SHORT-TERM CONTRACT FOR ASSESSING THE FEASIBILITY OF A LARGE-SCALE AERIAL SURVEY ON BLUEFIN TUNA SPAWNING AGGREGATIONS IN ALL THE MEDITERRANEAN SEA FOR OBTAINING USEFUL DATA FOR OPERATING MODELING PURPOSES

ATLANTIC-WIDE RESEARCH PROGRAMME ON BLUEFIN TUNA (ICCAT-GBYP Phase 3)

Final Report

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Background and objectives

The objectives of the comprehensive ICCAT Atlantic-Wide Research Programme on Bluefin Tuna (GBYP) are to improve basic data collection and our understanding of key biological and ecological processes and to develop a robust scientific management framework.

An important element of this programme is to develop fisheries independent indexes of population abundance. Therefore in 2010 and 2011 aerial surveys have been conducted in the Mediterranean on the most documented spawning grounds.

The purpose of this work is to assess the feasibility of a large-scale aerial survey on bluefin tuna spawning aggregations in all the Mediterranean Sea, as well as carrying out a similar assessment for the same areas previously surveyed, in order to analyse the power to detect population trends that consider additional variance, to obtain data that could be used as fishery independent indices for operating models, in order to allow the GBYP Steering Committee and the SCRS to fully consider the requirements and associated costs and benefits of a full or partial aerial survey.

In 2010 an analysis of the aerial survey was conducted and this included a power analysis that evaluated the ability of the survey to detect population trends in the East Atlantic and Mediterranean bluefin recovery plan. This original analysis was based on data from a single year. However, inter-annual variation (e.g. due to environmental variation and changes in population distribution) in abundance levels within areas will result in uncertainty in abundance estimates to be underestimated and the power of the survey to detect recovery to be overestimated. Despite many operational difficulties and problems, data have been collected in 2011 in Areas 1, 2 and 3CM (GBYP Phase 2) and a first power analysis was conducted for proposing two main scenarios for a Mediterranean comprehensive survey.

Due to the impossibility to have the required funds and the guarantee for obtaining all permits from all countries in the Mediterranean area, the Steering Committee recommended suspending the aerial survey in 2012.

Following the Commission meeting in 2012, during which several CPCs required to carry out the aerial survey in 2013, the GBYP Steering Committee requested a further assessment for evaluating a comprehensive survey, taking into account the limited amount of funds available for this part of the annual project.

The objectives of this contract are therefore to provide the followings:

A. A draft design for the whole Mediterranean Sea, except for the areas identified in the map (previously submitted) without any historical spawning and those where it is impossible to obtain flight permits due to particular situation; the design should allow for more spacing transect in the areas which were not surveyed in any previous GBYP aerial survey and more dense transects in the areas surveyed before; the total transect length should be about 42,000 km; the number of replicates shall take into account the total length constrain.
B. A power analysis of the above specified survey, taking into account the BFT recovery rate; this power analysis shall define the CVs under various hypotheses. Strengths and weakness of this survey should be reported.
C. A revision of the design already provided in 2011 (four areas), extending the area for the central-southern Mediterranean southwards, for a total of 42,000 km of transects.
D. A power analysis of the above mentioned partial survey, with the CVs under the various hypotheses considered. Strengths and weakness of this survey should be reported.

The contract will help evaluate the minimum survey area and appropriate stratifications and the trade-off between factors such as the spacing of transects and number of replicates, taking into account the recovery rates from the last bluefin tuna assessment.

STATEMENT OF WORK

Assumptions and hypothetical scenarios

Currently the East Atlantic and Mediterranean bluefin stock is assumed to be a single stock for purposes of stock assessment. However, evidence collected under the GBYP and other studies suggest that there are several stock components and the stock is actually a meta-population. However, at this time insufficient information is available to model the population structure of Bluefin tuna in the Mediterranean, therefore the simplest assumption considered is that of the bluefin stock assessment working group that it is a single stock. When information on stock structure becomes available, this feasibility study and survey design should be re-done taking that information into account. The data collected by the GBYP may support several alternative stock hypotheses in which case the strengths and weaknesses of alternative designs will need to be compared using management strategy evaluation.

Five blocks have been considered. The four spawning areas surveyed previously i.e. (1) Baleares, (2) Sicily, (3) Malta, (4) Cyprus, and (5) the Outside area (see Figure 1). The outside area (5) corresponds to the rest of the Mediterranean basin excluding the four spawning areas considered, the no spawning areas and difficult or impossible airspaces (see Figure 1).

Four scenarios were considered in order to evaluate the sensitivity of the survey index to assumptions about the stock distribution:

