Modelling Approaches: Risk Assessment
Eliciting uncertainties in GBYP

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SUMMARY

The GBYP Bluefin tuna rebuilding plan uses stochastic projections that do not capture all the uncertainty associated with stock assessment/ management variables. This could mean that the outcomes predicted by the projections are more optimistic than those achieved in reality, or at least may be different from reality. A methodology was sought to capture stakeholder perceptions of particular uncertainties that should be more effectively included in stock assessments of Bluefin tuna and then to provide preliminary quantification of their relative importance in terms of their impact on achieving management objectives. Ultimately, this will allow risk-based scenarios to be specified for the operating mode of a Management Strategy Evaluation approach, and enable SCRS and the GBYP Steering Committee to prioritize research. A spreadsheet-based questionnaire was developed and tailored further to capture measures of stakeholder uncertainty for risk-related variables, assumptions and hypotheses (identified from the literature and stakeholder consultation in Madrid, during 2011 and 2012). In this phase we approximately doubled the number of scientists in the stakeholder group consisting of 'experts', expanded the NGO stakeholder group, and have distributed questionnaires among the group representing managers and decision makers. The latest group has been the slowest to respond, in particular, we have not heard back yet from the representatives of the EC. Therefore, we can only offer a limited analysis at this point, but one which already highlights significant areas of both consensus and lack of consensus.

KEYWORDS

Bluefin tuna; Thunnus thynnus; *GBYP; stock assessment; risk analysis; uncertainty.*

1. Introduction

The objectives of the comprehensive ICCAT Atlantic-Wide Research Programme on Bluefin Tuna (GBYP) are to improve data collection, knowledge of key biological and ecological processes, assessment models and management. An important element of the programme is to develop a robust management advice framework consistent with the Precautionary Approach. This requires the development of new stock assessment methods that take into account the main sources of uncertainty and use the new data sets and knowledge provided by the GBYP. New data sets include, for example, historic catch and effort data, aerial surveys of spawning aggregations and tagging of juveniles. In order to evaluate novel approaches, the SCRS is developing a Management Strategy Evaluation (MSE) framework that includes a simulation or Operating Model. This will allow current and alternative assessment and advice frameworks to be evaluated with respect to their ability to meet multiple management objectives.

Although many sources of uncertainty were considered when formulating the East Atlantic and Mediterranean Bluefin Recovery Plan, not all sources of uncertainty have been explicitly considered. Therefore, a contract for a Risk Assessment to identify and provide a preliminary quantification of the main sources of uncertainty was offered for tender by ICCAT in 2011. This, following consultation with stakeholders, would allow appropriate scenarios, specified as appropriate probability distributions of values for input variables, to be specified for use in the Operating Model when evaluating the alternative advice frameworks.

Risk Analysis is a formal process in which risks are identified, assessed, prioritized and managed to ensure that management objectives are more likely to be met and communicated effectively. The BFT rebuilding plan is based on stochastic projections that considered a range of uncertainties. However, the SCRS stated that "the Commission might consider a probability of rebuilding standard different from that envisaged considering the unquantified uncertainties". This implicitly accepts that the projections do not capture all the uncertainty associated with the assessment and management of the stock and that the probabilities predicted by the

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projections may be more optimistic than those that will be achieved in reality. However, the unquantified sources of uncertainty were not explicitly identified, nor were the associated risks and their impact on achieving the management objectives evaluated. Therefore, the Contractor, in consultation with various stakeholders, must identify the main risks and provide a preliminary quantification of their relative importance. This will help the SCRS and the GBYP Steering Committee to prioritize research and provide managers a basis on which to evaluate the benefits of alternative management options to achieve a cost effective outcome for the Bluefin Recovery Plan.

For the next phase of risk assessment we collected more data in order to get feedback from a wider range of pertinent stakeholder groups. This was accomplished by attending two GBYP meetings in Madrid and Agadir in 2012, explaining the aims of the questionnaires both in front of the large group of stakeholders and in face-to-face individual conversations, and requesting that the stakeholders return filled-in questionnaires they were emailed. All questions regarding uncertainties identified in phase one were reviewed and, where appropriate, adjusted in the light of new information. We condensed the number of questions dealing with biology and added several related to management. Further, we tailored questionnaires to each of the stakeholder groups reflecting the differences in the depth and focus of expertise among groups. Therefore, the questionnaire presented to managers and decision-makers had a somewhat different focus than the one addressed to scientists and NGOs. However, the stakeholder group containing managers has so far had the lowest response rate despite the fact that they should be highly interested in the subject of uncertainty because of its relevance to decision-making. In this phase of risk assessment Imperial College London will derive, based on stakeholder input, a list of uncertainties that are most urgent candidates for further evaluation with the operating model once we had a chance to acquire more data, in particularly, from the manager group.

Evaluating sensitivity of the model through elasticity analysis (calculating a proportional change of the model output variable relative to a small change in the input variable) to identified sources uncertainties is the next step of risk assessment, moving from the qualitative to a quantitative phase. We are planning to participate in the ICCAT modellers meeting in the Spring 2013 where model sensitivity to various uncertainties will be determined, providing feedback from this project and drawing comparisons between scientists perceptions and model behaviour.

2. Method

Most potential sources of uncertainty were identified through literature review. The list of sources of uncertainties was refined and extended during discussion with ICCAT scientists, NGO representatives and managers, some of whom, later, responded to the questionnaire, results of which are discussed in this report. A complete list of questions (sources of uncertainty) and references can be found in Appendix 1. The goals of this evaluation were both pragmatic and strategic: we wanted to find out how large a problem each uncertainty represented for management, to what extent it can be reduced by further study, and what has already been done about each issue. The aim was to enable both description of the scale of the problem and quantification of the potential for mitigation of risks posed by each source of uncertainty relative to what is already practiced in producing the scientific advice. This would serve as a basis for prioritizing sources of uncertainty in order to facilitate future risk management actions.

2.1 Components

Therefore, for each source of uncertainty we asked respondents to evaluate three dimensions:

- Importance - potential impact on management goals
- Knowledge - potential to reduce uncertainty through more research
- Representation in current assessment.

2.1.1 Importance

Importance is rated in terms of the **potential impact (minimal, minor, moderate, major, or massive)** a particular variable/assumption/hypothesis (source of *uncertainty*) can have **on achieving management objectives.**

2.1.2 Knowledge

The second dimension concerns epistemological uncertainty or the potential to reduce uncertainty with greater knowledge, it is rated as follows:

1. Very low = the value of the variable is very well understood
2. Low = the value of the variable is extensively researched

3. Medium = the value of the variable is moderately well understood
4. High = the value of the variable is poorly understood
5. High uncertainty = there is little of no information about the variable.

