino are likely to be encountered.

Table 1
Characteristics of the SIODFA Fleet Vessel Acoustic Systems

Name	*F.T. Tomi Maru No. 58*	*F.T. Will Watch*
Operator	Taiyo Fisheries Co., Ltd	United Fame Investments Avarua, Rarotonga
Flag	Japan	Cook Islands
Echo sounders	FCV-10,FCV1500L,ES-70	Simrad ES60 Furuno FCV 40
Net acoustics	FNR-80	Furuno CN22 Simrad ITI
Navigation	Furuno Plotter GP-500	SeaPlot Pro chart plotting system Piscartus 3D seabed mapping system 3 x Furuno GPS
Underwater video system	n/a	Tritech Seacorder

3. TECHNICAL CAPACITY OF VESSEL BRIDGE OFFICERS

Both SIODFA vessels employ bridge officers with extensive experience in operating advanced acoustic systems on a day-by-day basis during fishing operations and ensuring that echo data are appropriately interpreted and archived if subsequent analysis is required. Some officers have been previously involved in quantitative acoustic surveys.

Vessel operators are confident that their bridge officers would be able to competently undertake quantitative acoustic surveys, however there may be possible ' hiccups' – see e.g., Shotton (2018) that must be anticipated. Pre-trip operating reviews could be undertaken if deemed required.

4. CONVERSION OF FISH ECHO INTENSITY TO FISH BIOMASS

Vessel acoustic systems measure and record the intensity of echoes from the target fish. An estimate of the abundance of the surveyed stock can be derived from the summed, i.e. integrated,

echo intensity. The assumption is made that greater the echo intensity the greater the biomass sonified by the transmit pulse and contributing to the summed intensity of the fish(es) echoes.

A coefficient is used to convert (integrated) echo intensity to fish biomass, the backscattering cross section area, commonly referred to by its decibel equivalent, the Target Strength . This is an important parameter as error in the value of the value used for the backscattering cross section is linearly transferred to the biomass estimate.

Backscattering cross section estimates (σb) can be derived in many ways, all of which have their strengths and weaknesses.

- Using models of known σb that approximate the swim bladder, backbone, body musculature, etc. and summing the components
- From identifying single fish echoes in the echo record, extracting the σb values and matching their distribution to the size distribution of fish caught from the same aggregation – a form of in situ determination – in my view this provides the best estimate but it not easy
- By lowering a transducer and stereo camera into a fish aggregation so that measurements of the echo intensity of individual fish are obtained and size estimates of the fish obtained by simultaneous stereo photography though care is needed to remain beyond the near field of the transducer. This method requires that the fish do not react to the transducer, by avoiding the lowered equipment, or by adopting a different pitch distribution and thus presenting a different distribution of σb.
- By using the known σb of fish of similar size and structure that are assumed to have a similar σb – size relation – a common practice in the absence of any alternative.

While all of these methods require careful measurement and suitable conditions, in principle, experimental determination of the species-specific back scattering cross section is possible. But, the process is non-trivial and results often have low precision arising from the manner of sound reflection from complex targets that fish present and the few fish that may be observed in appropriate experimental conditions. Despite this, acoustic surveys often provide the only direct method of assessment of stock abundance.

5. IMPLMENTATION/POSSIBILITY OF A VALID SURVEY DESIGN

5.1 General Requirements

The samples that are obtained during an acoustic fish stock abundance survey must be obtained in a manner that satisfies the requirements for valid population estimation and it is on this requirement that use of acoustic surveys to estimate population size of alfonsino stocks /populations in our area of interest fails. Further, the precision of the population estimate must enable acceptably sized confidence interval estimates. Bias, unavoidable as is common/usual, should be consistent across surveys and not be of such size to render the population estimate meaningless.

5.2 Bias of Population Estimates

Schools of alfonsino do occur in the open ocean in the SIOFA area. This is known because they may be encountered when trawlers, during search operations, move from one sea floor feature to another. However, alfonsino encountered in the open ocean cannot be captured, at least by aimed trawling, as they successfully evade the net. Alfonsino can only be caught when the aggregations are associated with seafloor features where they can be manoeuvring by the net in relation to the sea floor feature and so be caught. Thus, at any one time, it is expected that an unknown fraction of the alfonsino stock(s) will be unavailable for detection/sampling because they occur in areas where the fleet does not operate. However, they will be part of the exploited population for management purposes.