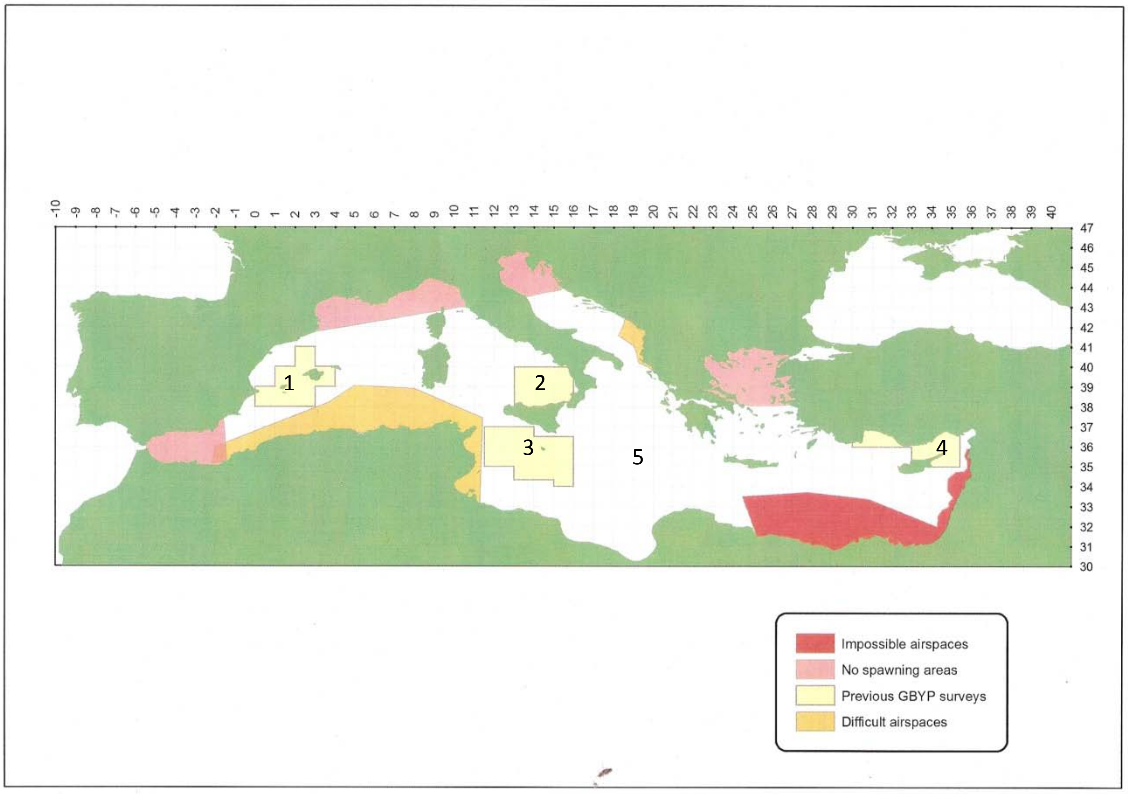


Figure 1. Blocks considered for this work

> _Scenario 1:_ there is equal or very similar density of fish outside compared to inside the spawning areas. Therefore, the same proportion of coverage is allocated to all 5 blocks for the draft survey design.
>
> _Scenario 2:_ the density of fish in area 5 (outside spawning areas) is half of that inside the spawning areas. Therefore, 50% of coverage is allocated to block 5 and 50% is allocated to the spawning areas 1 to 4 for the draft survey design.
>
> _Scenario 3:_ the density of fish in area 5 (outside spawning areas) is 10% of that inside the spawning areas. Therefore, 10% of coverage is allocated to block 5 and 50% is allocated to the spawning areas 1 to 4 for the draft survey design.
>
> _Scenario 4:_ the outside area is not considered and survey effort is carried out only inside spawning areas 1 to 4.

Within a scenario, the % coverage is approximately the same in each of the four spawning areas, but the % changes by scenario.

Draft survey designs

Draft survey designs have been produced in DISTANCE 6.0 for each of the 5 blocks for each of the 4 scenarios. Different numbers of replicates have been designed for each block, depending on the resulting line spacing and the percentage of coverage achieved by each scenario.

The total trackline on effort available was 42,000 km. For the calculations of the percentage of coverage, an effective strip width of 7km (3.5km half width) was considered. This value was chosen as it was the most common approximate width resulting in most blocks both in 2010 and 2011.

For each scenario, the proportion of the total trackline effort (42,000km) was calculated for each block according to the proportion of the surface area of each block and its proportion of hypothetical density (see Table 1). In this table, the line spacing between track lines is given assuming only one replica per survey.

Table 1. Percentage coverage assigned to each area in each scenario

Scenario 1: Equal coverage (same density inside and out)

		Area (km^2)	Proportion (%)	Km effort	% coverage	Line spacing (km)
1	Baleares	62264	3.1	1319	**11.3**	58.6
2	Sicily	54082	2.7	1146	**10.2**	59.7
3	Malta	107673	5.4	2282	**13.5**	51.1
4	Cyprus	56060	2.8	1188	**14.0**	49.4
5	Med	1701967	85.9	36065	**14.4**	48.0
		1982046		**42000**		

Scenario 2: 50% density out

		Area (km^2)	Proportion (%)	Km effort	% coverage	Line spacing (km)
1	Baleares	62264	11.1	4668	**49.1**	14.1
2	Sicily	54082	9.7	4055	**48.4**	14.2
3	Malta	107673	19.2	8073	**49.3**	13.9
4	Cyprus	56060	10.0	4203	**49.2**	13.8
5	Med	1701967	50	21000	**8.4**	83.3
		1982046		**42000**		

Scenario 3: 10% density out

		Area (km^2)	Proportion (%)	Km effort	% coverage	Line spacing (km)
1	Baleares	62264	20.0	8403	**88.9**	7.6
2	Sicily	54082	17.4	7299	**89.0**	7.7
3	Malta	107673	34.6	14532	**91.1**	7.5
4	Cyprus	56060	18.0	7566	**89.8**	7.5
5	Med	1701967	10	4200	**1.5**	468.0
		1982046		**42000**		

Scenario 4: only spawning areas

		Area (km^2)	Proportion (%)	Km effort	% coverage	Line spacing (km)
1	Baleares	62264	22.2	9337	**98.6**	6.9
2	Sicily	54082	19.3	8110	**101.4**	6.8
3	Malta	107673	38.4	16146	**101.8**	6.8
4	Cyprus	56060	20.0	8407	**100.6**	6.7
5	Med	1701967	0	0	**0.0**	
		1982046		**42000**		

As an example of the procedure, consider Scenario 1. he expected density and hence the expected coverage is the same in all 5 blocks. Therefore, the proportion of km of effort in each block should be the same as the proportion of the total surface area of each block and the total effort (42,000 km) is allocated according to these proportions (column ‘km effort’). Program DISTANCE was then used to generate a random survey sample using the km of effort required in each block and other design specifications (e.g. surface area of the block, half width). The sample survey yielded the % coverage (for that particular random sample) marked in blue in Table 1, as well as the line spacing. % coverage and line spacing will vary slightly for different random samples. The % coverage is the total length of the effort tracks multiplied by two times the half width (3.5 km).

