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PRODUCTIVITY AND SUSCEPTIBILITY ANALYSIS: APPLICATION AND SUITABILITY FOR DATA POOR ASSESSMENT OF ELASMOBRANCHS IN NORTHERN EUROPEAN SEAS.

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SUMMARY

National and European-wide shark conservation plans aim to manage elasmobranch stocks sustainably. However there has been limited success towards such targets, as a result of uncertainties and data deficiencies hampering traditional, quantitative assessment and thus effective and practicable management. To this end an assessment method (Productivity Susceptibility Analysis, PSA), was developed for elasmobranchs caught in four mixed fisheries in northern European shelf seas. In the pelagic ecosystem, porbeagle and shortfin mako were identified as the most vulnerable species, followed by two further commercially-important bycatch sharks (thresher and blue shark), and finally swordfish, a target teleost. In the demersal ecosystem, spurdog was found to be the most vulnerable species in both bottom trawl and set net fisheries. A further six elasmobranchs (including five batoids) and three teleosts (one target teleost) comprised the 10 most vulnerable species in bottom trawl fisheries, while in set net fisheries, 11 more elasmobranchs (including eight batoids) followed spurdog in the vulnerability ranking. These results are discussed in relation to commercially assessed species, included to 'ground-truth' the relative risk rankings and their conservation status through IUCN listings.

RÉSUMÉ

Les plans de conservation des requins à l'échelle nationale et européenne visent à gérer les stocks d'élasmobranches de manière soutenable. Toutefois, ces objectifs n'ont connu un succès que très limité, en raison des incertitudes et des insuffisances des données qui ont entravé l'évaluation traditionnelle et quantitative et par conséquent la gestion efficace et viable. À cette fin, une méthode d'évaluation (analyse de la susceptibilité de la productivité, PSA) a été mise au point pour les élasmobranches capturés dans quatre pêcheries mixtes dans les mers épicontinentales d'Europe du Nord. Dans l'écosystème pélagique, il a été identifié que le requin-taupe commun et le requin-taupe bleu constituent les espèces les plus vulnérables, suivies de deux autres espèces de requins capturées en tant que prises accessoires et revêtant une grande importance commerciale (renard de mer et requin peau bleue) et de l'espadon, un poisson téléostéen ciblé. Dans l'écosystème démersal, l'aiguillat s'est avérée être l'espèce la plus vulnérable dans les pêcheries de chalut de fond et de filet fixe. Six autres élasmobranches (y compris cinq batoïdes) et trois téléostéens (un téléostéen cible) composaient les 10 espèces les plus vulnérables des pêcheries de chalut de fond, tandis que dans les pêcheries de filet fixe, 11 autres élasmobranches (y compris huit batoïdes) suivaient l'aiguillat dans l'ordre de vulnérabilité. Ces résultats sont discutés par rapport aux espèces évaluées commercialement, y compris pour confirmer la classification du risque relatif et l'état de conservation par le biais des listes de l'IUCN.

RESUMEN

Los planes de conservación de tiburones a escala nacional o europea tienen la finalidad de conseguir una ordenación sostenible de los stocks de elasmobranquios. Sin embargo, la consecución de dichos objetivos ha sido limitada, debido a que las incertidumbres y las deficiencias en los datos impiden la realización de evaluaciones cuantitativas tradicionales y, por consiguiente, no permiten establecer una ordenación eficaz y viable. Con este fin, se ha desarrollado un método de evaluación (Análisis de la Susceptibilidad de la Productividad),

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para los elasmobranquios capturados en cuatro pesquerías mixtas en las plataformas continentales europeas septentrionales. En el ecosistema pelágico, el marrajo dientuso y el marrajo sardinero fueron identificados como las especies más vulnerables, seguidas de dos tiburones objeto de captura fortuita y comercialmente importantes (tiburones zorro y tintorera) y finalmente del pez espada, un teleósteo que es especie objetivo. En el ecosistema demersal, se descubrió que la mielga era la especie más vulnerable, tanto en las pesquerías de arrastre de fondo como en las de redes fijas. Otras seis especies de elasmobranquios (entre las que se incluían cinco batoideos) y tres teleósteos (un teleósteo objetivo) son las diez especies más vulnerables en las pesquerías de arrastre de fondo, mientras que en las pesquerías de redes fijas 11 elasmobranquios más (entre los que se incluyen ocho batoideos) seguían a la mielga en la clasificación de vulnerabilidad. Se debaten estos resultados en relación con especies evaluadas comercialmente, lo que incluye la confirmación las clasificaciones de riesgo relativo y su estado de conservación mediante los criterios de inclusión en las listas IUCN.

KEYWORDS

Elasmobranch, By catch, Life history, Vulnerability, Northeast Atlantic, Fishery management.

1. Introduction

In European waters, scientific agencies have only been able to forecast the size of fish stocks, fishing mortality rates and catch levels for just over one third of commercial stocks (e.g. EC COM(2009a) 224, Annex II). This is often because scientific advice is limited by inaccurate data on landings, discards and effort, or lack of information from fishery-independent surveys. Additionally, some groups of fish that are not assessed currently (e.g. because they are of minor commercial importance in overall landings) can be highly susceptible to the impacts of fishing and there may be requirements to consider such species in ecosystem advice. The UK 'Shark, Skate and Ray Conservation Plan', aims to: "*manage elasmobranch stocks sustainably so that depleted stocks recover and that those faring better are fished sustainably*" (Defra, 2011), yet to progress towards such targets for data deficient species, different assessment methods and management procedures are required. Presently, assessing and managing stocks that are of an uncertain status and often data limited are not achievable through the traditional assessment methods.

Following the UN Code of Conduct for Responsible Fisheries (FAO, 1995), however, the "best scientific evidence available" should be used to evaluate the state of any fisheries to support decisions, while the precautionary approach to fisheries management requires a formal consideration of uncertainty. In order to address such principles, various risk-based approaches have been considered for data-poor, multi-species scenarios, including Ecological Risk Assessments (ERAs). Such approaches attempt to evaluate the vulnerability of a species or stock to overfishing based on its biological sensitivity or productivity, and its susceptibility to the main fisheries operating over its range. This approach has been increasingly used to identify species at risk within multispecies fisheries. Within an ERA framework (e.g. Hobday *et al*., 2006), a hierarchical approach is taken to evaluate the effects of fishing that moves from a largely qualitative analysis of risk that can involve stakeholder judgement (level 1), through a semi-quantitative approach (e.g. PSA, level 2) to a fully quantitative approach (level 3), which requires appropriate data to be available. In this way, the vulnerability or stock status of a species can be assessed (e.g. Fletcher, 2005; Griffiths *et al*., 2006), or at least allow the more vulnerable stock to be identified and prioritised for future research/assessment. ERA approaches have expanded from single species applications to focus upon an implementation approach for the ecosystem-based approach for fisheries management (Smith *et al*., 2007; Zhou *et al*., 2009), allowing rapid assessment of the potential species at risk within an ecosystem to particular fisheries and gears.

Elasmobranchs are generally considered as vulnerable to over-fishing (Ellis *et al*., 2008 and references cited therein), as they are often long-lived, slow growing and of low fecundity. While there are, or have been some directed fisheries for these species in the North East Atlantic, many of these species represent non-target 'bycatch' species in UK fisheries, which may or may not be retained. There is frequently limited information on the biology for many elasmobranch species, especially with regards to various skate species, and their interactions with commercial gears and discard survival. As a result, analytical assessments have only been possible for few species, including spurdog (De Oliveira *et al*. 2010), with advice for the more frequently occurring continental shelf demersal species based on temporal trends in relative abundance from groundfish surveys. Nevertheless, given the requirements for precautionary management, and the introduction of the EC's Community Plan of Action for sharks (EC COM, 2009b), there is a need to provide some form of advice for other species.

ERA and PSAs have been considered for elasmobranch species around the world. For example, Cortés *et al*. (2008, 2010) and Simpfendorfer *et al*. (2008) used PSAs to examine the vulnerability of pelagic elasmobranchs taken in pelagic longline fisheries in the Atlantic Ocean, while Arrizabalaga *et al*. (2009) performed a PSA for bycatch species caught in ICCAT fisheries. However, the degree to which these approaches have been 'ground-truthed' varies.