2.1.3 Represented

The third dimension measures the status quo and asks if a particular source of uncertainty can be represented better in the assessment or scientific advice. In this question we elicit to what extent a given source of *uncertainty* is **already taken into account** in the assessment:

1. Very well represented = full distribution of uncertainty has been integrated into the assessment methodology
2. Well represented = some percentile values have been used
3. Represented = some sensitivity analysis or MSE evaluation has been done
4. Poorly represented = uncertainty in the variable is not considered (deterministic)
5. Very poorly represented or **not at all** = the variable has not (or barely) been represented or considered in the assessment

2.2 Visualisation

Imperial developed a new and specific to ICCAT visualisation method which is based on risk visualisation techniques developed in FP7 project PRATIQUE (to improve Pest Risk Analysis in agriculture) and adopted by European and Mediterranean Plant Protection Organisation (EPPO) (Baker et al., 2009; Leach et al., 2011, Mumford et al., 2011). The three components of risk, described in the previous section, are visualized in terms of the variously sized bubble (knowledge-related uncertainty) located in a two dimensional space defined by 'importance' and 'represented' components. The size of the bubble portrays the degree of knowledge related uncertainty; small size depicts low uncertainty, the size of the bubble increases as uncertainty increases (Figs 1 and 2). In this visualization method, colour and sizes provide a relative view, not linked to specific risk preferences/judgments.

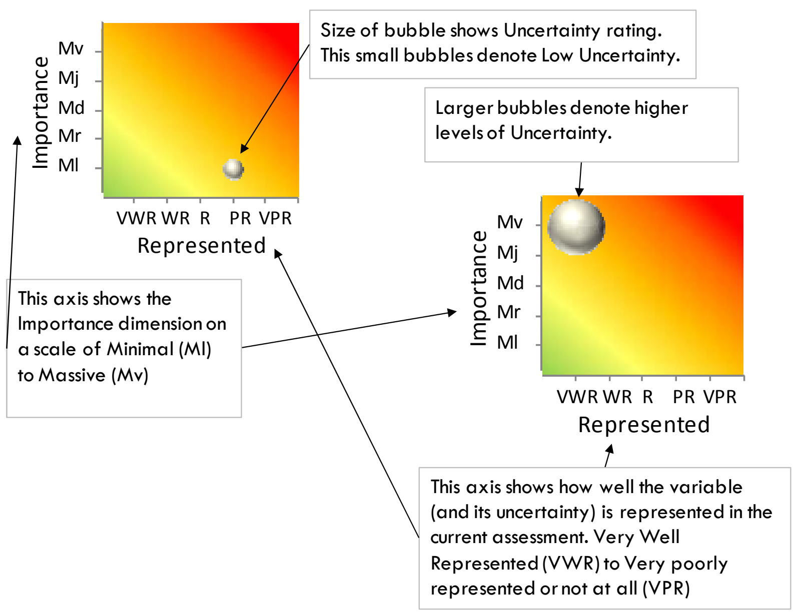

Figure 1. Visualising responses by individual experts

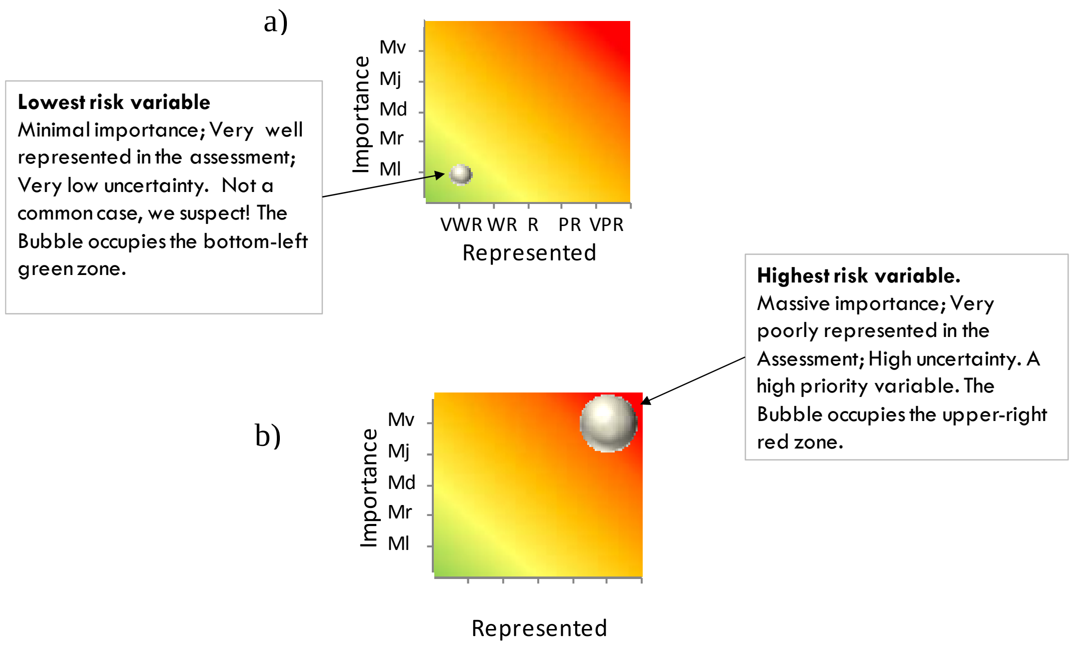

Figure 2. Examples of visualisation of expert responses at opposite ends of scale: a) lowest risk variable; b) highest risk variable

3 Preliminary Results

3.1 Raw data visualisation

Data from each of the respondents was collated into a spreadsheet and presented in two ways:

a) Bar charts, in which the variables were grouped according to type (Reference points, Recruitment, Population structure, Model, Management, Life History Traits, Environmental, Catch). For each variable the distribution of respondent's scores is shown for the three dimensions of Importance, Knowledge (Uncertainty) and Representation (Figures 3, 4 and 5 respectively).
b) Hoop diagrams have a similar format to those shown in Figures 1 and 2 except that hoops instead of opaque bubbles were used to allow all responses to be seen in the same chart, colour is used to indicate stakeholder groups; the full list of variables presented as hoop diagrams is available in Appendix 1).