In scenario 2, block 5 (outside spawning areas) has an hypothetical density of 50% that of inside the spawning areas. The proportion is thus spread accordingly: 50% for block 5 and 50% for the spawning areas together. And so on for the other scenarios.

For blocks 1 to 4 and scenarios 2 to 4, where the line spacing is narrow, the same calculations have been done for 2, 3 and 4 replicates achieving the same total coverage when adding them up but increasing line spacing between track lines as the number of replicates increase. The details of these calculations are not shown in the table for simplicity, but are provided in the associated spreadsheet. However, the average numbers (showing little variation among blocks) are as follows:

Scenario 2: 2 replicates: average of 23.6 km line spacing; 3 replicates: average of 45.5 km line spacing.

Scenario 3: 2 replicates: average of 15.7 km line spacing; 3 replicates: average of 23.5 km line spacing; 4 replicates: average of 31.8 km line spacing.

Scenario 4: 2 replicates: average of 14 km line spacing; 3 replicates: average of 21.2 km line spacing; 4 replicates: average of 29 km line spacing.

Hence, when more effort per block is available (as it increases for spawning blocks going from scenario 1 to 4), there is the option to do either more replicates with larger spacing or less replicates with tighter spacing. It is important to highlight that a too tight spacing is not recommended because the distance at which groups could be seen may overlap among track lines. For example, in 2010 and 2011, groups were sighted up to distances of 7.5 or 7.7 km from the trackline. Therefore, with only one replicate in scenarios 2 to 4, these distances may overlap as they are larger than the half of the distance (spacing) between track lines.

Annex I shows examples of line tracks for each scenario, considering one replicate (or the sum of several replicates).

Estimation of coefficients of variation

Partial coefficients of variation

To be able to calculate coefficients of variation, a hypothetical density had to be applied to each block. The densities obtained in 2010 were taken as reference (disregarding 2011) for two reasons: (a) in 2010 the four blocks 1 to 4 were surveyed while in 2011 block 4 was not surveyed; and (b) results for block 3 (Malta) in 2011 were anomalous in comparison with the other blocks in 2011 and 2010. Therefore it was considered safer to take 2010 as reference for this work.

Table 2 shows the expected density per area per scenario (using the density from 2010 for blocks 1 to 4 and adjusting the density for the outside area according to the specification of the scenario). The derived expected number of schools per block/scenario and expected abundance of groups are also shown. The expected density of schools in each block in scenarios 1 to 4 are just the same densities obtained in 2010 for blocks 1 to 4. For block 5, the expected densities were calculated as follows:

Scenario 1: $$E\left(D_{5(1)}\right) = \frac{\sum_{i=1}^{4} E(n_{i4})}{\sum_{i=1}^{4} A_i}$$

where $E(D_{5(1)})$ is the expected density of schools in block 5 in scenario 1; $E(n_{i4})$ is the expected number of schools in block i in scenario 4 given the coverage and density specified for each block; and A_i is the surface area of block i. Scenario 4 (instead of 2010) is taken as reference for the expected number of schools in block i due to the slight difference of surface areas with respect to 2010 and given that it is the scenario where only blocks 1 to 4 are surveyed and therefore yields the best expected density.

Scenario 2: $$E\left(D_{5(2)}\right) = \left(\frac{\sum_{i=1}^{4} E(n_{i4})}{\sum_{i=1}^{4} A_i}\right) * 0.5$$

where $E(D_{5(2)})$ is the expected density of schools in block 5 in scenario 2; and it is multiplied by 0.5 because the density considered for block 5 in this scenario is 50% of that within spawning areas (blocks 1 to 4).

Scenario 3: $$E\left(D_{5(3)}\right) = \left(\frac{\sum_{i=1}^{4} E(n_{i4})}{\sum_{i=1}^{4} A_i}\right) * 0.1$$

where $E(D_{5(3)})$ is the expected density of schools in block 5 in scenario 3; and it is multiplied by 0.1 because the density considered for block 5 in this scenario is 10% of that within spawning areas (blocks 1 to 4).

The expected number of schools in Table 2 is calculated as:

$$E(n_{ij}) = (E(D_{ij})*1000)*S_{a(ij)}$$

where j is scenarios 1 to 5; i is block i (1 to 5); $E(n_{ij})$ is the expected number of schools in block i in scenario j given the coverage and density specified for each block and scenario; $E(D_{ij})$ is the expected density of schools in block i in scenario j (multiplied by 1000 as density is given as groups per 1000 km^2); and $S_{a(ij)}$ is the searched area in block i in scenario j. $S_{a(ij)}$ is calculated as $L_{ij}*2*esw_{ij}$ where L_{ij} is the length of the effort track (column “Km effort” in Table 1) in block i in scenario j and esw is the effective strip half width (same for all blocks and scenarios: 3.5km).

The coefficients of variation for the density of schools, for the detection functions and for the cluster size (taken as Weight) obtained for 2010 and 2011 are shown in Table 2. For the four scenarios, the expected coefficient of variation of $E(n_{ij})$ was estimated for each block taking as follows:

$$CV_{E(n_{ij})} = 100 * \frac{\sqrt{E(n_{ij}) * 2}}{E(N_{ij})}$$

Where $CV_{E(n_{ij})}$ is the coefficient of variation of $E(n_{ij})$; and $E(n_{ij})$ is the expected number of schools in block i in scenario j given the coverage and density specified for each block and scenario. Some overdispersion is assumed (variance of E[n] is twice E[n]).

