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Esturgeons et polyodons

METHODOLOGIES UTILISEES POUR L'EVALUATION ET LE SUIVI DES STOCKS PARTAGES D'ESPECES D'ACIPENSERIFORMES

Le rapport joint en annexe a été soumis par L'Organisation des Nations Unies pour l'alimentation et l'agriculture * (FAO). Les conclusions et les recommandations de ce rapport sont incluses ci-dessous dans les trois langues de travail de la Convention.

Conclusions et recommandations de l'atelier

L'atelier réaffirme que pour être en mesure de faire une évaluation des stocks entiers, il faudrait que les informations, à savoir les estimations de l'abondance des stocks résultant des études des chaluts, soient réunies pour toute l'aire de répartition des stocks en appliquant une seule méthodologie, faute de quoi les estimations pourraient être entachées de biais inconnus.

La méthodologie iranienne décrite dans l'étude de 2004 de la FAO est inappropriée pour estimer les TAC. L'atelier recommande que tous les pays exploitant le stock suivent la même procédure unifiée.

La méthodologie approuvée par les cinq pays de la mer Caspienne et actuellement appliquée par l'Azerbaïdjan, la Fédération de Russie, le Kazakhstan et le Turkménistan est meilleure que celle décrite dans l'étude de 2004 de la FAO. De réels progrès ont été faits depuis le rapport de 2004. Le premier progrès a été l'accord inter-Etats de 2006, qui définissait les normes de l'étude et donnait une mise à jour de l'estimation des TAC. Le second a été le document présenté par la délégation russe, qui proposait une méthodologie améliorée correspondant pleinement à la pratique internationale. Certaines parties de cette procédure ont déjà été intégrées dans la méthodologie actuelle.

Les participants à l'atelier recommandent que la Commission sur les bioressources aquatiques poursuive ces améliorations en envisageant une méthodologie qui inclut toutes les données pertinentes et qui calcule l'état des stocks et les points de référence biologiques.

L'atelier recommande de préparer, si possible, une description technique complète des méthodes.

L'atelier recommande d'organiser, avec l'appui de la FAO, deux ateliers techniques à l'intention des spécialistes:

* *Les appellations géographiques employées dans ce document n'impliquent de la part du Secrétariat CITES ou du Programme des Nations Unies pour l'environnement aucune prise de position quant au statut juridique des pays, territoires ou zones, ni quant à leurs frontières ou limites. La responsabilité du contenu du document incombe exclusivement à son auteur.*

1) Un atelier sur les méthodes d'estimation des esturgeons de la mer Caspienne. Cet atelier portera sur la conception des études et l'analyse des données qui en résultent.

2) Un atelier sur l'application de méthodes modernes pour évaluer les stocks et les TAC pour les espèces d'esturgeons de la mer Caspienne.

TCP/INT/3101 **MEETING REPORT No. 2**

Stock Assessment and TAC Methodologies

REPORT OF THE

FAO and CITES Technical Workshop

Rome, Italy
11-13 November 2008

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2008

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Stock assessment terms glossary
Словарь терминов используемых в методах оценки запасов

Biological reference points – биологические ориентиры
Bycatch - прилов
Bootstrapping – метод бутстреп
Carrying capacity – максимально возможный размер популяции

Catch per unit of effort – улов на единицу усилия
Catchability coefficient - Коэффициент улавливаемости
Cohort – когорта, поколение
Confidence bound - доверительная граница
Confidence interval – доверительный интервал
Control rule – правило регулирования
Density dependent growth and mortality – зависящие от плотности рост и смертность
Discards - невостребованный улов
Exploitation rate коэффициент эксплуатации
Fecundity - Плодовитость
Fishery dependent data - промысловые данные
Fishing effort - промысловое усилие
Fishery independent data- непромысловые данные
Fishing mortality – промысловая смертность
Fishing mortality threshold граница промысловой смертности
Gear selelctivity Gear efficiency – коеффициент уловистости
Growth overfishing - перелов по росту
index of abundance – индекс численности
Instantaneous mortality rate – мгновенный коэффициент промыслово смертности
Intrinsic growth rate скорость роста популяции
Maturity ogive - кривая зрелости
Maximum spawning potential – максимальный репродуктивный потенциал
Maximum sustainable yield MSY максимальный устойчивый улов
Minimum stock size threshold – граница минимального размера запаса
Natural mortality - естественая смертность
Optimum yield – оптимальный улов
Overcompensation сверхкомпенсация
Overfished - переловленный запас
Overfishing перелов
Partial recruitment частичное пополнение
Recruitment попоплнение
Reproduction - воспроизводство
Retrospective analysis ретроспективный анализ
Risk assessment оценка риска
Sensitivity analysis анализ чувствительности
Spawning stock- нерестовое стадо
Spawning stock biomass - биомасса нерестового стада
Stock - запас
Stock assessment оценка запаса
Stock assessment model - модель оценки запаса
Stock – Recruitment Model – модель запаса - пополнение
stock size threshold - граница величины запаса
Total mortality – общая смертность
Обший допустимый улов (ОДУ)
Virtual population analysis – виртуальный популяционный анализ, ВПА
Yield per recruit – улов на единицу пополнения