3.1.1 Bar chart visualisation

Bar charts presented in Figures 3, 4, and 5 enable a quick overview of the partition of the total number of respondents' answers for each source of uncertainty grouped into categories (Reference points, Recruitment, Population structure, Model, Management, Life History Traits, Environmental, Catch). These are displayed in separate figures for each of the dimensions (Importance, Knowledge, and Representation). In this representation the stakeholders are considered altogether. The answers are colour-coded so that both dominating attitudes and a consensus can be apparent at a glance. For example, looking at Figure 3, at the last question regarding catch-under-reporting, we can immediately tell that all of the respondents thought that it is moderately, majorly or massively important as both yellow and green colours are absent, and that the latter two categories dominate. Looking at Figure 3 as a whole, it can be seen that red spectrum colours, which represent higher importance, dominate, i.e. no source of uncertainty can be viewed as having a minor influence on achieving management objectives according to all questioned experts. Similarly, Figures 4 and 5 show that for all sources of uncertainty at least some experts think that the knowledge and representation of uncertainty in each variable is insufficient and can be improved.

3.1.2 Hoop diagram visualisation

The hoop diagrams are a powerful tool for displaying the degree of consensus among experts within each variable in each of the three dimensions. For example, for Environmentally driven recruitment variability there is a high degree of consensus regarding the high Importance, poor Knowledge (high uncertainty) and poor Representation in the current assessment as indicated by consistently large hoops and that the hoops all occupy the upper right (high risk) quadrant of the chart (Appendix 1, Question 5). For “Ecological\environmental (other than climate change) potential to change population dynamics” (Appendix 1, Question 6), there is a consensus in with respect to high knowledge uncertainty but there is a lot of disagreement about how this is uncertainty is already represented. The final example in the hoop diagram for Appendix 1, Question 21, shows how experts had little agreement across any of the three dimensions related to the Risk attitude of managers.

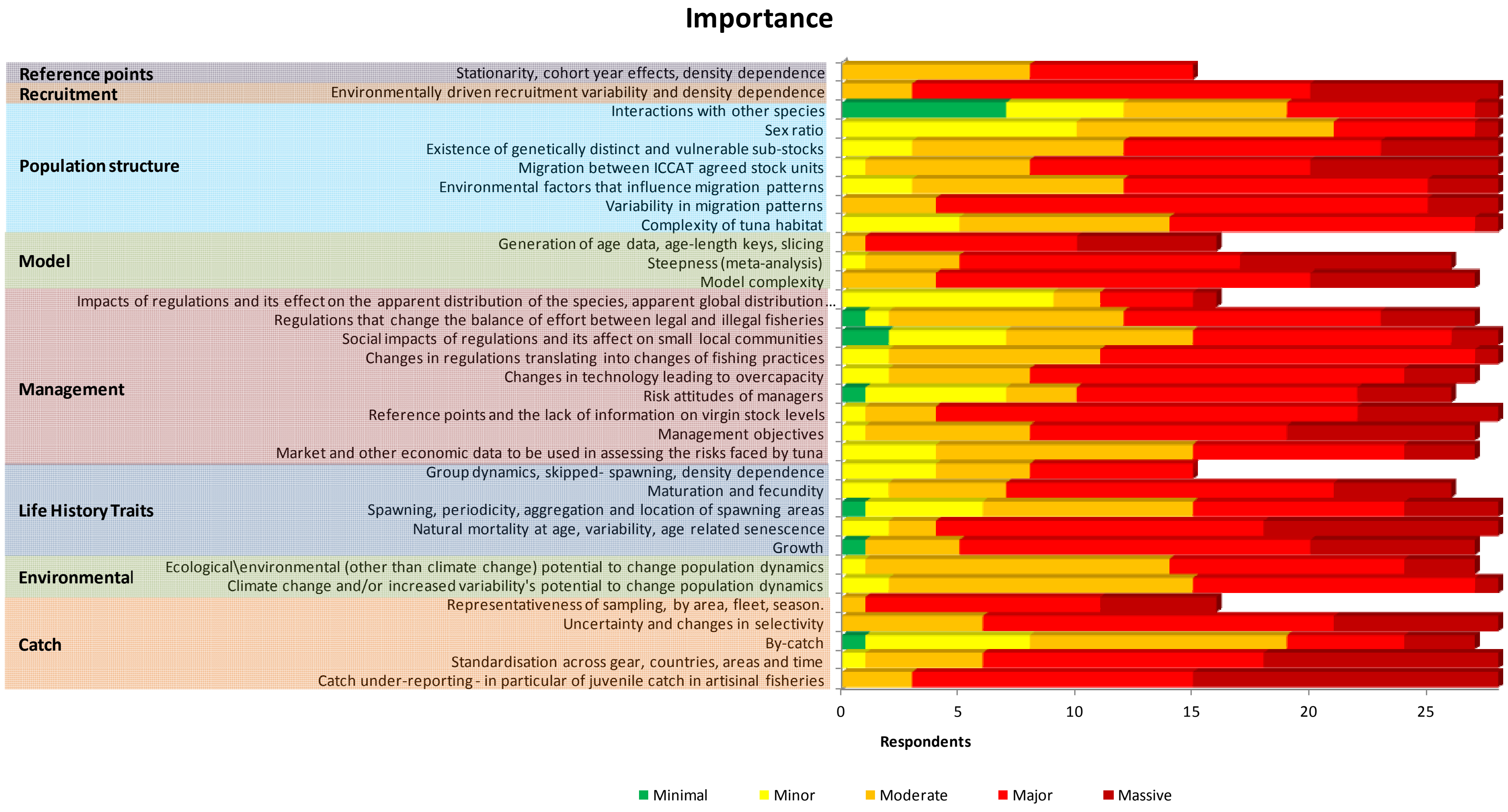

Figure 3. Importance of a variable.