For the detection function, an hypothetical CV=20% was assumed (the approximate average %CV of the four detection functions estimated in the 2010 and 2011 analyses). In the same way, an hypothetical CV=20% was assumed for the cluster size (weight) (the approximate average %CV for cluster size in the four detection functions estimated in the 2010 and 2011 analyses). The total CV for each block in each scenario was estimated using the Delta method combining the CVs of $E(n_{ij})$, detection function ($CV_{df_{ij}}$) and cluster size/weight ($CV_{w_{ij}}$):

$$CV_{T_{ij}} = \sqrt{{CV_{df_{ij}}}^2 + {CV_{w_{ij}}}^2 + {CV_{E(n_{ij})}}^2}$$

Weighted total coefficients of variation

The total expected coefficient of variation for each scenario was calculated through the sum of the variances weighted by area and density of each block (i.e. weighted by the estimated abundance), as follows:

$$CV_{TW_j} = \frac{\sqrt{\sum_{i=1}^{5} \sigma_{ij}^2 * w_{ij}}}{\sum_{i=1}^{5} E(n_{ij})}$$

where *j* is scenario *j*; *i* is block *i*; CV_{TW_j} is the total expected coefficient of variation for scenario *j*; $E(n_{ij})$ is the expected number of schools in block *i* in scenario *j* given the coverage and density specified for each block and scenario; σ_{ij}^2 is the variance of $E(n_{ij})$ in block *i* and scenario *j*; and w_{ij} is the weight of block *i* in scenario *j*. The weight w_{ij} was calculated using the proportion of total expected abundance over all blocks (i.e. expected density multiplied by the surface area, for each block in each scenario) as index.

Table 3 shows the parameters used in these calculations and the final weighted total CV for each scenario.

Table 2. Estimated and expected densities and coefficients of variation for 2010-2011 and the four scenarios respectively

2010		Number of schools	Density schools (1000 km^-2)	Abundance groups	%CV n	%CV det. Func	% CV Weight	% Total CV
1	Baleares	7	0.157	9.8	55.0	14	8	57.3
2	Sicily	6	0.236	12.4	52.6	31	5.6	61.3
3	Malta	19	0.508	46.1	44.1	14	24.6	52.4
4	Cyprus	31	3.054	168.1	39.8	31	12.9	52.1
		63	**0.535**	**236.0**				
2011								
1	Baleares	11	0.196	12.2	37.0	17.4	35.3	54.0
2	Sicily	10	0.162	8.5	36.0	17.4	35.3	53.3
3	Malta	35	3.98	399.9	26.0	15.2	35.3	46.4
		56	**0.449**	**421**				

		Expec. Num. Of schools	Expec. Density schools (1000 km^-2) (as 2010)	Expec. Abundance groups	Expec. % CV n (b=2)	%CV det. Func	% CV Weight	% Total CV
Scenario 1: Equal coverage (same density inside and out)								
1	Baleares	1.5	0.157	9.8	117.4	20	20	120.8
2	Sicily	1.9	0.236	12.8	102.8	20	20	106.6
3	Malta	8.1	0.508	54.7	49.6	20	20	57.1
4	Cyprus	25.4	3.054	171.2	28.1	20	20	39.8
5	Med	223.9	0.887	1509.7	9.5	20	20	29.8
		261	**0.887**	**1,758**	8.8			
Scenario 2: 50% density out								
1	Baleares	5.1	0.157	9.8	62.4	20	20	68.5
2	Sicily	6.7	0.236	12.8	54.6	20	20	61.5
3	Malta	28.7	0.508	54.7	26.4	20	20	38.7
4	Cyprus	89.9	3.054	171.2	14.9	20	20	32.0
5	Med	65.2	0.444	754.9	17.5	20	20	33.3
		196	**0.665**	**1,003**	10.1			
Scenario 3: 10% density out								
1	Baleares	9.2	0.157	9.8	46.5	20	20	54.5
2	Sicily	12.1	0.236	12.8	40.7	20	20	49.6
3	Malta	51.7	0.508	54.7	19.7	20	20	34.5
4	Cyprus	161.7	3.054	171.2	11.1	20	20	30.4
5	Med	2.6	0.089	151.0	87.6	20	20	92.0
		237	**0.807**	**399**	9.2			
Scenario 4: only spawning areas								
1	Baleares	10.3	0.157	9.8	44.1	20	20	52.4
2	Sicily	13.4	0.236	12.8	38.6	20	20	47.9
3	Malta	57.4	0.508	54.7	18.7	20	20	33.9
4	Cyprus	179.7	3.054	171.2	10.5	20	20	30.2
		261	**0.887**	**248**	8.8			