Introduction

At the FAO and the World Bank workshop in April 2008 where all the five Caspian countries participated it was agreed: "*that a workshop should be held under the TCP Project with the following objectives: (i) identify, develop and test changes to the current stock assessment methodologies; and (ii) identify any support needed from development partners*". Such a workshop would further allow the countries to comply with a request from the CITES[1] Animals Committee.

In response to the above recommendation, FAO and CITES organized *the Technical Workshop on Stock Assessment and TAC[2] Methodologies* in Rome on 11-13 November, 2008 and invited all the five Caspian countries: Azerbaijan, Islamic Republic of Iran, Kazakhstan, Russian Federation and Turkmenistan to attend. Although all the five countries responded positively to the invitation with the nomination of their workshop participants, I. R. Iran and Turkmenistan were regrettably unable to send their delegations to the workshop due to problems getting visas for the delegates to enter Italy within the timeframe available. Postponing the workshop would have created a number of problems including the risk of not being able to comply with the request of the CITES Animals Committee. It was therefore decided to go ahead with the workshop in the understanding that the countries absent from the workshop would be fully communicated with the outcomes. All participants to the workshop and their contact details are listed in Appendix A.

Objectives of the workshop

1: To review the methodology used by the Caspian countries to assess stock status and set TACs for sturgeons in the Caspian Sea.
2: If necessary suggest improvements to the methodologies used, in order to ensure that they comply with contemporary international practices.
3: Identify any follow up action needed to implement proposed changes.

Opening of the meeting

The meeting was opened by Mr. Kevern Cochrane, Chief of the Fishery Management and Conservation Service, FAO, by welcoming all the delegates. He then outlined the objectives of the workshop. Mr. John Jorgensen provided a brief overview of the status of the Technical Cooperation Programme and what FAO plans to complete before it ends in April, 2009.

Mr. Radu Suciu, representative of the CITES Animals Committee explained that he saw this as a golden opportunity for the countries to discuss their fisheries management in a neutral forum.

The participants then introduced themselves, and offered some remarks on their expectations.

Presentations

FAO had contracted Dr. Robert Mohn and Dr. Alexei Sharov as independent experts for the technical discussions that took place during the workshop (for brief descriptions of their backgrounds please refer to Appendix B).

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[1] Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES.
[2] Total Allowable Catches.

Dr. Mohn gave a presentation on general aspects of stock assessment using the Canadian cod fishery as an example. He began by saying that there were three main questions to be addressed: 1) what is the stock status? 2) where is it going? and 3) how sure are you? His emphasis, however, was on the third question. Measurement, process and model errors were defined and examples of each were presented. The problems of resource productivity and the determination of biological reference points were then discussed.

He concluded with recommendations that processes which would assure the flow of data, biology and models be set up. The establishment of a Caspian working group on stock assessment with the participation of experts from all the countries would provide a vehicle for these exchanges and provide for review, research planning and training. Further recommendations included the use of more than one model for a single fishery as contrast between models would reveal more about the stock and uncertainty in model parameters and errors.