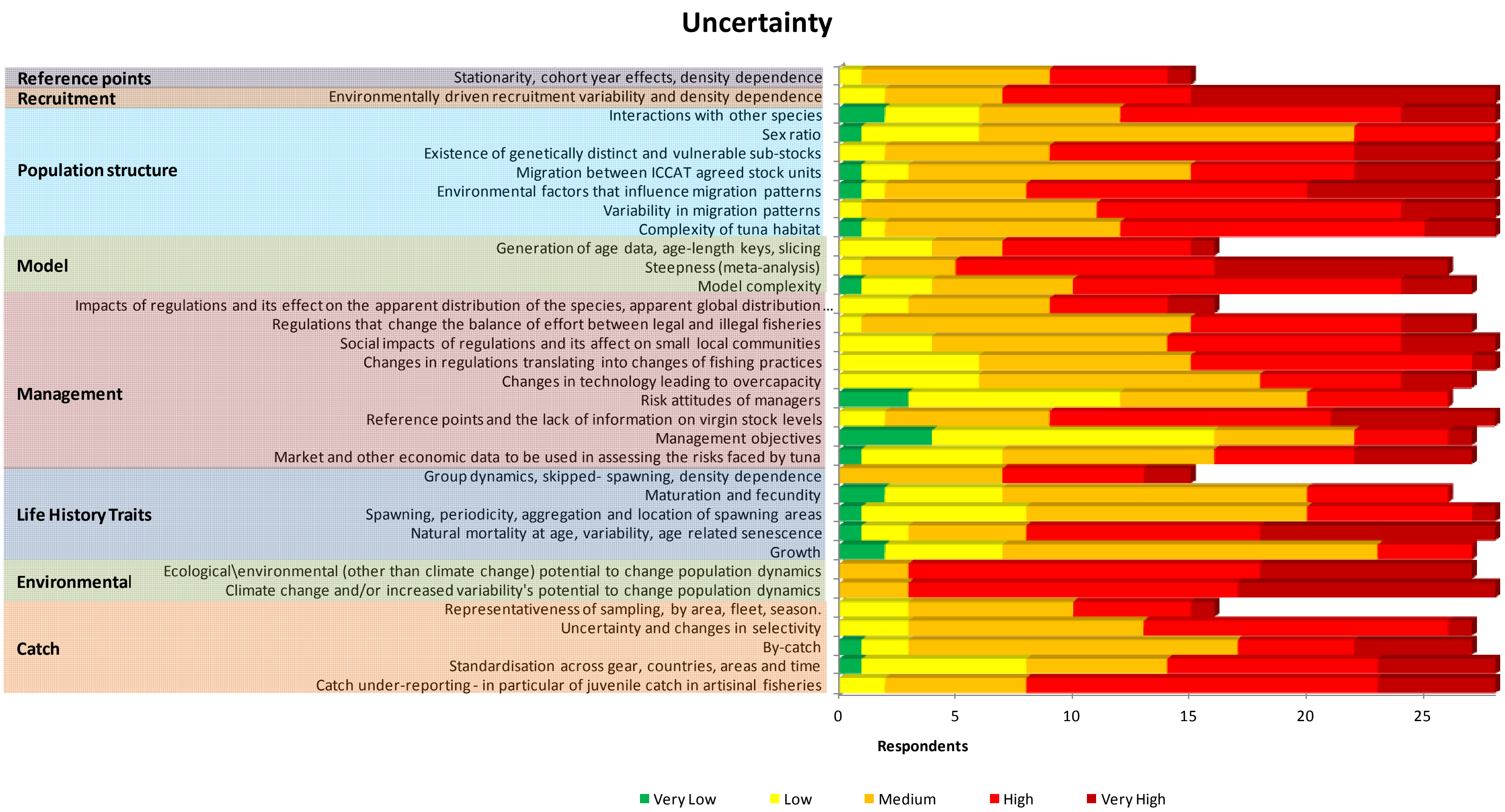

Figure 4. Potential to reduce knowledge uncertainty in the variable.

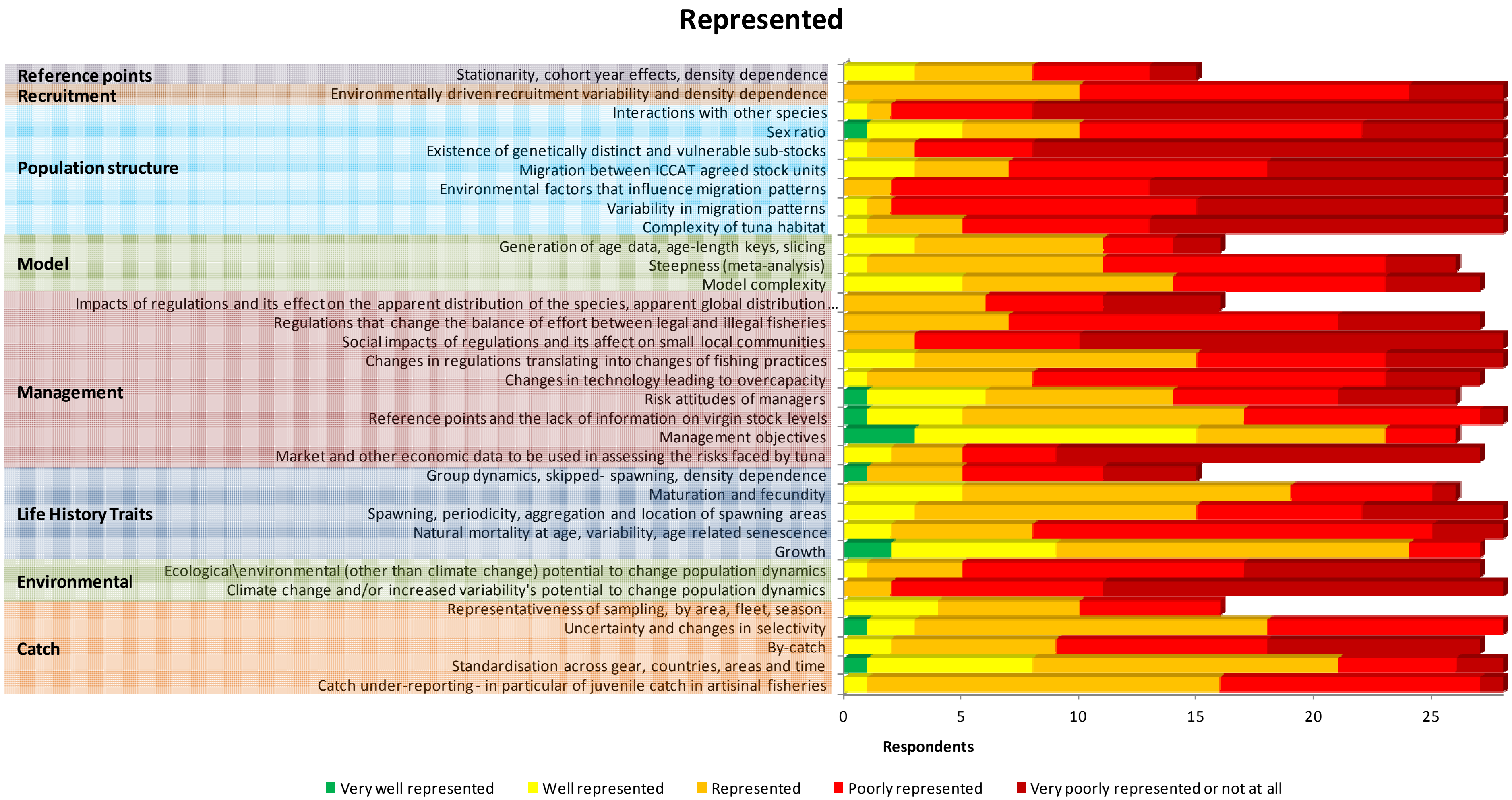

Figure 5. How well uncertainty in a variable is already represented in the assessment?