Table 3. Weighted total coefficients of variation

Block	Area	Density	Abundance	n	Total CV	var	Weight	Weighted var	Weighted CV
Scenario 1: Equal coverage (same density inside and out)									
1	62,264	0.157	9.8	1.5	1.208	3.07	0.0056	0.01706	
2	54,082	0.236	12.8	1.9	1.066	4.07	0.0073	0.02957	
3	107,673	0.508	54.7	8.1	0.571	21.49	0.0311	0.66866	
4	56,060	3.054	171.2	25.4	0.398	102.39	0.0974	9.97006	
5	1,701,967	0.88705	1509.7	249.6	0.298	5541.09	0.8587	4758.09112	
Total	**1,982,046**		**1758**	**286.5**		**5672.11**	**1.0000**	**4768.7765**	**0.2411**
Scenario 2: 50% density out									
1	62,264	0.157	9.8	5	0.685	12.4	0.0097	0.12050	
2	54,082	0.236	12.8	7	0.615	17.0	0.0127	0.21611	
3	107,673	0.508	54.7	29	0.387	123.3	0.0545	6.72470	
4	56,060	3.054	171.2	90	0.320	825.7	0.1706	140.89632	
5	1,701,967	0.44352	754.9	73	0.333	584.5	0.7524	439.77909	
Total	**1,982,046**		**1003**	**203**		**1562.91**	**1.0000**	**587.7367**	**0.1194**
Scenario 3: 10% density out									
1	62,264	0.157	9.8	9	0.545	25.3	0.0245	0.61904	
2	54,082	0.236	12.8	12	0.496	35.7	0.0320	1.14233	
3	107,673	0.508	54.7	52	0.345	317.0	0.1369	43.40755	
4	56,060	3.054	171.2	162	0.304	2416.4	0.4286	1035.77816	
5	1,701,967	0.0887	151.0	3	0.920	7.2	0.3780	2.70501	
Total	**1,982,046**		**399**	**238**		**2801.58**	**1.0000**	**1083.6521**	**0.1385**
Scenario 4: only spawning areas									
1	62,264	0.157	9.8	10	0.524	28.9	0.0393	1.13893	
2	54,082	0.236	12.8	13	0.479	41.2	0.0514	2.11432	
3	107,673	0.508	54.7	57	0.339	378.6	0.2202	83.34545	
4	56,060	3.054	171.2	180	0.302	2943.3	0.6891	2028.27295	
Total	**280,079**		**248**	**261**		**3391.95**	**1.0000**	**2114.8717**	**0.1763**

Power Analysis

In the previous reports a power analysis was conducted once the data had been collected to determine the ability to detect trends in abundance depends. In this study we conduct a power analysis using the 2010 data to conduct a cost benefit analysis of different survey designs prior to conducting the survey.

The power analysis is conducted for a range of survey CVs and evaluates the number of years required before any given increase in the population can be detected. The power of an upward trend in abundance being detected is calculated using linear regression given i) estimates of survey variability (CV), ii) the number of annual surveys, iii) the relationship between CV and population density and iv) the percent rate of change (see Gerrodette, 1987 and 1991). All modelling was conducted in R using the /pkg{fishmodels} package in order to allow the methods to be implemented in the Management Strategy Evaluation framework to be developed under the GBYP.

Conducting a power analysis requires choosing appropriate power and significance levels. The power of a statistical test is the probability of correctly rejecting a null hypothesis (H_0) when the hypothesis is false (in this case the H_0 is that there has been no increase in the population). As the power increases, the chances of a Type II error (i.e. a false negative) occurring decrease (Greene 2000). Conventionally a test with power greater than 0.8 level (or \beta<=.2) is considered statistically powerful.

The statistical power determines the ability of a test to detect an effect, if the effect actually exists (High 2000). The significance level is chosen depending on the acceptable risk of drawing the wrong conclusion. Smaller levels of \alpha increase confidence in the determination of significance, but run an increased risk of failing to reject a false null hypothesis (a Type II error, or “false negative”), and so have less statistical power. The selection of the level \alpha thus inevitably involves a compromise between significance and power, and consequently between the Type I error and the Type II error.

It was also assumed i) that the survey CV was independent of population size (i.e. consistent with the stock assessment assumptions) and ii) that the population increase was linear (since the stock is recovering to B_{MSY} and so density dependence will limit population increase).

Table 4 show the population increase required to detect a significant upward trend (at the 95% level) with a power of 80%, while figure 2 shows the spawning stock biomass (SSB) for the six projection trajectories used to provide management advice to the Commission by the SCRS (values are relative to the 2012 level). Table 5 summaries the CVs by area for the different survey designs.

These table and figures allow important questions to be answered. For example e.g. If stock is a single stock what CV will be required to detect a doubling of the population within 10yrs?

Table 4 shows that if the CV is 25% then it will take 11 years whilst if the CV is 20% it will take 6 years, so the answer would be a CV of 20-25%. The next question would be what survey design would provide a CV of between 20% & 25%? From Table 5 it can be seen that.

The CV of the survey is a factor that can be controlled to some extent by the design of and the funding for a survey. The population increase is determined by the biology of a stock and management. Even with perfect management as assumed by the Commission and the SCRS there is however considerable uncertainty about the response of the stock to management, i.e. the SCRS projections predict that stock may increase between 50% and 200% by 2023.

Table 4. Calculation of the population increased required to detect a significant (at the 95% level) with a power of 80%.

		CV								
	Year	**0.2**	**0.25**	**0.3**	**0.35**	**0.4**	**0.45**	**0.5**	**0.55**	**0.6**
1	5	280	630	>1000	>1000	>1000	>1000	>1000	>1000	>1000
2	6	180	310	620	>1000	>1000	>1000	>1000	>1000	>1000
3	7	140	230	370	720	>1000	>1000	>1000	>1000	>1000
4	8	120	180	280	460	920	>1000	>1000	>1000	>1000
5	9	110	160	230	350	590	>1000	>1000	>1000	>1000
6	10	100	140	200	290	450	780	>1000	>1000	>1000
7	11	90	130	180	250	370	580	>1000	>1000	>1000
8	12	90	120	160	220	320	470	780	>1000	>1000
9	13	80	110	150	200	280	400	610	>1000	>1000
10	14	80	110	140	190	250	350	510	820	>1000
11	15	70	100	130	170	230	310	440	660	>1000
12	16	70	90	120	160	210	280	390	560	900
13	17	70	90	120	150	200	260	350	490	740
14	18	70	90	110	150	190	240	320	430	630
15	19	60	80	110	140	180	230	290	390	550
16	20	60	80	100	130	170	210	270	360	490

Table 5. Summary

	Scenario			
Area	**1**	**2**	**3**	**4**
1	121%	69%	54%	52%
2	107%	62%	50%	48%
3	57%	39%	34%	34%
4	40%	32%	30%	30%
5	30%	33%	92%	
1 to 4	24%	19%	18%	18%
1 to 5	24%	12%	14%	18%