What is the population of interest forms a fundamental basis to survey sampling methodology and is commonly treated early in most treatments of this topic. Cochran (1966) defines population as the aggregate from which the sample is chosen. The sampled population should coincide with the population whose biomass is to be estimated. To the extent that this is not the case, then the estimate will only apply to the sampled population. Mood & Graybill (1963) note that statements about a target population are not valid (in a relative-frequency-probability sense) unless the target population is also the sampled population. Sokal and Rohlf (1969) note too (their italics) "the totality of individual OBSERVATIONS about which inferences are to be made ...". Sukhatme et al. (1984) start their tome (p1) with a more general discourse on populations but which is complemented by noting that when there is variability in the sample units how they are chosen is of importance.

Another alfonsino behavioural characteristic complicates the use of acoustic assessment surveys. Skippers report that this species highly is sensitive to the presence of fishing vessels (presumably their engine noise) and will leave an area in response to continued local-area vessel operation. Thus, a survey design which repeats transects across an alfonsino aggregation may well result in the target population fleeing the survey area. The population being surveyed at the start of the survey will not be the same population as at the time of the last transect. This phenomenon should be easy to identify, though to my knowledge, while it has been observed, it has not been done in our quantitative survey context.

A third concern is that if a survey objective is to determine a population total, then the survey area must encompass the area of occurrence of the target alfonsino stock or be a known fraction of this total area. The area where alfonsino may be encountered is relatively huge, e.g. SWI Ridge, Walters Shoal, and it is unlikely that the size of the fraction sampled will be meaningful. Even a dedicated survey vessel operating 24 hours a day could take weeks to survey the area of concern, and still may not encounter an alfonsino aggregation/school.

This is a long discourse on what most will find intuitively obvious. If the amount of alfonsino that are surveyed constitute an unknown fraction of the population total, an estimate of the population total based on the survey results will be biased to an unknown degree and as a result be of no use for assessment purposes. What is obtained is a minimum biomass estimate subject to various errors and a function of the survey effort. In certain defined circumstances, such a minimum biomass estimate may be useful.

5.3 Standard Error – the Degree of Precision Required

The results of a sample survey inevitably vary if a survey is repeated, either in time, area, or both – sampling variability. The precision of the survey result can be increased by taking more samples, i.e., longer surveys, but this adds to cost and error in a population estimate will invariably remain.

Further, departure of the alfonsino from the survey area will increase with time passing. Thus, it is important that decision makers (the MoP) know, or at least have some idea, about the degree of precision in the estimates they use in making their management decisions, e.g. in permitted yields and/or fleet (And, ideally, how to use such estimates of precision in making minimum expected loss [risk] decisions). As precision is a function of the inverse square root of the sampling effort, there is a decline in the improvement of the precision of the population estimate as sampling effort increases. However, in the case of alfonsino, if the fish flee the survey area because of nose avoidance, the actual standard error of the population estimate (bias + precision) may increase with increasing numbers of transects. This note offers no guidance on what to do in this situation other than note the existence of this danger.

6. CONCLUDING THOUGHTS

In our view, useful acoustic surveys to estimate population totals of alfonsino in the SIOFA fisheries are not possible primarily because of the probable occurence of major negative bias should population estimates be attempted, i.e., there must be more fish in the population than is given by the survey-derived estimate. This is a consequence of the behaviour of alfonsino:

i. An unknown fraction of the population is available for fishing and would be surveyed if surveying was undertaken only after aggregations of alfonsino were encountered,

ii. Fishing experience shows that alfonsino may or may not be present in association with known seafloor features where they can be fished when á vessel is present: when fish are absent from features, the fish may have moved to another feature or maybe have adopted an 'oceanic behavioural mode'. In any event it will be unknown if the absence of fish is because there are none, or they are unavailable for survey/capture.

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Annex

DRAFT FOR COOK ISLANDS MEETING

ACOUSTIC SURVEY FOR ASSESSMENT OF AGGREGATIONS OF ALFONSINO OR ORANGE ROUGHY IN THE SOUTHERN INDIAN OCEAN

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January 2018

1. INTRODUCTION

Design of acoustic surveys refers to the manner or ships track that is followed when the acoustic survey of the target stock is undertaken. Conventionally there are four main practices:

i. The vessel makes a single zigzag or series of legs orthogonal to the coast across the area in which the targeted stock/species is expected to be so as to use all of the time that is available for the survey.

ii. Use of a probabilistic design. The transects may consist of parallel legs or any linearized design and their position is randomized according to a probability model, inevitably a uniform probability method but often following a design stratified over the range of the target species so as to minimize the standard error of the population estimate.

iii. An aggregation-based design in which a survey is initiated when a fish aggregation is encountered. The vessel then executes a more or less star-shaped track in which the vessel repeatedly passes through the centre of the aggregation or a grid design, again centred on the fish aggregation that has been located.

iv. The surveyed follows on minute by minute decisions on the vessel during the acoustic survey – this haphazard method is not further considered here as the results are not amenable to scientific analysis.