In this paper we examined the utility of the PSA approach to multispecies fisheries management and ecosystem advice, by developing a PSA framework for elasmobranchs, based upon biological productivity characteristics and their susceptibility to the fisheries that catch them. Specifically, we:

- Identified key biological and fisheries parameters that informed on the potential biological sensitivity and fisheries susceptibility.
- Related the biological and fisheries parameters to those used by the MSC (Marine Stewardship Council) criteria, to allow parity between PSA approaches and outcomes and transparency of approach.
- Undertook sensitivity analyses to examine which parameters were redundant or not informative.
- Examined the potential role of PSAs for a representative range of teleost and elasmobranch taxa (with an emphasis on data deficient elasmobranchs) within UK waters, and determined the vulnerabilities of these species to commercial fishing pressures in both the demersal and pelagic ecosystems.
- Trialled methods to 'ground truth' the framework by applying the same approach to a number of demersal teleost species for which analytical assessments and stock status estimates were available.
- Considered uncertainty in our estimates by running Monte Carlo simulations in 'R'.

2. Materials and methods

There are several hierarchies for undertaking ERAs, ranging from level 1 (qualitative) to level 3 (quantitative). Here a level 2 productivity-susceptibility analysis was undertaken for a broad spectrum of fish species, with emphasis on elasmobranchs, in order to evaluate the suitability for these methods to be able to identify those species for which improved assessments are required and/or precautionary management. We included 86 species (57 teleosts and 29 elasmobranchs) from two fisheries in the demersal environment (bottom trawl and set net), and two further fisheries from the pelagic ecosystem (longline and trawl). Although the biology of some of the species considered was well known, we attempted to include a wide range of data poor species, including some species for which ICES have been unable to provide advice. The inclusion of such species necessitated a more qualitative approach, and allowed a range of contrasting life histories (and therefore sensitivities) to be incorporated.

Vulnerability was assumed to be influenced by two components: the productivity or biological sensitivity of the stock (related to its biological characteristics) and its fisheries susceptibility (related to the likely impact of the specific fishery/gear on the stock). Each of these components was comprised of a number of different traits or factors.

Several different parameters were explored to inform on a species productivity and biology, however following sensitivity analyses and after stakeholder consultation it was decided to develop this PSA from criteria used by the MSC in their interpretation of the risk-based framework, with respect to their certification process. Pair-wise correlations were run on the values for the biological and then for the susceptibility parameters, to identify any high correlations where one parameter effectively related to another, thus rendering one almost 'redundant'. Following these initial analyses, it was decided to include an additional parameter under productivity; this was the 'patchiness of distribution'. This was deemed to be important given that limited consideration to the natural ecological distribution or habitat restrictions are currently included under the MSC criteria. For example, a species such as *Raja undulata* (undulate ray) may be locally abundant, but their highly fragmented distribution (Ellis *et al*. 2012) likely makes them more sensitive to localised depletion than a species of comparable productivity but with a more cosmopolitan distribution. Sensitivity analyses identified this parameter as highly influential in the analyses. Likewise, we also modified the fisheries susceptibility attributes employed by the MSC, adding in ‘aggregating nature’ and ‘market value’ to reflect parameters that were both shown to be influential, and lacking representation or correlation to other criteria.

2.1 Biological sensitivity (B)

We included eight traits (life-history characteristics and distributional patterns) to confer biological sensitivity (**Table 1**), as noted below. These traits were selected as they are used as MSC criteria, can either be scored qualitatively (in the case of data poor scenarios) or it would be possible to use quantitative values within the various traits for some species-complexes. Initially age was not considered for inclusion, given that for data limited species (elasmobranchs in particular) it is one of the biological parameters that is most often lacking. However, given the strong relationships (e.g. Von Bertalanffy growth function, Bertalanffy, 1938) between length and age (both maximum and –at maturity), we stayed true to the MSC criteria.

(1) Average age at maturity (T_{mat}): This is not always well known for many species, however, given the large age range represented in the categories, correlations of age to the length parameters (L_{max} and L_{mat}), and with comparisons being made to sister taxa of known ages, qualitative estimates were possible.

(2) Average maximum age (T_{max}): Taken to be the maximum age that a species reaches on average, not ever recorded. Again, this parameter is not always well known, but as above, by drawing upon knowledge from other taxa and parameters, a best estimate could be made. The oldest recorded specimen (where available) from Fishbase (Froese and Pauly 2012), was used on occasions, only as a guide.

(3) Fecundity (F): Absolute levels (or ranges, as fecundity often increases with fish length) are not reliably known for many species, although often, the general order of magnitude can be estimated from their reproductive strategy and from estimates for sister taxa.

(4) Average maximum size (L_{max}): Maximum length is known to correlate with many life-history characteristics. This value is usually well known for most fish species.

(5) Average size at maturity (L_{mat}): This is again correlated to other life history parameters, and usually approximately known, at least well enough to assign to a category.

(6) Reproductive strategy (R): Although there are many reproductive modes in fishes (e.g. Balon, 1984), fish were divided into three broad categories: broadcast spawners, demersal egg-layers (including brooders and guarders) and viviparous species (both placental and aplacental).

(7) Trophic Level (TL): Taken from Fishbase (Froese and Pauly 2012) in all cases.

(8) Patchiness of distribution (P_D): Patchy distributions are often considered to confer sensitivity to over exploitation, and so we attributed fish to either continuous, restricted or highly fragmented distributions.

2.2 Fisheries susceptibility (F)

We included six aspects of fish-fishery interactions to confer susceptibility to fisheries (**Table 2**). It should be stressed that these factors are most often fishery-specific, and hence the matrix should be completed for each fishery/stock under consideration. In contrast, the biological sensitivities noted above may be used between several fisheries (unless there are important regional differences in both fishing patterns and biology). The factors used were:

(1) Spatial overlap with fishery (S): The extent to which the geographical distribution of the species is overlapped by the fishery. This can be done quantitatively with GIS (e.g. the proportion of the fish distributional area in relation to the distribution of the fishery), although the two data sets required for such a quantitative analysis are often lacking. Therefore, we scored this based on ‘expert judgement’ (based on knowledge of landings data, participation in scientific trawl surveys and scientific literature).

(2) Depth in relation to gear (D_G): Fishing gears may fish primarily at certain depths (e.g. distance from the seabed or below the surface), and so some fish species may be encountered to varying degrees. If data from

electronic tagging studies are available, then this factor can be semi-quantified. Again, this was scored based on expert judgement.

(3) Selectivity and gear catchability (C): The likelihood of fish getting caught in a trawl or gillnet will depend on several factors, including size and body shape, swimming speed, escape responses and, for those species closely associated with the seafloor, burying ability. Additionally, trawl nets fished on rough ground will have lower ground contact than, for example, fine ground, which may allow some increase in fish escapement. The potential for longline capture was assessed by the degree of piscivory[3] (i.e. less piscivorous species will be less likely to take the bait or get hooked).

(4) Aggregating nature (A): Those species that can form large aggregations or schools may be more efficiently targeted and so may be more susceptible.

(5) Market value (V): It is assumed that those species for which the market value is highest (£/kg) will be more likely to be actively targeted, or if a bycatch species, retained.

(6) Post-capture mortality (M): The fate of the fish will be a combination of many factors, including as to whether they are a target species, a commercial or non-commercial bycatch species, management in place (e.g. quota or size restrictions) and, for fish that are discarded, the likelihood of surviving. Given that management may change over time, this could lead to subtle changes in the current study.

2.3 Scoring

Each biological trait was scored and placed into one of the following categories: high productivity (low risk – score = 1), medium productivity (medium risk – score = 2) or low productivity (high risk – score = 3).

Each fisheries susceptibility parameter was classed as having low susceptibility (low risk, score = 1), medium susceptibility (medium risk, score = 2) or high susceptibility (high risk, score = 3), and scored accordingly.

Confidences in each of our trait scores were applied. These were assigned using the IPCC (Intergovernmental Panel on Climate Change) confidence rankings (IPCC, 2005).

Level of confidence	Low	Medium	High	Very high
Chance	2 out of 10	5 out of 10	8 out of 10	9 out of 10
Score	0.2	0.5	0.8	0.9

The scores for each of the traits were then summed, to give a total score for each species. The total scores were than ranked to give the overall vulnerability for each species. Each trait was also given a lower and an upper ‘possible’ score, to identify where any uncertainty was perceived to occur. However, as a score could not go below 1 or above 3, bounds were put in place at these levels. Monte Carlo simulations were then run on the probabilities and upper and lower possible scores for each trait to simulate the variation expected due to uncertainty. This gave us the overall 90% confidences in our scores.