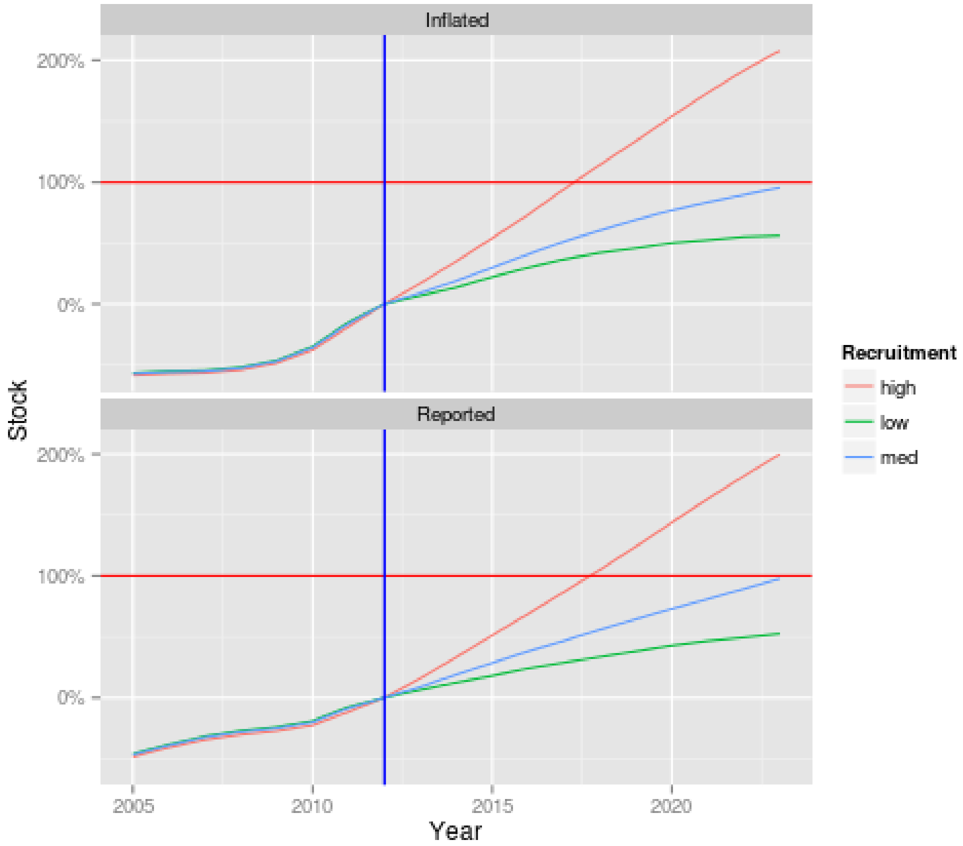


Figure 2. Spawning stock biomass trajectories for the six projections, values are relative to the 2012 levels. 6 scenarios were considered by the SCRS for the stock projections i.e. for Recruitment, high, medium or Low and for the Historic Catch, reported or inflated.

DISCUSSION

The objective of the contract was to perform a “cost benefit analysis” of alternative survey designs by conducting a simple power analysis. Two types of area were considered i.e. i) spawning areas that had previously been surveyed and so there was prior knowledge about fish density and distribution and ii) areas that had not been surveyed previously and so there was uncertainty about the actual distributions and densities. Therefore 4 scenarios were considered for the assumed densities in the previously unsurveyed area (i.e. 100%, 50%, 10% or 0% of that in the spawning areas), since the survey effort was dependent on the assumed densities then the effort distribution and hence CVs for each area also varied by scenario.

Table 5 shows the estimates of the CVs, these are based on assuming that the variance of the detection functions and the relationship between school and biomass was the same across all areas. The variance was solely a function of the density of schools (i.e. number of schools per area). It was also assumed that there was no temporal or spatial heterogeneity or if there was this could be explained by the use of appropriate covariates.

It can be seen that the CVs for the individual areas are greater than for the areas combined, i.e. assuming a single population. The CVs vary from 120 to 40% by spawning area when effort is distributed equally over the spawning areas and the entire Mediterranean and from 50 to

30% when only the spawning areas are surveyed; decreasing as survey effort within the spawning areas increases. The CV of the area outside increases as the assumed stock density declines due in part to the reduction in effort and the lower encounter rate. The CV of the combine indices is lower, for all the spawning areas combined it ranges from 24 to 18% declining as effort in these areas increases. However for all areas the CV declines then increases with effort, the lowest CV of 12% being seen for scenario 2.

These results assume that there is no temporal or spatial variation. However additional variance may arise from the fact that the estimated sampling variances for the abundance estimates do not account for yearly variation in abundance levels in areas due to inter-annual changes in distribution of the populations. If the additional variance is ignored, uncertainty on abundance estimates tends to be underestimated (SC/61/IA8). In the previous reports a level of additional variance of 20% was assumed.

By referring to tables 4 and 5 the power of the survey to detect trends can be evaluated, e.g. If the population is a meta-population (i.e. the spawning areas contain different stock components) then even without any additional variance, if there is any increase in stock components a double of population size will only be detectable after more than 16 years. If the stock is a single homogeneous population then with a CV of 20% a stock doubling would be detected after 6 years.

Strengths and weaknesses

A key assumption is the relationship between effort and CV. If there is no overdispersion, CV = sqrt(n)/n, where n is proportional to effort. We assume that variance of n is 2 x n to account for some overdispersion but this is simply a scalar here. Therefore, CV is proportional sqrt(effort)/effort. This relationship should be explored more fully and empirically using resampling methods by first combining the data from the original replicates and then re-calculating the variances.