4 Discussion

The aim of the elicitation is to deconstruct each source of uncertainty into components in order to facilitate the next stages, which are the quantification and mitigation of risks. The tools presented in this paper assist in prioritisation of uncertainties, while also indicating and visualising the degree of consensus among experts and/or stakeholders on particular issues. Perceptions of uncertainty in fisheries often vary widely among scientists, managers and interest groups, and hence tools that can ensure inclusivity and that are able to represent differences of opinion are invaluable where decision-making depends on broad agreement and more generally, where effective management depends on commitment from stakeholders. Respondents were required to score each variable in each of three dimensions: importance of the variable; knowledge-based uncertainty in the variable; and the degree to which that variable was represented in the current assessment. These dimensions were used because they describe the aspects about a source of uncertainty that are relevant in a risk-based management framework: 'Could it make a difference?', 'Is the problem tractable?', 'To what extent has it already been tackled?' The raw data was visualized using a novel graphical method to help ICCAT stakeholders negotiate greater consensus.

Figures 3, 4, and 5 present the broad findings of the consultation so far. The Appendix contains the hoop diagrams for every source of uncertainty and presents the details of differences of opinion found amongst individuals. The colour coding of individual answers according to stakeholder group offers a preliminary glimpse of possible differences among stakeholder groups. Because the management constituency is still largely absent due to a lack of response from that group no firm conclusions can be made at this time. Following additional data that should be forthcoming from managers, the results will be shared and discussed with relevant stakeholders. The implications of the findings will need to be considered in conjunction with GBYP leadership. The main output of this assessment will be a contribution to model development and evaluation of model sensitivities to a subset of uncertainties of higher priority.

5 Acknowledgements

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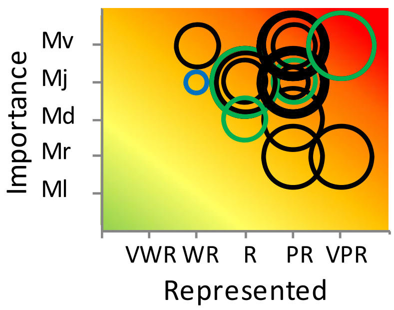
Appendix 1. Detailed responses for each variable, hypothesis or assumption

This appendix presents for each variable the scores obtained in during the first and second phase of the assessment. The graphics describe the score for each variable (see Section 3.1.2 for an explanation of how the three variables are depicted). Green colour represents NGO answers, blue – managers, black – scientists.

1. Natural mortality at age

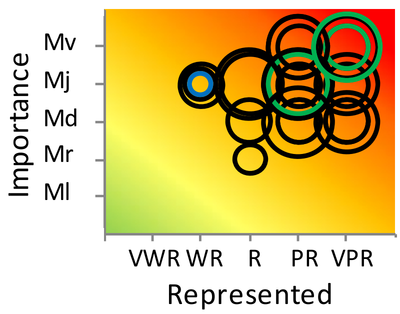
   Sources:
   Like many fish populations, natural mortality rates (M) are poorly known for bluefin tuna (BFT Manual (Fromentin) 2006).
   ****
   However, it is generally agreed that: (i) long-lived fish, such as bluefin tuna, have a lower and less variable M than short-lived ones, (ii) M's are higher during juvenile stages than during the onset of adulthood (disregarding senescence), and (iii) M's also vary with population density, size, sex, predation and environment (e.g. Vetter 1987).
   ****
   Predation purportedly comes mainly from large pelagic sharks and killer whales, as depicted at the entrance of the Gibraltar Straits during bluefin tuna spawning migration (Nortarbartolo di Sciara 1987).
   ****
   In the absence of direct and consistent estimates of M for Atlantic bluefin tuna, the natural mortality vector of the Southern bluefin tuna is generally used for the East-Atlantic and Mediterranean stock assessment, whereas a constant M of 0.14 is assumed for the West Atlantic bluefin tuna (ICCAT 1999; ICCAT 2003a). However, both solutions remain unsatisfactory and tagging experiments and modelling are needed to progress on this issue (BFT Manual (Fromentin) 2006).



2. Migration between ICCAT agreed stock units

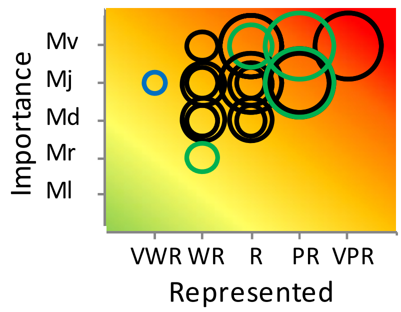
   Sources:
   Understanding bluefin tuna migratory behaviour is crucial for management, as spatial variability governs the definition of management units, stocks and boundaries. ICCAT currently manages BFT as two stocks with the boundary between the two spatial units being the 45°W meridian. This delimitation was originally established for management convenience (see ICCAT 2002a), but it has been recently criticised, as higher rates of trans-Atlantic migration than previously suspected have been detected through electronic tagging (BFT Handbook (Fromentin) 2006))

   ****
   ... though Block et al. (2005) still advocated [the existence] of distinct spawning areas between East and West Atlantic stocks, these authors also postulated that significant overlapping distribution on North Atlantic feeding grounds; an hypothesis already raised by several past authors, such as Tiews (1963) or Mater et al. (1995).



3. Standardisation across gear, countries, areas and time

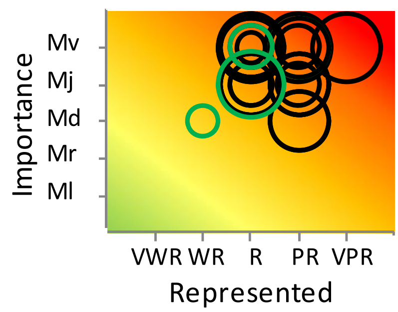
   Source:
   ICCAT meeting (27/06/2011)



4. Catch under reporting

   Sources:
   Subsequent reductions in the magnitude of landings are questionable, since under-reporting may have occurred after the implementation of a TAC (Fromentin 2003; ICCAT 2005).

   Juvenile Catch mis-reporting artisanal and recreational fisheries typically catch juvenile tunas in coastal areas and controls are difficult.



5. Recruitment variability

   Sources:
   Egg production is age (or size)-dependent: a 5-years old female produces an average of five million eggs (of ~1mm), while a 15-20 years female can carry up to 45 million eggs (Rodriguez-Roda 1967).
   ****
   Little is known about the effects of the age-structure of the spawning stock, as well as the condition of the spawners, on the viability of the offspring, but recent studies on groundfish or rockfish have demonstrated that such relationship may be crucial for long-live fish species (Berkeley et al. 2004; Birkeland and Dayton 2005; Cardinale and Arrhenius 2000; Marteinsdottir and Begg 2002).