The level of confidence was not applied to reproductive strategy, as there was neither uncertainty nor ‘bridging’ between life history strategies. In this case, the confidence was set to 1, and the upper and lower values possible were set to the actual score. In the case of the ‘trophic level’ parameter, any trophic level occurring within 0.1 of the borderline scores for the category was assigned a medium confidence (0.5) otherwise all other trophic levels scored 0.8 (i.e. we assumed a ‘high’ confidence in Fishbase estimates).

The total vulnerability scores and their variation due to uncertainty allowed us to rank the species in terms of the most to least vulnerable for each fishery independently, and also for the UK shelf sea fish assemblage as a whole. This method has the ability to identify where precautionary management measures may be needed and future research efforts should lie. The results of these PSAs were examined in relation to commercial importance and importance to UK waters to aid advisory measures.

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[3] For the purposes of this paper, we assumed piscivory to relate to predating on both fish and cephalopods.

3 Results

3.1 PSA Rankings, Tables and Plots (Table 3-5 and Figures 1-4)

The final position rankings for all species considered in these analyses are shown for both demersal fisheries (**Table 3**), both pelagic fisheries (**Table 4**) and all four fisheries combined (**Table 5**). The species indicating the highest vulnerability in both of the demersal fisheries was spurdog. The most vulnerable teleost in the demersal environment was Norway redfish (ranking 3rd and 13th), followed by cod as the main target teleost. In the pelagic fisheries, porbeagle and shortfin mako ranked equally most vulnerable in both fisheries, with all eight elasmobranchs considered ranking in the top ten. The most vulnerable teleost was swordfish. The lowest placed elasmobranch was marbled electric ray, ranking 61st overall. Despite the biological sensitivity score being the same, the fisheries susceptibility has significant power over the rankings, with a 27 place difference seen in an elasmobranch (nurse hound), and a 15 place difference in a teleost (wolffish) between the two demersal metiers, despite both operating in the same environment. Conversely, more parity between the two pelagic fisheries was seen, with the largest rank difference being just four places (albacore tuna); however many fewer species were considered (19 pelagic species versus 67 demersal species).

The PSA plots (**Figures 1-4**) demonstrated the biological sensitivity of all elasmobranchs (in red) in relation to the teleosts (in blue). Many more teleosts are more susceptible in the fisheries than elasmobranchs, for example, in the demersal bottom trawl (**Figure 1**), only thornback and blonde ray (both commercially caught species of elasmobranch) are at a susceptibility level on par with that of other valuable target or bycatch species (e.g. saithe, hake, lemon sole, sole, sea bass, turbot and john dory), and are below that of the main target species (cod, haddock and whiting).

These plots also clearly identified that the 90% confidence intervals surrounding the scores are generally larger for elasmobranchs than teleosts – especially with respect to the biology. This is not surprising, and such uncertainty is part of the rationale for adopting a less quantitative approach.

3.2 Conservation status of elasmobranchs in relation to rankings (see Table 5)

The species with the highest level of conservation concern under IUCN criteria are listed as ‘Critically endangered’. Four elasmobranchs in the present study have been listed as such in the Northeast Atlantic: porbeagle shark, spurdog, common skate[4] and angel shark, which had overall rankings of 1, 1, 22 and 45 respectively in this study. These four species had highly sensitive biological scores (19-21). Furthermore, porbeagle and spurdog were also at high risk in their respective fisheries with respect to distributional overlaps. Common skate and angel shark however, had lower overlaps with the fisheries, which moved them down the vulnerability list. The next level of concern is ‘Endangered’, and three more elasmobranchs were included in this category: undulate ray, basking shark and white skate, which ranked 11, 42 and 50 overall. Additionally, six other species are classified as ‘Vulnerable’: shortfin mako (1), thresher shark (5), cod (6), tope (8), sandy ray (11) and haddock (22).

The conservation status of these species, in comparison to their relative rankings, indicates that biology is very influential in the PSA. This could be a consequence of 8 biological parameters being employed in the PSA, versus 6 for fisheries susceptibility, however this biological emphasis in also mirrored in the MSC application. The rationale to support such a biological emphasis is the precautionary approach to fisheries management, where biologically sensitive species are of conservation interest and where large uncertainty may lie. However, overall species ranking highly vulnerable in these PSA correlated well to those represented under the IUCN listings.

3.3 PSA ground truthing with respect to commercially assessed species

The species included in this study for which ICES advice is available are shown in **Table 6**. We found that spurdog came out as (joint) most vulnerable in this assessment. The qualitative assessment from ICES found that the spawning stock biomass (SSB) of the stock was below possible reference points. ICES advice based on the precautionary approach was for no target fishery on this stock, and recommendations were made to develop a rebuilding plan for this stock.

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[4] Recently found to be a complex of two species. The present study refers to the *Dipturus batis*-complex.

The most vulnerable teleost in the demersal fisheries was Norway redfish. ICES do not have a stock assessment for this species. However, two other species of redfish (*Sebastes mentella* and *S. marinus*) have seven assessments on different stocks, all of which are of ‘unknown status’. The qualitative trends vary from low SSB to stable dependent upon stock area. The data deficiency of this genus, which hampers quantitative assessment, is in accordance with other species exhibiting similar life histories, such as elasmobranchs. The next most vulnerable demersal teleost was cod, which ranked as the most vulnerable teleost overall in UK waters. The stock status of this species is mixed, with cod in the Celtic Seas currently viewed as in a relatively good state and harvested sustainably, while in the Irish Sea and the North Sea they are considered to be in need of reduced fishing mortality and long-term management plans are being established.

In the pelagic environment, the two most vulnerable teleosts were swordfish (ranked 6th overall) and albacore tuna (ranked 14th overall). Quantitative assessments of these species are conducted by ICCAT (**Table 7**), which found that swordfish (in 2009) had a relatively healthy status. However this is only after stock rebuilding measures and low Total Allowable Catches (TAC’s). The albacore tuna assessment (2009) indicated that the North Atlantic stock is in need of rebuilding, with suitable TAC’s being recommended by The Commission to facilitate rebuilding. ICCAT have also carried out assessments for porbeagle and shortfin mako (both ranked joint first overall) and blue shark (ranked joint 8th overall), indicating them to be in a poor, unknown and relatively healthy state respectively, albeit with concerns over data quality. Therefore, in the pelagic environment, the available assessments with which the utility of ground-truthing was evaluated against provided a somewhat ambiguous picture - similar to that seen in the demersal PSA.

Despite our attempts to include quantitatively assessed teleosts as a way to ‘ground-truth’ our results, it appears that it is not a robust method upon which firm conclusions can be drawn.

4. Discussion

We modified existing PSA’s by incorporating ‘patchiness of distribution’ as a biological sensitivity factor (not utilised in previous studies), perhaps as a result of not being a consideration in other areas focussed on (e.g. the pelagic high seas in Arrizabalaga *et al*., 2011). Similarly we added in ‘aggregating nature’ and ‘market value’ to the fisheries susceptibility parameters. The decision to include these additional parameters (compared to the MSC risk-based framework) was based upon the results of the sensitivity analyses. Within the biological components some important correlations were identified, for example between ‘reproductive strategy’ and ‘length at birth’ (0.79), and between ‘reproductive strategy’ and ‘fecundity’ (0.89). Despite these correlations, and so potential redundancy, given that ‘length at birth’ and ‘fecundity’ were themselves not correlated, all three parameters were informative and thus retained. ‘Patchiness of distribution’ showed not be correlated well to any other parameters, and was also included, and proved to be an important consideration for some of the more coastal, demersal species, like undulate ray. For the susceptibility parameters no important correlations were identified, therefore, all of these characteristics were deemed informative and were retained. By performing sensitivity analyses, redundant or non-informative parameters can be identified, and excluded where necessary. Similarly the inclusion of additional parameters specific to the environment and or species being assessed should also be considered.

This study applied a formal consideration of uncertainty (a requirement of the precautionary approach to fisheries management) to each score, using an internationally recognised confidence scoring system. By combining this approach and Monte Carlo simulations to model the variability around our scores, this method is more robust than some other semi-quantitative PSAs, in terms of ‘inaccuracies’ or variation in expert judgement.