There are factors that influence additional variance (e.g. due to variability in availability due to proportion of schools at the surface). The value of additional variance came from marine mammals, however additional variance for tuna is likely to be significantly larger as they are not obliged to come to the surface and causes of doing so are poorly understood and will be related to environmental conditions and other factors that will vary spatially and temporally.

Also by specifying 4 scenarios in advance it was not possible to answer additional questions explicitly, e.g. what if 12,000 Km more track length was made available. To do this would require the whole analysis to have been redone. In hindsight a more generic approach would have been better, i.e. to have explored the relationship between effort and CV for each area for a range of effort levels. Then CVs could have been predicted interactively for any survey design.

Another problem with the choice of scenario is that the analysis assumes that there is perfect knowledge already of the density outside the area. This is not the case. A better procedure would have been to calculate CVs for each survey design based on the different scenario, i.e. the CV that would be expected if the scenario on which that design was based was wrong but one of the other scenario was right -.i.e. the risk of a specific design with the wrong scenario.

This would result in a matrix of CV's (e.g. rows being survey design and columns being the actual population distributions).

This also means that using an adaptive survey design may be useful since after a few years the densities outside the areas will be better known, factors affecting the CVs due to school size and sighting should be better understood, and the population structure hypotheses developed. All of which will influence the optimal design.

Also for operational reasons the survey design is likely to change from that used in this report. While this would not be expected to change the general conclusions it will require the analysis to be reconducted prior to a survey going ahead.

In this study it is assumed that the survey will be used as an index of abundance independently of a stock assessment model. However, the GBYP will hopefully develop new stock assessment methods which would use the index as an input in which case the power to detect trends may be improved.

ACKNOWLEDGEMENTS

Many thanks are due to Prof. Phil Hammond for his advices, comments and suggestions of the work done here and of the report.

REFERENCES

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology. 68(5): 1364-1372.

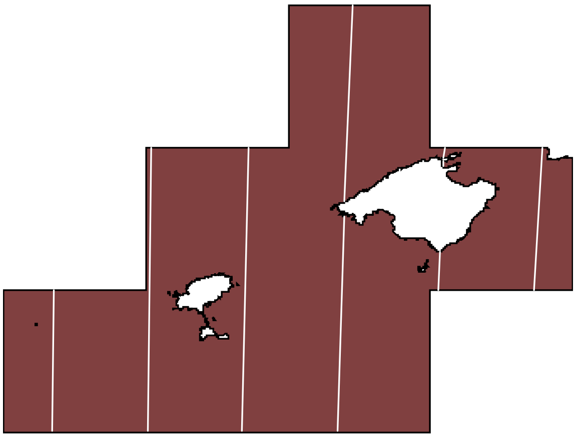
Gerrodette, T. 1991. Models for power of detecting trends - a reply to Link and Hatfield. Ecology 72(5): 1889-1892.

Greene, William H. 2000. Econometric Analysis, 4th ed. Prentice Hall.

High, Robin. 2000. http://cc.uoregon.edu/cnews/summer2000/statpower.html

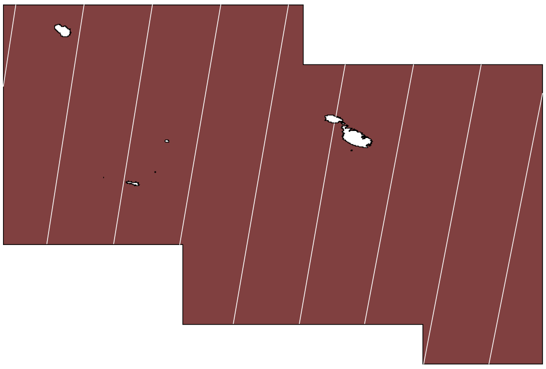
ANNEX I

Scenario 1: Equal coverage (same density inside and out)