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The degree of complexity of population structure on the one hand (Fromentin and Powers 2005) and the potential impact of environmental changes on the migratory behaviour (Ravier and Fromentin 2004) could strongly affect the reproductive strategy and recruitment success of bluefin tuna.
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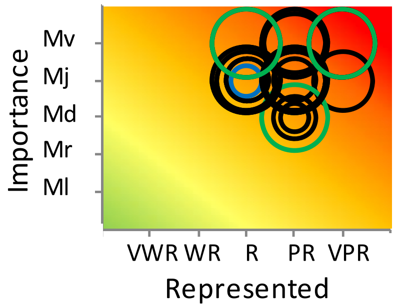
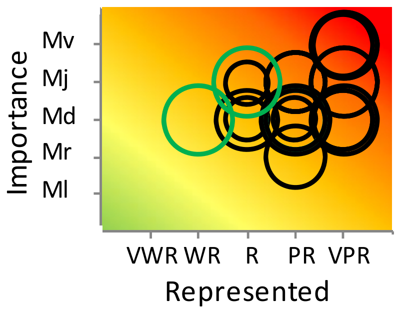
The identification of the major abiotic and biotic forces controlling bluefin tuna recruitment remains thus obscure (BFT Manual (Fromentin) 2006).



6. Ecological\environmental (other than climate change) potential to change population dynamics

Source:
ICCAT meeting (27/06/2011)



7. Steepness (meta-analysis)

Source:
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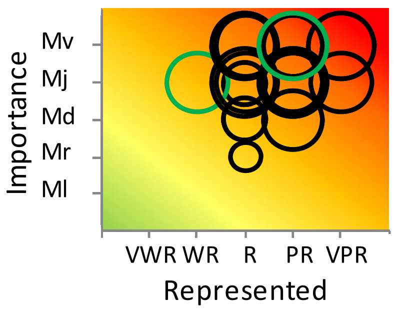
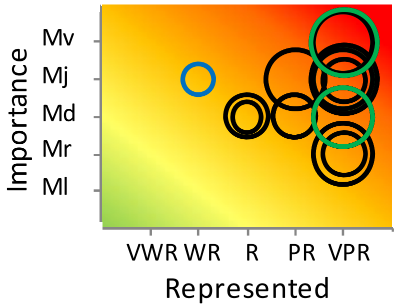


8. Existence of genetically distinct and vulnerable sub-stocks

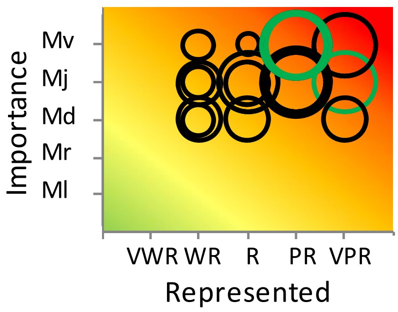
   Sources:
   Although the results remain somewhat controversial, most recent and extensive studies (Carlsson et al. 2004; 2006) tend to support the hypothesis of a complex population structure, with, for instance, genetic differences within the Mediterranean Sea and the central North Atlantic. [confirmed Riccioni et al., 2009; Riccioni et al. 2010]

   Atlantic bluefin tuna may be seen as a metapopulation, i.e. a collection of discrete local populations, occupying distinct and patchy suitable habitats and displaying their own dynamics (including migration), but with a degree of demographic influence from other local populations through dispersal. (BFT manual (Fromentin), 2006)



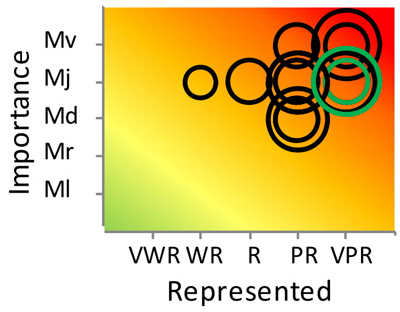
9. Model complexity

   Source:
   Uncertainty and complexity about the equations describing life-history and dynamics (ICCAT meeting (27/06/2011)).



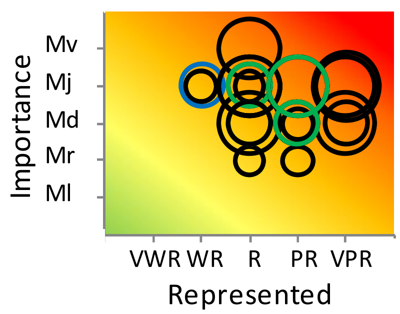
10. Variability in migration patterns

   Source:
   Electronic tagging indicated that migration and movement patterns of bluefin tuna vary considerably between individuals, years and areas (Block et al. 2001; de Metrio et al. 2002; Lutcavage et al. 1999).



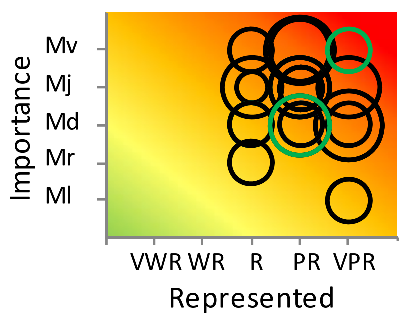
11. Changes in regulations translating into changes of fishing practices

    Source:
    Is uncertainty in responses to management measures considered? Is uncertainty of effects of new measures on fishing behaviour, data collection, spatial distribution of effort etc considered in the management advice? ICCAT meeting (27/06/2011)



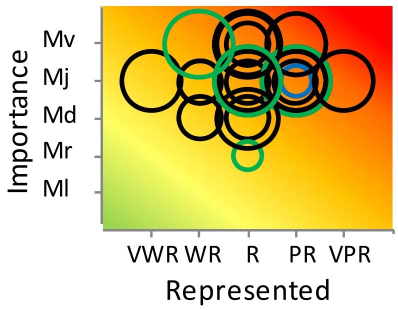
12. Regulations that change the balance of effort between legal and illegal fisheries

    Source:
    Is the uncertainty regarding the effects of management on the balance between legal and illegal fishing considered, including knock-on effects to data quality, etc? ICCAT meeting (27/06/2011)



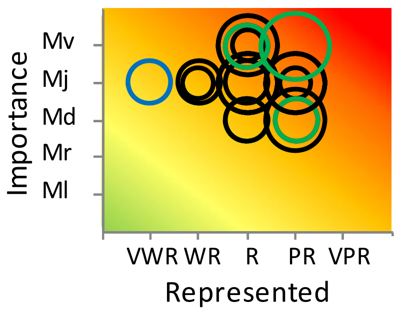
13. Reference points and the lack of information on virgin stock levels