We also included teleosts for ‘ground truthing’. The disparity documented between the relative stock status of cod in the Celtic, Irish and North Seas, illustrates the point that a *species relative vulnerability* is entirely proportional to the fishing pressure exerted upon it and the time frame that *their constituent stocks* are subjected to such pressures for. Therefore, within a PSA framework, even though a species’ overlap horizontally and vertically with the fishery in question can be estimated and scored, it does not take into account the actual pressure placed upon a stock, how much of that stock is exposed, and how long such a pressure is present for, in direct relation to the stock’s longevity and fecundity.

It must be pertinent to recognise and acknowledge that this PSA ***only*** indicates a semi-quantitative representation of risk in the particular fishery against which it was assessed. Clearly most fish species are components of mixed fisheries and caught by several different gear types, therefore, a species of low risk in these fisheries examined here could be at a very large risk of exploitation in other métiers, such as beam trawl, trammel, drift and seine nets, and pots. Therefore, an investigation into the cumulative impacts from all sub-fisheries and multi-gear, multi-species regions like the UK shelf seas should be considered (e.g. Zhou *et al.* 2011). Although not addressed in this broad scoping PSA, susceptibility can vary regionally, and more fine-scale PSAs for the shelf seas surrounding the UK, and their regional fisheries would be of benefit. Such approaches could also benefit from incorporating the views of fishers and other stakeholders.

The biology here was broadly categorised, and so may not reflect important parameters/events such as year class strengths of cohorts of teleosts for example. Reasons such as this could explain why a demersally targeted teleost (mostly in beam trawl fisheries), plaice, despite only ranking 42nd, appears to have a worse stock status than either sole or cod. It has been stated that plaice are subject to a high discarding mortality rate, and although being a component of this PSA, the level of discard mortality would be partly dependent upon TAC's and quota fulfilments - a parameter that cannot be evaluated easily. Although this attempt to ground truth data deficient species with assessed teleosts had varied success in the present study, this was often as a result of 'unknown' stock status and a limited number of assessments. It could however have useful applications for areas with more species that have been quantitatively assessed.

5. Future developments:

This preliminary study has allowed several methods associated with data deficient assessment to be applied and evaluated. However, it has also acted as a catalyst for promoting further application and ideas. In the future, we hope to develop the PSA in a number of ways, for example:

- Conduct a level 1 Scale Intensity and Consequence Analysis (SICA), to take into account the impact of a stressor (e.g. commercial fishing) to the whole ecosystem (e.g. including the benthic habitat) as part of the EAFM (e.g. Williams *et al.* 2011), thus investigating the cumulative impacts from all sub-fisheries and multi-gear, multi-species areas like the Celtic Sea (e.g. Zhou *et al.* 2011).
- Assess the observer coverage needed to estimate bycatch rates, following the approach employed by Kell *et al.* (in prep).
- Examine the associated catch when bycaught elasmobranchs are recorded in fisheries observer data, to estimate quantities of unreported bycatch. The aim being to predict, for example, that for every one tonne of target species (e.g. cod) caught using a particular gear in a designated area (e.g. ICES sub-area or rectangle), there is likely to be X kg of (e.g. dogfish and skates), of which proportion 'Y' is likely to be landed, and 'Z_1' and 'Z_2' discarded alive and dead respectively.
- Examine the consequences of changing the number of categories used to score each trait, would five categories be more appropriate and robust than three, even for highly data deficient species?

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Table 1: Biological traits used as attributes to confer biological sensitivity

	High productivity (low risk, score=1)	*Medium productivity (medium risk, score=2)*	*Low productivity (high risk, score=3)*
Age at maturity (T_{mat})	< 5 years	5-15 years	> 15 years
Maximum age (T_{max})	< 10 years	10 – 25 years	> 25 years
Fecundity (F)	> 20,000 eggs per year	100 – 20,000 eggs per year	< 100 eggs per year
Maximum length (L_{max})	< 100 cm	100-300 cm	> 300 cm
Length at maturity (L_{mat})	< 40 cm	40-200 cm	> 200 cm
Reproductive strategy (R)	Broadcast spawner	Demersal egg layer	Live bearer
Trophic Level (TL)	< 2.75	2.75 – 3.25	> 3.25
Patchiness of distribution (P_D)	Continuous	Restricted	Fragmented

Table 2: Fisheries susceptibility factors considered in PSA

	Low susceptibility (low risk = 1)	*Medium susceptibility (medium risk = 2)*	*High susceptibility (high risk = 3)*
Spatial overlap	< 10% overlap	10-30% overlap	> 30% overlap
Depth in relation to gear	< 10% of time	10-30% of time	> 30% of time
Gear catchability	Gear inappropriate to catch species	Some captures, but escapement likely	Gear appropriate for species
Aggregating nature	Do not form schools – more solitary	Loosely aggregated for most of year	Strongly aggregating most of the time
Market value (£ per kg)	< 0.8	0.8-1.25	>1.25
Post-capture mortality	Evidence of post-capture release and survival	Discarded but survivorship unknown	Retained species / majority dead if discarded

Table 3: Vulnerability ranks for UK demersal species and two demersal fisheries (bottom trawl and set net).

Scientific Name	Common Name	FAO Species Code	Bottom Trawl				Set net			
			Score	Rank	Lower 90% C.I.	Upper 90% C.I.	Score	Rank	Lower 90% C.I.	Upper 90% C.I.
Squalus acanthias	Spurdog	DGS	34	1	31	34	37	1	33	36
Galeorhinus galeus	Tope shark	GAG	32	3	29	32	35	2	30	34
Raja brachyura	Blonde ray	RJH	33	2	30	33	34	4	30	33
Raja clavata	Thornback ray	RJC	32	3	29	32	33	6	29	33
Leucoraja circularis	Sandy ray	RJI	31	6	28	33	33	6	29	34
Leucoraja fullonica	Shagreen ray	RJF	31	6	28	33	33	6	29	34
Raja undulata	Undulate ray	RJU	29	13	30	33	35	2	31	34
Sebastes viviparus	Norway redfish/haddock	SFV	32	3	30	34	30	13	28	31
Mustelus asterias	Starry smooth hound	SDS	31	6	28	31	31	10	27	31
Gadus morhua	Cod	COD	31	6	28	31	30	13	27	30
Dipturus batis	Common skate	RJB	30	11	28	32	32	9	30	34
Raja microocellata	Small-eyed ray	RJE	28	17	28	33	34	4	30	34
Raja montagui	Spotted ray	RJM	29	13	26	30	31	10	28	31
Squatina squatina	Angel shark	AGN	28	17	28	32	31	10	28	32
Anarhichas lupus	Wolfish	CAA	31	6	29	33	28	21	27	30
Dipturus oxyrinchus	Long-nosed skate	RJO	29	13	25	28	29	17	24	27
Pollachius virens	Saithe	POK	30	11	27	31	28	21	25	29
Leucoraja naevus	Cuckoo ray	RJN	28	17	26	30	29	17	27	31
Scyliorhinus canicula	Lesser-spotted dogfish	SYC	29	13	19	23	28	21	18	21
Rostroraja alba	White (Bottlenosed) skate	RJA	27	23	26	31	30	13	26	31
Dasyatis pastinaca	Sting ray	JDP	28	17	26	29	27	24	24	28
Dicentrarchus labrax	Bass	BSS	26	28	24	28	29	17	26	29
Torpedo nobiliana	Common electric ray	TTO	26	28	27	31	29	17	26	30
Lophius piscatorius	Anglerfish	MON	27	23	25	29	27	24	25	28
Merluccius merluccius	Hake	HKE	27	23	25	28	27	24	25	28
Molva molva	Ling	LIN	27	23	25	29	27	24	25	28
Psetta maxima	Turbot	TUR	27	23	25	29	27	24	25	28
Melanogrammus aeglefinus	Haddock	HAD	28	17	26	29	26	31	24	27
Merlangius merlangus	Whiting	WHG	28	17	26	29	26	31	24	27
Scyliorhinus stellaris	Nurse hound	SYT	24	40	27	31	30	13	27	31
Solea solea	Sole	SOL	25	33	24	27	27	24	24	28
Amblyraja radiata	Starry ray	RJR	26	28	25	29	26	31	25	29
Zeus faber	John dory	JOD	26	28	24	28	25	35	23	27
Lepidorhombus whiffiagonis	Megrim	MEG	26	28	24	27	25	35	23	27
Torpedo marmorata	Marbled electric ray	TTR	24	40	25	30	27	24	24	29
Microstomus kitt	Lemon sole	LEM	25	33	23	27	25	35	24	27
Pleuronectes platessa	Plaice	PLE	25	33	23	26	25	35	23	26
Mullus surmuletus	Red mullet	MUR	24	40	23	26	26	31	24	27
Conger conger	Conger eel	COE	25	33	22	26	24	40	21	26
Labrus bergylta	Ballan wrasse	USB	24	40	23	28	25	35	24	28
Glyptocephalus cynoglossus	Witch	WIT	25	33	23	27	23	42	22	26
Trisopterus luscus	Bib	BIB	25	33	23	26	22	45	20	23
Trisopterus minutus	Poor cod	POD	25	33	23	26	22	45	20	23
Spondyliosoma cantharus	Black sea bream	BRB	24	40	22	26	24	40	23	26
Myxine glutinosa	Hagfish	MYG	24	40	24	29	23	42	23	28
Ammodytidae spp.	Sand eel	SAN	24	40	21	25	22	45	21	24
Trigla lucerna	Tub gurnard	GUU	24	40	23	26	22	45	21	25
Capros aper	Boarfish	BOC	24	40	23	27	20	52	20	24
Syngnathus acus	Greater pipefish	SGQ	23	50	23	28	23	42	23	27
Limanda limanda	Dab	DAB	22	53	21	25	22	45	21	24
Eutrigla gurnardus	Grey gurnard	GUG	23	50	22	25	21	51	20	24
Trisopterus esmarkii	Norway Pout	NOP	23	50	22	25	20	52	19	23
Arnoglossus laterna	Scaldfish	RGX	22	53	20	24	20	52	19	22
Agonus cataphractus	Pogge	AFT	21	55	20	24	20	52	20	23
Enchelyopus cimbrius	Four-bearded rockling	ENC	21	55	19	23	19	58	18	21
Ciliata mustela	Five-bearded ockling	LCM	21	55	19	23	19	58	18	21
Callionymus lyra	Common dragonet	LYY	21	55	18	22	19	58	18	21
Liparis liparis	Sea snail	LIL	20	61	20	24	20	52	20	24
Buglossidium luteum	Solenette	GSM	21	55	19	24	19	58	18	22
Raniceps raninus	Tadpole fish	RCR	20	61	20	25	20	52	20	24
Pomatoschistus minutus	Sand goby	OBZ	20	61	20	23	19	58	19	22
Microchirus variegatus	Thickback sole	MKG	20	61	19	23	19	58	18	22
Echiichthys vipera	Lesser weever	TOZ	21	55	26	29	18	66	24	29
Taurulus bubalis	Sea scorpion	SCO	19	66	20	23	19	58	20	23
Zeugopterus punctatus	Topknot	ZGP	19	66	20	23	19	58	19	23
Gaidropsarus vulgaris	Three-bearded rockling	GGU	20	61	19	23	18	66	17	21
Cepola macrophthalma	Red band fish	CBC	19	66	19	23	18	66	18	22