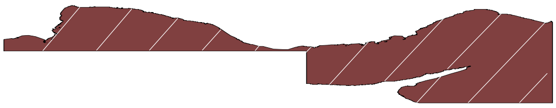


Block 1: Baleares

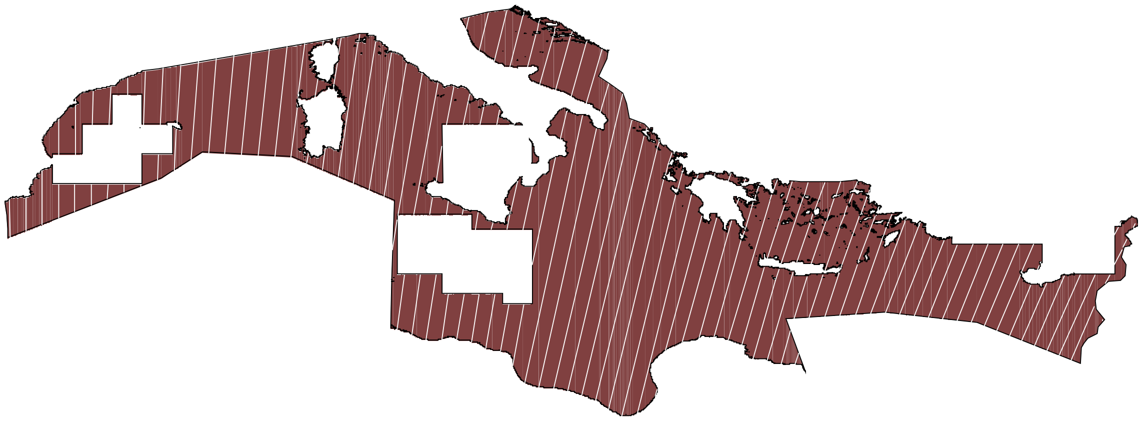
Block 2: Sicily



Block 3: Malta



Block 4: Cyprus

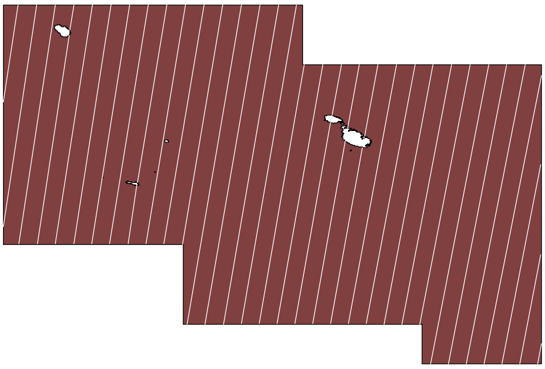


Block 5: Outside area

Scenario 2: 50% density out

Block 1: Baleares

Block 2: Sicily



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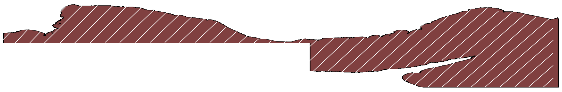

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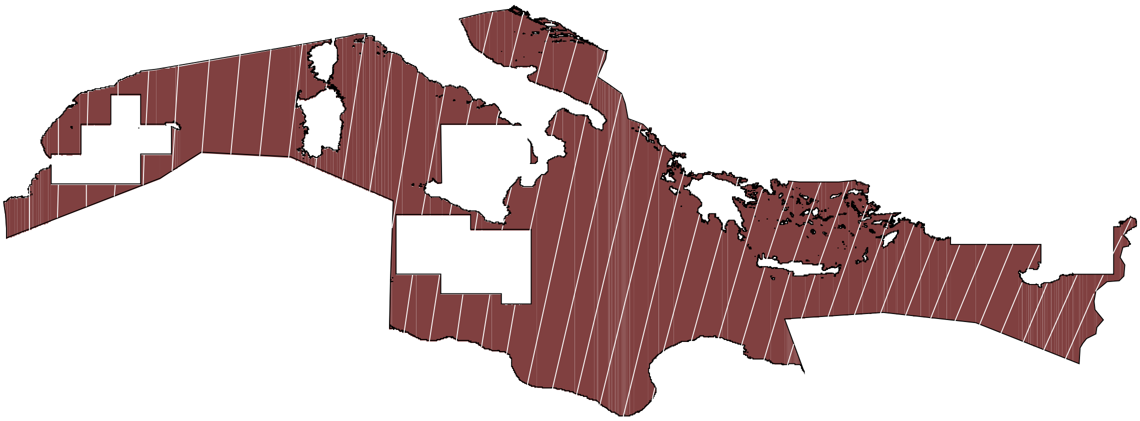


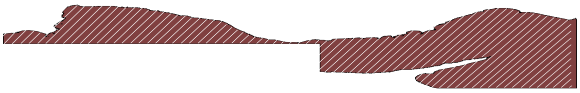
Block 5: Outside area

Scenario 3: 10% density out

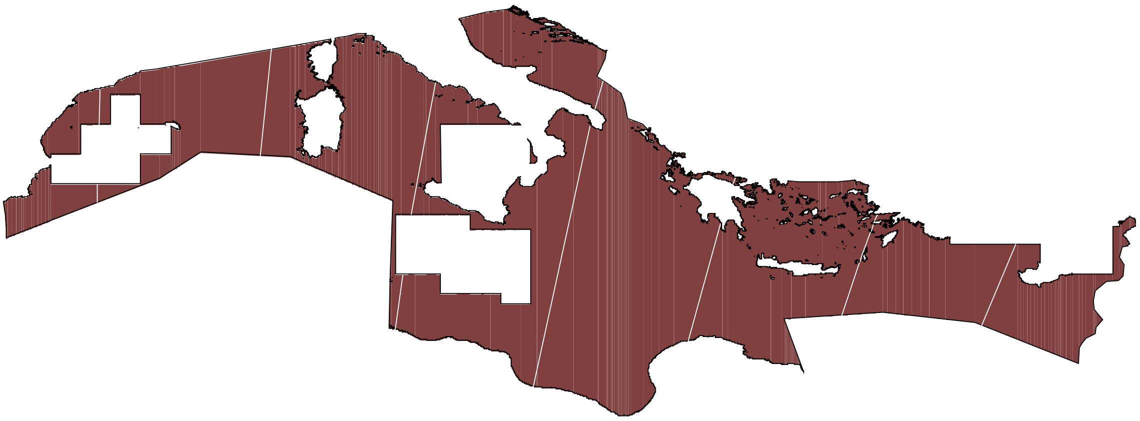
Block 1: Baleares

Block 2: Sicily

Block 3: Malta



Block 4: Cyprus

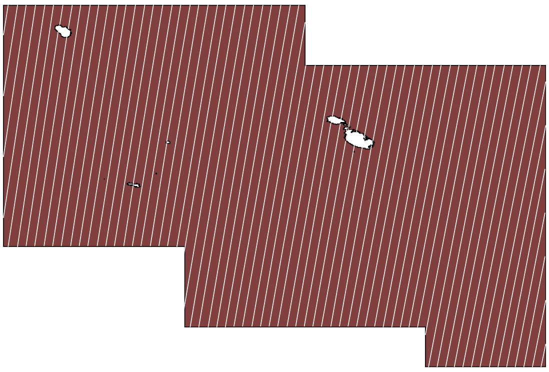


Block 5: Outside area

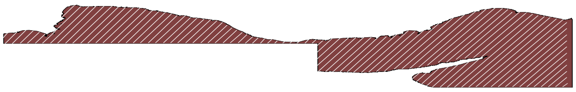
Scenario 4: only spawning areas

Block 1: Baleares

Block 2: Sicily



Block 3: Malta



Block 4: Cyprus