Source:
Have risk attitudes of managers/stakeholders been elicited? Is there uncertainty / ambiguity about the levels of risks that stakeholders or managers find acceptable? ICCAT meeting (27/06/2011)



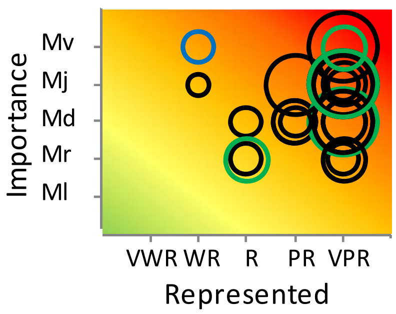
14. Uncertainty and changes in selectivity

Source: ICCAT meeting (27/06/2011)



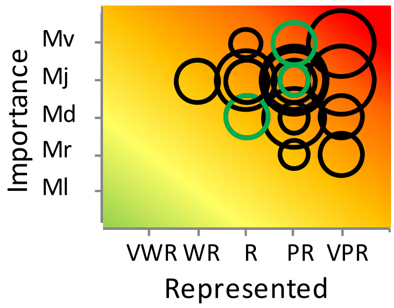
15. Market and other economic data to be used in assessing the risks faced by tuna

Source:
ICCAT meeting (27/06/2011)



16. Changes in technology leading to overcapacity

Source:
Does assessment keep up with the changes in technology? How do changes in technology affect risks to sub-populations (e.g. an ability to locate groups poses greater risks to smaller genetic units)? How is uncertainty regarding technological change accounted for? ICCAT meeting (27/06/2011)

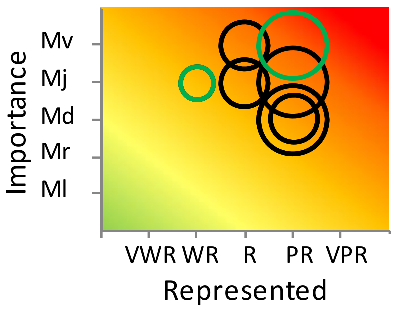


17. Age of maturity

Source:
… showed that Atlantic bluefin tuna mature at 110-120cm (25-30kg) in the East Atlantic and Mediterranean Sea, so at approximately 4 years old (BFT Manual (Fromentin) 2006).

The size of the fish spawning in the Gulf of Mexico were always greater than 190cm, which would correspond to about 8 years old (BFT Manual (Fromentin) 2006).

After several decades of studies, age-at-maturity remains uncertain for the Atlantic bluefin tuna, especially for the West Atlantic (depending on the authors, the 50% maturity varies between age 5 and age 12). Further investigations are thus still needed, using for instance the same sampling protocol and same methodology on both sides of the Atlantic (Fromentin and Powers 2005).

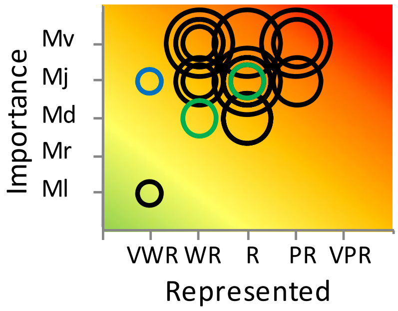


18. Fish growth

Source:
Still, age-size relationships remain uncertain, especially for older individuals (> 8 years) BFT Manual (Fromentin) 2006.
****
The count of annuli on otoliths, spines, vertebrae and scales are indeed impaired by various sources of errors, such as the coalescence or the disappearance of the first marks or conversely to the multiple marking due to migration patterns (see Compean-Jimenez and Bard 1980; Compean-Jimenez and Bard 1983; Cort 1991; Farrugio 1981; Mather et al. 1995).
****
Decomposition of bluefin tuna length-frequency data into age-classes becomes difficult for fish older than 5 years, as the cohorts tend to become indistinguishable (Fromentin 2003).

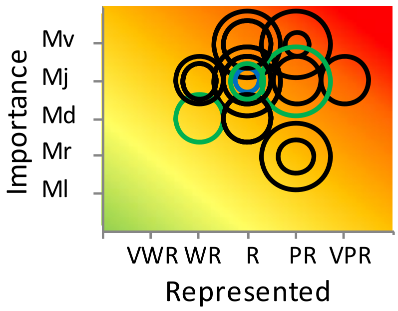
****

Innovative modelling approaches, such as the growth model developed by Evenson et al. (2004), which integrates data from the three key sources (length-frequency, tag recapture and hard structures) within the same estimation framework could and should be applied to bluefin tuna (BFT Manual (Fromentin) 2006).



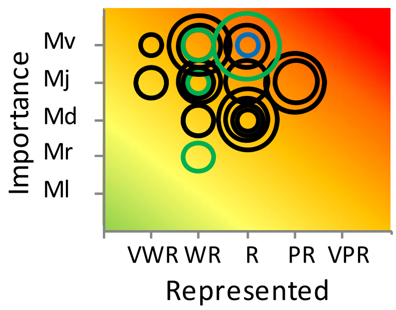
19. Maturation and fecundity

Source:
Fromentin and Fonteneau 2001; BFT Manual (Fromentin) 2006



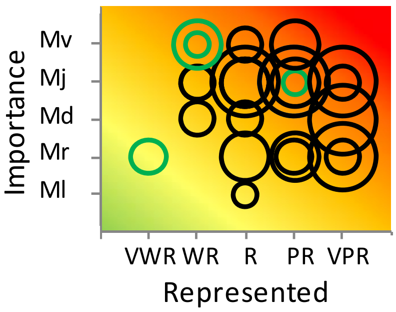
20. Management objectives

Source:
Are management objectives ambiguous and does that source of linguistic uncertainty matter? (ICCAT meeting (27/06/2011))



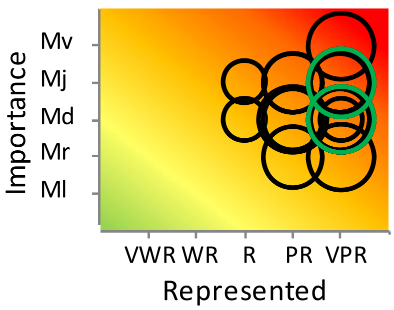
21. Risk attitudes of managers

Source:
Have managers expressed their preferences for risks? What level of risk, with respect to particular objectives, do they find acceptable? (ICCAT meeting (27/06/2011))



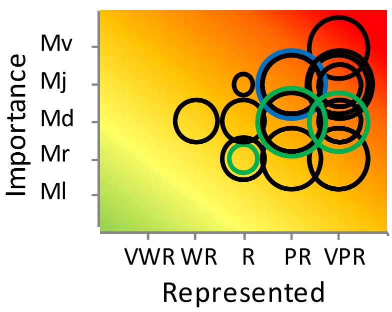
22. Climate change and/or increased variability's potential to change population dynamics