Table 4: Vulnerability ranks for pelagic species in two fisheries (longline and pelagic trawl)

Scientific Name	Common Name	FAO Species Code	Longline				Pelagic Trawl			
			Score	Rank	Lower 90% C.I.	Upper 90% C.I.	Score	Rank	Lower 90% C.I.	Upper 90% C.I.
Lamna nasus	Porbeagle shark	POR	37	1	34	38	35	1	34	38
Isurus oxyrinchus	Shortfin mako	SMA	37	1	34	37	35	1	34	37
Alopias vulpinus	Thresher shark	ALV	36	3	33	37	34	3	33	37
Prionace glauca	Blue shark	BSH	35	4	32	36	32	4	32	36
Xiphias gladius	Swordfish	SWO	33	5	30	33	30	6	27	31
Myliobatis aquila	Eagle ray	MYL	30	6	27	31	30	6	27	31
Somniosus microcephalus	Greenland shark	GSK	29	8	27	30	31	5	27	30
Thunnus alalunga	Albacore tuna	ALB	30	6	28	31	27	10	25	29
Cetorhinus maximus	Basking shark	BSK	29	8	27	30	30	6	27	30
Pteroplatytrygon violacea	Pelagic stingray	PLS	29	8	25	31	28	9	25	31
Scomber scombrus	Mackerel	MAC	24	11	23	25	27	10	26	29
Mola mola	Ocean sunfish	MOX	24	11	22	27	26	12	22	27
Engraulis encrasicolus	Anchovy	ANE	23	13	22	24	26	12	22	24
Sardina pilchardus	European Pilchard (Sardine)	PIL	23	13	22	24	26	12	22	24
Clupea harengus	Herring	HER	23	13	22	24	26	12	22	24
Lampris guttatus	Opah (Moon-fish)	LAG	22	16	21	25	24	16	21	25
Lepidocybium flavobrunneum	Escolar	LEC	22	16	21	25	23	18	21	25
Ruvettus pretiosus	Oilfish	OIL	22	16	21	25	23	18	21	25
Luvar imperialis	Luvar	LVM	21	19	21	25	24	16	21	25

Table 5: Overall vulnerability ranks for all UK species considered in PSA. IUCN Status (IUCN, 2011): DD: Data Deficient; LC: Least concern; NT: Near threatened; VU: Vulnerable; EN: Endangered; CR: Critically Endangered.* indicates the Northeast Atlantic stock status.