Only options (ii) and (iii) are considered here, although the circumstances in our fishery strongly support the third design listed above.

2. PROBABILISTIC DESIGNS

Probabilistic designs are the standard method of statistical sampling. The results from such surveys can be analysed with conventional statistical models about which there is essentially no dispute and the results are accepted as good with minimum bias and known variance (from which confidence intervals can be calculated)

These methods have been widely used from at least the mid-1970s (e.g., Shotton & Bazigos) by a variety of institutions undertaking acoustic surveys, though at that time the conventional approach often followed that of (i) above. This method is commonly attributed to (Jolly & Hampton 1990). To use this method, the area to be sampled has to be delimited before the acoustic survey begins. The survey area may be extended during the survey but this introduces the risk of biasing the abundance estimate in that early transects will not have covered the survey area in which fish occur. It is to be discouraged. Adding randomized transects during the survey may result in the added transects not being where locations of fish have been found. It also introduces the risk of bias from adding transects until a desired result is obtained. It is to be avoided.

By having each randomized transect represent one observation, the consequences of serial correlation of observations across an area being surveyed (which will invalidate or at least bias, simple variance estimates) and the arbitrariness of the size of the sampling unit in such cases is avoided. The cost is fewer observations, and thus degrees of freedom in estimating the variance, but this is compensated for by reduction in the variability of sample results because of the larger samples that are measured.

There appear to be two operational difficulties in using commercial vessels to undertake probability-based surveys.

i. The vessel skipper/bridge officer has to have a good understanding of the principles of the survey design method, which is unlikely to be the reality. Usually in it inconceivable to them that one would sample where there is unlikely to be any fish – a requirement of the method and were they to do so, experience is that they may not accept the results of such a survey

ii. Surveying using this method may involve a substantial interruption in fishing activities – keep in mind that the pay of the officers and crew depend to a major extent on the amount of fish caught and skippers are in a competitive situation with other skippers and fishing companies. Operators have some, but not unlimited, leverage over their skippers – upon whom the survival/success of the company depends.

iii. Deciding when to initiate a probabilistic survey during commercial fishing operations is fraught with complications. Skippers may prefer to do it when there appears to be little or no fish so as not to interfere with fishing when fish are abundant. And, they will not be likely to be concerned about in-survey problems or considerations.

GEO-STATISTICAL AGGREGATION-BASED SURVEYS

Aggregation-based surveys may be undertaken when a large aggregation of fish are encountered. Considerable detail of this method of survey is given by Patchell in Shotton (2006). The survey results provide an estimate of the biomass of fish that were measured (in fact estimated) to be present in the particular aggregation that was surveyed. If only one aggregation is measured in a management area, then the estimate provides a minimum estimate of the biomass that was present in that area at that time. If further aggregations are measured in that area belonging to the same stock, and it is highly confident that they do not include fish that were sonified in an early aggregation-based survey in that area. then the two estimates can be combined to give a total. Extreme care is warranted in this situation to ensure that an erroneous over-estimate of total abundance is not obtained arising from the mobility of the fish.

Geostatistical methods depend on interpolation of acoustic observations between the transects that are surveyed. The total estimate is then calculated from summing all of the elements in the sample area. There seems to be different views on how to handle results from such a situation. If more than one survey of a single stock is done in a year Niklitschek & Patchell (2015) sum the different estimates and take an average. A variance estimate is obtained from these separate estimates. The statistical model implicit in this case is unclear.

I believe that doing this misinterprets the geo-statistical model. Geo-statistical-based estimates are possible using a probabilistic model, e.g. deciding where to sample on a rock to determine ore content (the origin of this method). But this is not our situation, which is better described as a Maxi-Min estimator. For example if three geo-statistical samples were obtained, say from three different cruises within a year on the Sleeping Beauty stock, the maximum measure of fish abundance from the respective surveys would provide a minimum estimate of the fish abundance. We know that there cannot be less than the amount of fish there was measured by the geo-statistical measure. If may be more, it will not be less than what was measured. Hence the maximum measure from the geo-statistical measure will provide a minimum measure of the stock biomass. From knowledge of removals in subsequent years and assumptions of reduction in numbers from natural mortality (this method is referred to in Tingley 2019) updated estimates should be possible – albeit all subject to using all information that becomes available.

DISCUSSION

I see no alternative to using the commercial fishing vessels involved in the respective fisheries in the SIOFA area to undertake the acoustic abundance surveys, indeed I believe this to be an elegant solution to what needs to be done in this 'boutique'-type fishery. However, it should be stressed that this involves considerable cost and commitment to the management of the fishery by those who are involved in its prosecution. This investment on the part of the commercial sector in the management of the fishery should be explicitly recognized. How this could be done is beyond the ambit of this note.

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