Source:
Climatic changes may affect marine ecosystems. How can the models that rely on equilibrium and stationarity assumptions be used when we know that the underlying conditions are changing? Assuming that climate change will impact species composition, location, resilience to exploitation, how are we to define management objectives, targets and benchmarks? (ICCAT meeting (27/06/2011))



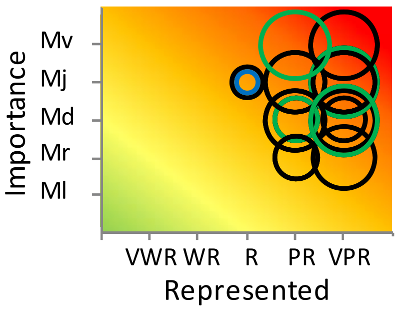
23. Complexity of tuna habitat

Source:
Despite this general agreement, bluefin tuna habitat appears more complex than what could be explained by these oceanic features, alone, and much more remains to be learned (Royer et al. 2004; Schick et al. 2004).



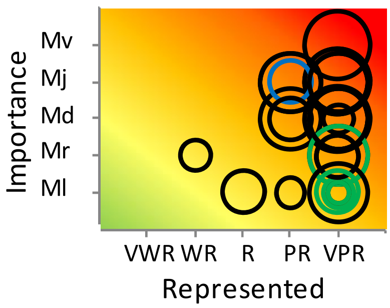
24. Environmental factors that influence migration patterns

Source:
... spatial dynamics of bluefin tuna may be environmentally driven (Marsac 1999; Ravier and Fromentin 2004).



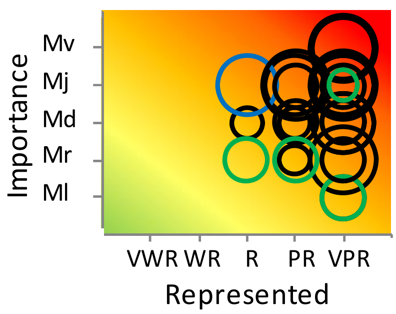
25. Interactions with other species

Source: How well is the impact of tuna fishery on other species understood? What are the risks to non-target species? What is the impact on marine biodiversity?



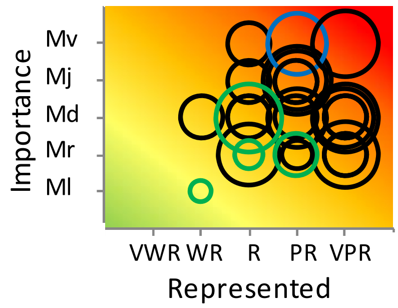
26. Social impacts of regulations and its affect on small local communities

Source: Are impacts of regulations on local communities assessed? How well are socio-economic risks taken into account? And how does the perception of those risks, as well as uncertainty over impacts on national fisheries, affect management?



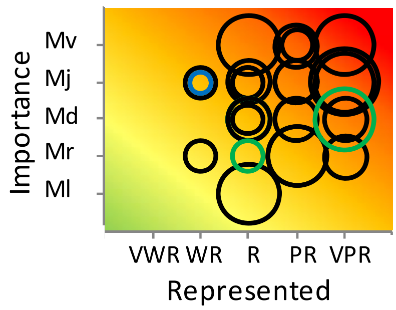
27. Bycatch

Source:
ICCAT meeting (27/06/2011)



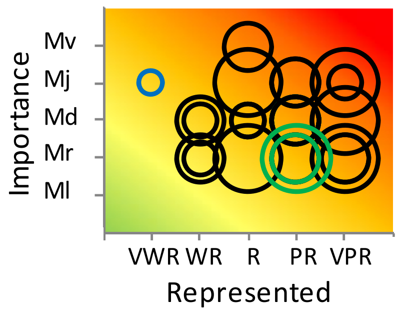
28. Spawning, periodicity, aggregation and location of spawning areas

Source:
It is generally assumed that bluefin tuna spawns every year, but electronic tagging experiments, in captivity, suggest that individual spawning might occur only once every two or three years (Lutcavage et al. 1999).

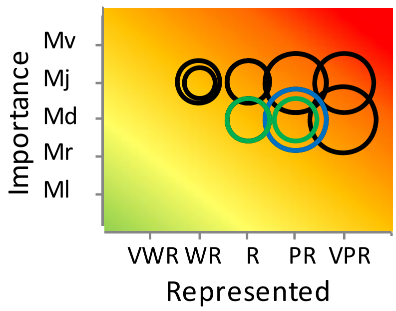


29. Sex ratio

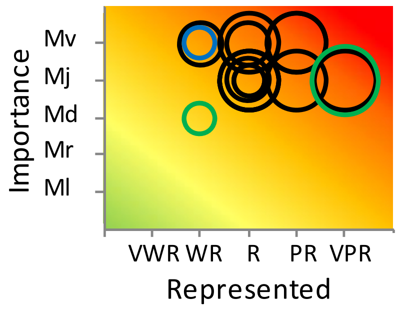
Source:
The proportion of males appears to be higher in catch samples of large individuals, which could be due to a higher natural mortality or lower growth for females (ICCAT 1997). A recent study done by de la Serna et al. (2003) indicated that such differences may vary among gears and areas.
****
Hattour (2003) has found higher or equal (depending on the year) proportion of females for all sizeclasses in the catches of purse seiners operating in the central Mediterranean.



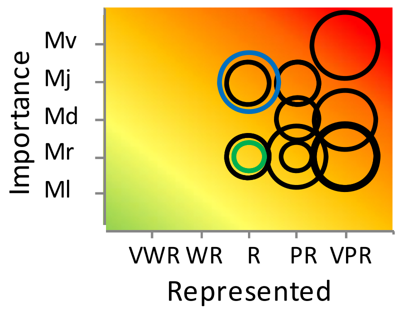
30. Stationarity, cohort year effects, density dependence



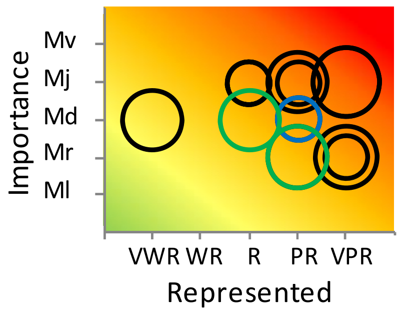
31. Generation of age data, age-length keys, slicing



32. Impacts of regulations and its effect on the apparent distribution of the species, apparent global distribution of the species.



33. Group dynamics, skipped- spawning, density dependence



34. Representativeness of sampling, by area, fleet, season.