Scientific Name	**Common Name**	**FAO Species Code**	**Status**	**Biological Sensitivity Score**	**Fishery Susceptibility (Metier 1)**	**Fishery Susceptibility (Metier 2)**	**Overall Score (both metiers)**	**Overall Rank UK**
Lamna nasus	Porbeagle shark	POR	**CR**	21	16	14	51	1
Isurus oxyrinchus	Shortfin mako	SMA	**VU**	21	16	14	51	1
Squalus acanthias	Spurdog	DGS	**CR**	20	14	17	51	1
Raja brachyura	Blonde ray	RJH	**NT**	17	16	17	50	4
Alopias vulpinus	Thresher shark	ALV	**VU**	21	15	13	49	5
Gadus morhua	Cod	COD	**VU**	13	18	17	48	6
Raja clavata	Thornback ray	RJC	**NT**	17	15	16	48	6
Xiphias gladius	Swordfish	SWO	**LC**	15	18	15	48	6
Prionace glauca	Blue shark	BSH	**NT**	20	15	12	47	9
Galeorhinus galeus	Tope shark	GAG	**VU**	20	12	15	47	9
Leucoraja circularis	Sandy ray	RJI	**VU**	18	13	15	46	11
Leucoraja fullonica	Shagreen ray	RJF	**NT**	18	13	15	46	11
Raja undulata	Undulate ray	RJU	**EN**	18	11	17	46	11
Thunnus alalunga	Albacore tuna	ALB	**NT**	12	18	15	45	14
Raja microocellata	Small-eyed ray	RJE	**NT**	17	11	17	45	14
Dicentrarchus labrax	Bass	BSS	**LC**	11	15	18	44	16
Sebastes viviparus	Norway redfish/haddock	SFV	**na**	18	14	12	44	16
Pollachius virens	Saithe	POK	**na**	14	16	14	44	16
Raja montagui	Spotted ray	RJM	**LC**	16	13	15	44	16
Mustelus asterias	Starry smooth hound	SDS	**LC**	18	13	13	44	16
Dipturus batis	Common skate	RJB	**CR**	19	11	13	43	21
Melanogrammus aeglefinus	Haddock	HAD	**VU**	11	17	15	43	21
Merlangius merlangus	Whiting	WHG	**na**	11	17	15	43	21
Anarhichas lupus	Wolfish	CAA	**na**	16	15	12	43	21
Leucoraja naevus	Cuckoo ray	RJN	**LC**	15	13	14	42	25
Merluccius merluccius	Hake	HKE	**na**	12	15	15	42	25
Scyliorhinus canicula	Lesser-spotted dogfish	SYC	**LC**	15	14	13	42	25
Solea solea	Sole	SOL	**na**	10	15	17	42	25
Psetta maxima	Turbot	TUR	**na**	12	15	15	42	25
Scomber scombrus	Mackerel	MAC	**LC**	10	14	17	41	30
Lophius piscatorius	Anglerfish	MON	**na**	13	14	14	41	30
Myliobatis aquila	Eagle ray	MYL	**DD**	19	11	11	41	30
Engraulis encrasicolus	Anchovy	ANE	**na**	9	14	17	40	33
Sardina pilchardus	European Pilchard (Sardine)	PIL	**na**	9	14	17	40	33
Clupea harengus	Herring	HER	**LC**	9	14	17	40	33
Zeus faber	John dory	JOD	**na**	11	15	14	40	33
Microstomus kitt	Lemon sole	LEM	**na**	10	15	15	40	33
Molva molva	Ling	LIN	**na**	14	13	13	40	33
Dipturus oxyrinchus	Long-nosed skate	RJO	**NT**	18	11	11	40	33
Lepidorhombus whiffiagonis	Megrim	MEG	**na**	11	15	14	40	33
Mullus surmuletus	Red mullet	MUR	**na**	10	14	16	40	33
Cetorhinus maximus	Basking shark	BSK	**EN**	20	9	10	39	42
Pteroplatytrygon violacea	Pelagic stingray	PLS	**LC**	18	11	10	39	42
Pleuronectes platessa	Plaice	PLE	**LC**	11	14	14	39	42
Squatina squatina	Angel shark	AGN	**CR**	21	7	10	38	45
Spondyliosoma cantharus	Black sea bream	BRB	**na**	10	14	14	38	45
Amblyraja radiata	Starry ray	RJR	**LC**	14	12	12	38	45
Dasyatis pastinaca	Sting ray	JDP	**DD**	17	11	10	38	45
Glyptocephalus cynoglossus	Witch	WIT	**na**	10	15	13	38	45
Labrus bergylta	Ballan wrasse	USB	**LC**	12	12	13	37	50
Trisopterus luscus	Bib	BIB	**na**	10	15	12	37	50
Somniosus microcephalus	Greenland shark	GSK	**NT**	23	6	8	37	50
Scyliorhinus stellaris	Nurse hound	SYT	**NT**	17	7	13	37	50
Trisopterus minutus	Poor cod	POD	**LC**	10	15	12	37	50
Rostroraja alba	White (Bottlenosed) skate	RJA	**EN**	20	7	10	37	50
Torpedo nobiliana	Common electric ray	TTO	**DD**	19	7	10	36	56
Conger conger	Conger eel	COE	**na**	13	12	11	36	56
Mola mola	Ocean sunfish	MOX	**na**	15	9	11	35	58
Ammodytidae spp.	Sand eel	SAN	**na**	11	13	11	35	58
Trigla lucerna	Tub gurnard	GUU	**na**	11	13	11	35	58
Capros aper	Boarfish	BOC	**na**	10	14	10	34	61
Limanda limanda	Dab	DAB	**na**	10	12	12	34	61
Torpedo marmorata	Marbled electric ray	TTR	**DD**	17	7	10	34	61
Trisopterus esmarkii	Norway Pout	NOP	**na**	9	14	11	34	61
Lampris guttatus	Opah (Moon-fish)	LAG	**na**	12	10	12	34	61
Lepidocybium flavobrunneum	Escolar	LEC	**na**	12	10	11	33	66
Eutrigla gurnardus	Grey gurnard	GUG	**na**	11	12	10	33	66
Myxine glutinosa	Hagfish	MYG	**LC**	14	10	9	33	66
Luvar imperialis	Luvar	LVM	**na**	12	9	12	33	66
Ruvettus pretiosus	Oilfish	OIL	**na**	12	10	11	33	66
Syngnathus acus	Greater pipefish	SGQ	**na**	14	9	9	32	71
Arnoglossus laterna	Scaldfish	RGX	**na**	10	12	10	32	71
Enchelyopus cimbrius	Four-bearded rockling	ENC	**na**	10	11	9	30	73
Ciliata mustela	Five-bearded ockling	LCM	**na**	10	11	9	30	73
Callionymus lyra	Common dragonet	LYY	**na**	10	11	9	30	73
Agonus cataphractus	Pogge	AFT	**na**	11	10	9	30	73
Buglossidium luteum	Solenette	GSM	**LC**	10	11	9	30	73
Raniceps raninus	Tadpole fish	RCR	**na**	10	10	10	30	73
Gaidropsarus vulgaris	Three-bearded rockling	GGU	**na**	9	11	9	29	79
Echiichthys vipera	Lesser weever	TOZ	**na**	10	11	8	29	79
Pomatoschistus minutus	Sand goby	OBZ	**na**	10	10	9	29	79
Liparis liparis	Sea snail	LIL	**LC**	11	9	9	29	79
Microchirus variegatus	Thickback sole	MKG	**na**	10	10	9	29	79
Cepola macrophthalma	Red band fish	CBC	**na**	9	10	9	28	84
Zeugopterus punctatus	Topknot	ZGP	**na**	10	9	9	28	84
Taurulus bubalis	Sea scorpion	SCO	**na**	11	8	8	27	86

Table 6: ICES Fish stock advice (for 2012, following 2011 assessments) for species considered in this study

Species	*Stock*	*Stock Status*		*ICES Advice (For 2012)*	*PSA Rank*
		F	*SSB*		
Anglerfish	Celtic Sea, West Scotland and North Sea	**Unknown**	**Stable**	Reduce catch	31
Boarfish	NE Atlantic	**No overfishing**	**Insufficient info**	No increase in catch	61
Cod	Celtic Sea	**Harvested sustainably**	**Above MSY $B_{trigger}$** **Full reproductive capacity**	$F_{MSY} = 0.4$ Landings set at 10,000 t	6
	North Sea	**Above MSY target**	**Below trigger**	Landings should be no more than 31,800 t EU long-term management plan adopted	
European seabass	NE Atlantic	**Insufficient information**	**Insufficient information**	No increase in catch	17
Grey Gurnard	NE Atlantic	**Insufficient information**	**Insufficient information**	No increase in catch	66
Haddock	Celtic Sea	**Stable**	**Strong increase**	No increase in catch	22
	North Sea	**Harvested sustainably**	**Full reproductive capacity**	Landings should be 41,575 t	
Hake	Northern	**Above MSY target**	**Undefined** **Above poss ref. points**	Landings no more than 51,900 t	26
Herring	NE Atlantic	**Harvested sustainably**	**Full reproductive capacity**	Catches no more than 833,000 t	33
Ling	NE Atlantic	**Unknown**	**Unknown**	Constrain catches to 2003-2008 average, and a reduction in catches should be considered	33
Mackerel	NE Atlantic	**Above target** **Increased risk**	**Above trigger** **Full reproductive capacity**	Landings should be between 586, 000 tonnes and 639, 000 t	15
Megrim	Celtic Sea	**N/A**	**N/A**	Catch and effort reduction	33
Plaice	Celtic Sea	**Unknown** **Above poss ref. points**	**Unknown** **Below poss ref. points**	Catches should be reduced. Discards exceed landing and technical measures should be introduced to reduce discard rates	42
	North Sea	**Harvested sustainably**	**Full reproductive capacity**	Catches should be no more than 84,410 t	
Red Mullett	NE Atlantic	**Insufficient information**	**Insufficient information**	No increase in catch	33
Sole	Celtic Sea	**Appropriate** **Harvested sustainably**	**Above trigger** **Full reproductive capacity**	Landings no more than 1,060 t	26
	North Sea	**Harvested sustainably**	**Full reproductive capacity**	Landings no more than 15,700 t	
Spurdog	NE Atlantic	**Below target**	**Undefined** **Below poss ref.**	No targeted fishery, catches in mixed fisheries should be reduced	1

		🟩	**points**	to the lowest possible level. A rebuilding plan should be developed for this stock	
Whiting	Celtic Sea	**Unknown**	**Unknown Increasing trend**	Catches should not be allowed to increase. Technical measures should be introduced to reduce discard rates	22
	North Sea	**Undefined Stable**	**Undefined At recent average**	TAC of 21,300 t	

Table 7: ICCAT Advice for pelagic species covered in this study.

Species	*Stock Status*		*Management recommendations*	*PSA Rank*
	F	*B / SSB*		
Albacore tuna (2009 assessment)	**F above F_{MSY} (current F_{2007}/F_{MSY} ratio is 1.05)**	**Overfished (SSB/SSB_{MSY} <1) SSB_{2007}/SSB_{MSY} = 0.62**	The Commission recommended the establishment of a TAC of 28,000 t for 2010 and 2011 [Rec. 09-05] (to allow rebuilding)	8
Blue Shark (2008 assessment)	**F_{2007}/F_{MSY} = 0.13-0.17**	**B_{2007}/B_{MSY} = 1.87-2.74**		8
Porbeagle shark (2009 assessment)	**F_{2008}/F_{MSY} = 0.04-3.45**	**B_{2008}/B_{MSY} = 0.09-1.93**	Overfished	1
Shortfin mako shark (2008 assessment)	**F_{2007}/F_{MSY} = 0.48-3.77**	**B_{2007}/B_{MSY} = 0.95-1.65**		1
Swordfish (2009 assessment)	**Below F_{MSY} since 2005 F_{2008}/F_{MSY} = 0.76**	**Not overfished At or above B_{MSY} B_{2009}/B_{MSY} = 1.05**	The Committee continues to note that the allowable country-specific catch levels agreed in [Recs. 06-02, 08-02, and 10-02] continue to exceed the TAC adopted by the Commission and the scientific recommendations. Such potential catches could compromise the rebuilt state of this stock.	11

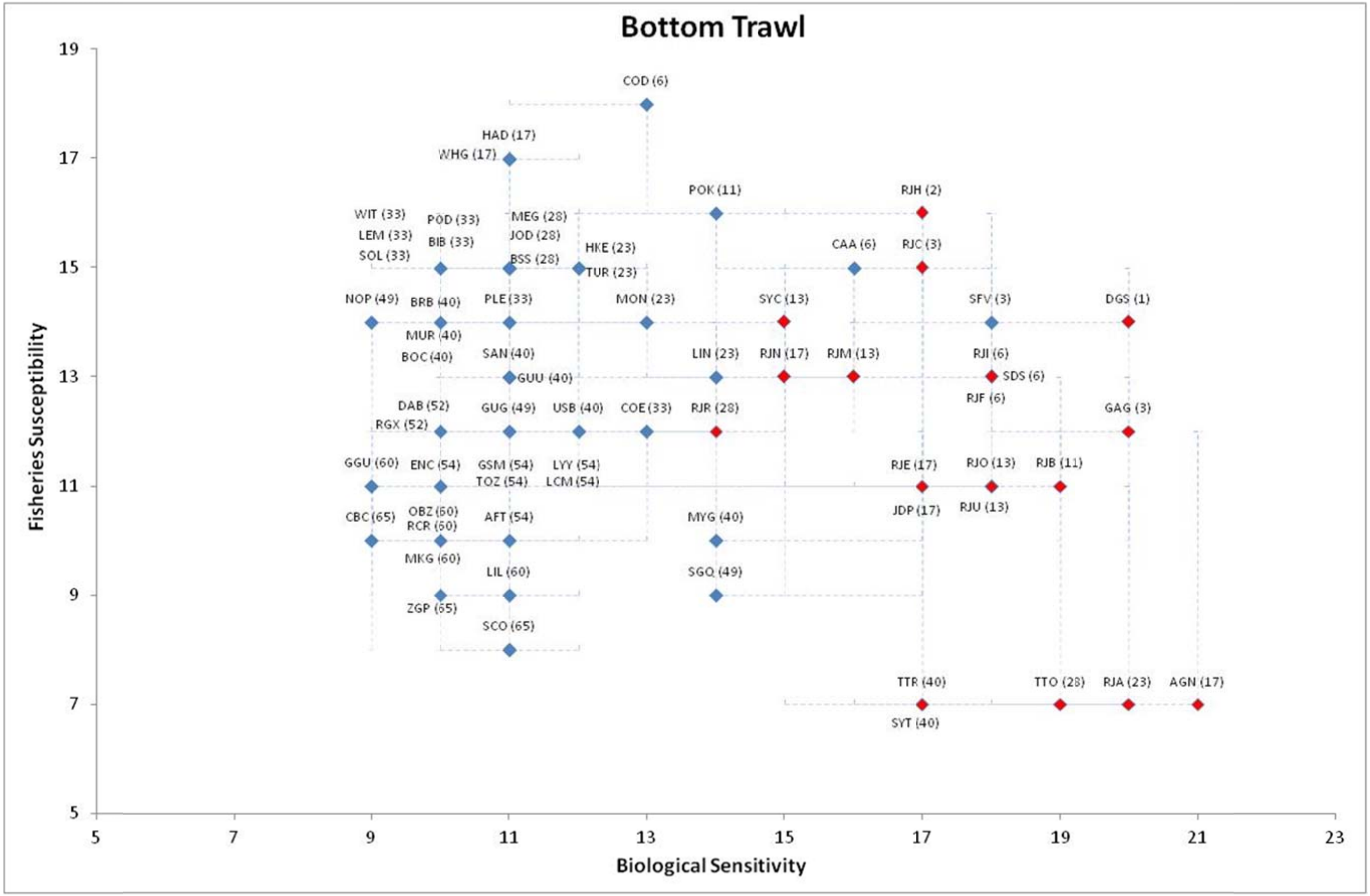

Figure 1: Plot of the overall vulnerability (in brackets) of species (3-letter codes in **Tables 3** and **5**) considered in the demersal bottom trawl fishery.

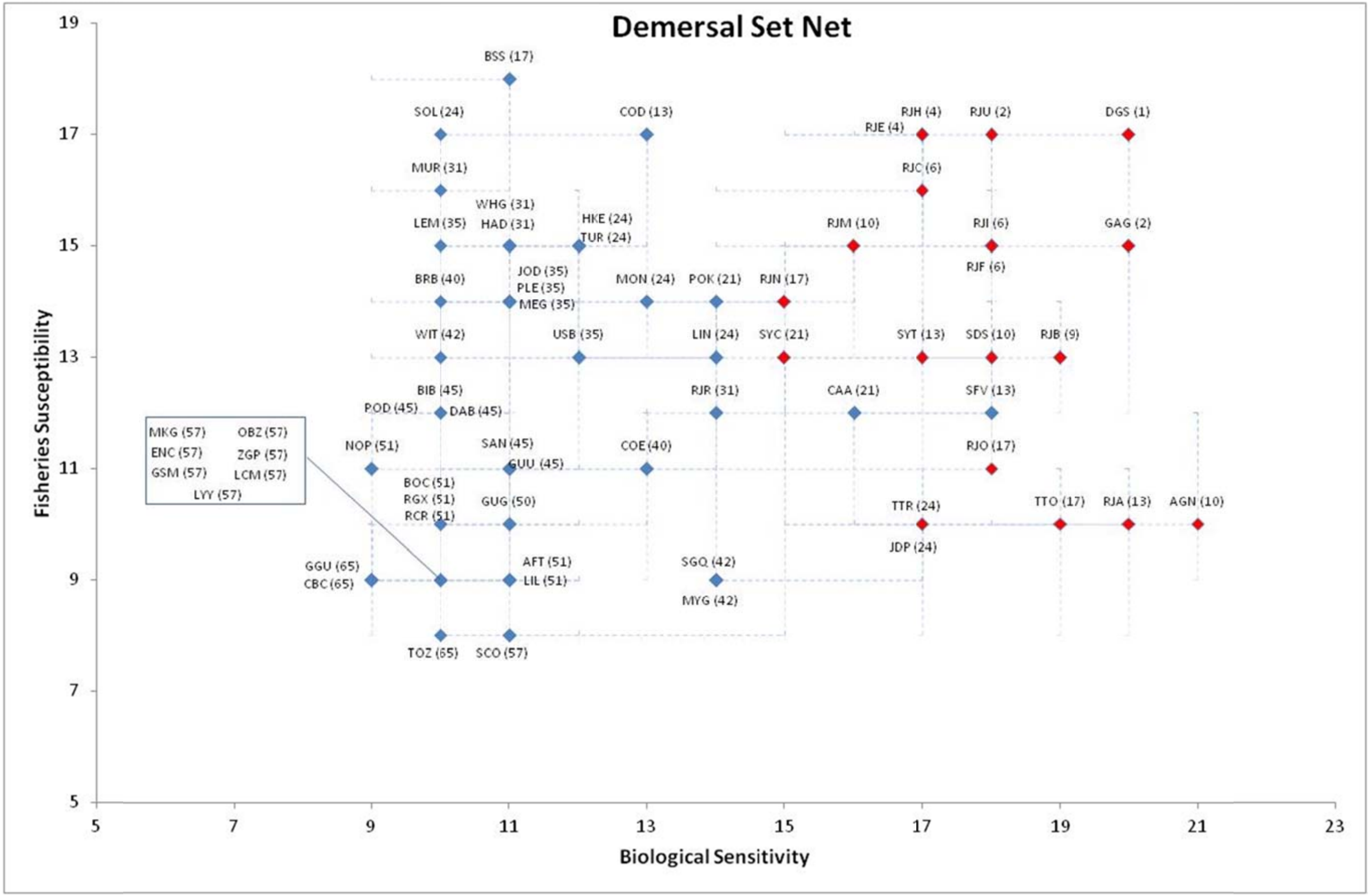

Figure 2: Plot of the overall vulnerability (in brackets) of species (3-letter codes in **Tables 3** and **5**) considered in the demersal set net fishery.

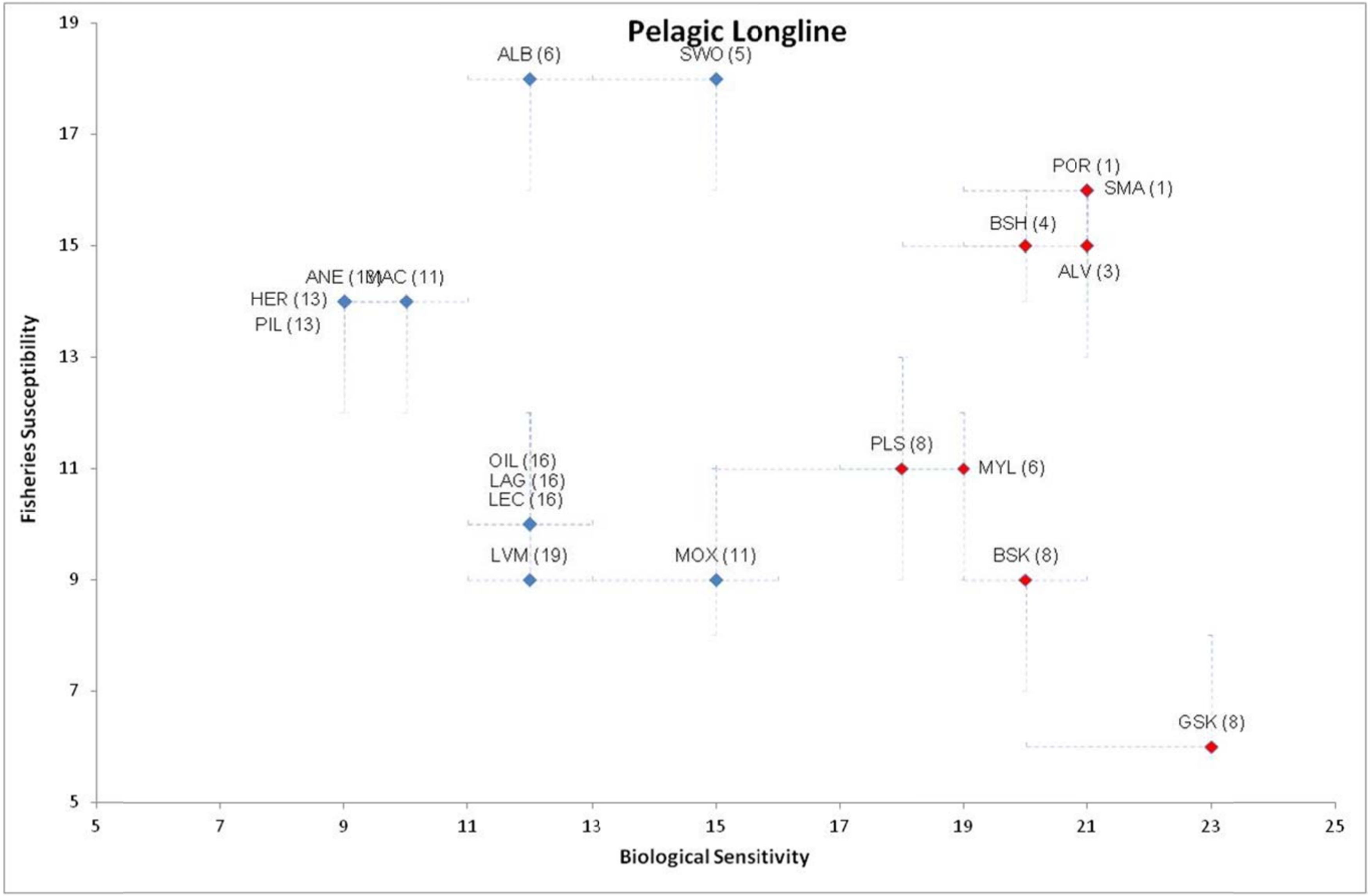

Figure 3: Plot of the overall vulnerability (in brackets) of species (3-letter codes can be found in **Tables 4-5**) considered in the pelagic longline fishery.

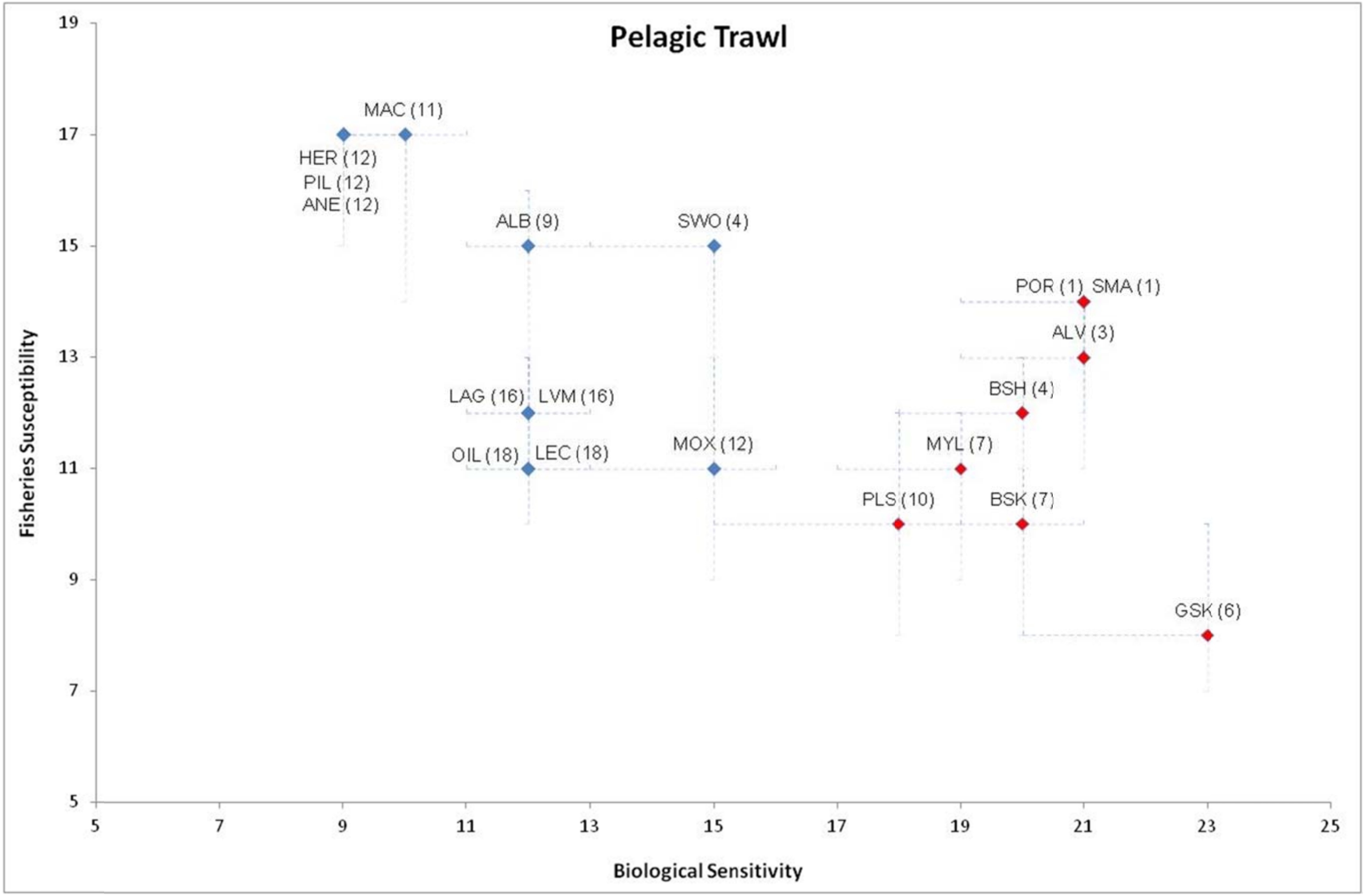

Figure 4: Plot of the overall vulnerability (in brackets) of species (3-letter codes in **Tables 4-5**) considered in the pelagic trawl fishery.