Dr. Sharov presented the stock assessment of striped bass fishery on the Atlantic coast of the United States as an example how different data sources can be used to enhance stock assessment and which procedures should be followed for setting TACs in a multi-state shared fishery.
Atlantic striped bass is an anadromous species distributed along the Atlantic coast of North America from Canada in the north to Florida in the south. Striped bass undergoes extensive seasonal migration along the coast. The stock was severely overfished in mid 1980s and a moratorium was established for five years to enhance stock restoration. The stock is currently managed by the Atlantic States Marine Fisheries Commission. Each fishing jurisdiction (state) is under mandatory obligation to submit to the Commission an annual report on the fishery results. Such a report includes information on total landings in number of fish and weight, landings separated into commercial and recreational, estimates of commercial and recreational discard mortality, size and age structure of the catch and age specific indices of abundance derived from fishery dependent and fishery independent surveys. The data are reviewed by the Striped Bass Stock Assessment Committee comprised of the member states' representatives. An age structured model (ADAPT earlier and Statistical Catch at Age Model more recently) is used to estimate population abundance at age, fishing mortality at age and spawning stock biomass. Uncertainty in estimates of fishing mortality and population size is characterized through the probability distribution of these variables derived from bootstrapping procedure. Estimates of fishing mortality and spawning stock biomass are compared to biological reference points (targets and thresholds for fishing mortality and biomass) to make a conclusion regarding the status of the stock. The assessment results are reported to management board alongside with the management advice. The assessment is also subjected to periodical peer review by a panel of independent experts to ensure quality of the results.
The major purpose of the presentation was to demonstrate the steps involved in stock assessment and management process, data collection, data review, model selection, review of model results and final adoption of management advice. Important elements of the process are technical collaboration and decisional transparency.

Dr. Babayan from the Russian delegation gave a brief presentation entitled *TAC assessment methodologies for Caspian sturgeons*. Instead of providing technical details of the methodologies used in Russia, he focused on the peculiarities of the Caspian sturgeon fisheries that need to be taken into consideration when developing methods for stock assessment and the setting of TACs:

i) hatcheries play a key role of in the reproduction of sturgeon stocks, providing 45-97% of the catch.
ii) there is a large-scale illegal, unreported and unregulated (IUU) fishery;
iii) irregularity in spawning of adult sturgeon individuals;
iv) the sturgeons perform extensive seasonal migrations throughout the Caspian Sea basin;
v) legal fishing occurs only on spawning stocks in rivers.

Dr. Babayan then presented a flowchart showing the TAC setting procedure based on survey-data. The steps involved in the TAC estimation include the estimation of stock biomass and spawning stock, determination of fishing mortality and TAC calculation.

Dr. Babayan continued with an interesting Harvest Control Rule and a model-based method of setting TACs for the Caspian sturgeon fisheries, but the status of the method and whether it is currently being applied in the Caspian Sea was not clear. However, the use of a harvest control rule would be an important step towards the international standard practice, and the age-structured population dynamic model in VPA style a substantial improvement in assessment methodologies.

The take-home message from Dr Babayan's presentation was that the Caspian Sea sturgeon fisheries present unique features and great complexity and therefore, innovative techniques and close cooperation between countries are needed to maintain the long-sustainability of the fishery.

After the presentations, past and current sturgeon management practices applied in the Caspian Sea were discussed at length. However, because all of the necessary documentation and the relevant data were not available, the original objective of the workshop could not be fully met.

Regarding the methodology, the countries present underlined that a number of things have changed since the FAO review of the methodology in 2004 and referred to the "Interstate agreement" that had been endorsed by the five Caspian countries and submitted to CITES in 2008. That agreement describes the methodology used but only in general terms and does not provide the scientific detail necessary to provide a proper assessment. In addition there was uncertainty as to the progress made in incorporating the method described by Dr. Babayan into the methodology currently in use. The consultants therefore were unable to undertake a thorough review of the methods of assessment and TAC setting currently in use. They emphasised that openness and transparency of the process is the most critical element of the stock assessment. During such a process data and methods are described in such details that they could be examined, discussed and verified by all parties involved. The Russian delegation explained that some of the data were classified and could not be disclosed, but at the same time indicated that it would be possible to produce a report providing detailed technical description of the methodology used.

Conclusions and Recommendations of the Workshop[3]

The workshop reaffirms that in order to be able to produce an assessment of the entire stocks, it is necessary that the collection of information, and namely the stock abundance estimates from trawl surveys, should cover the whole area of the stock distribution with a single methodology. Failure to comply with this requirement may bias the estimates in unknown ways.

The Iranian methodology as described in the 2004 FAO review is inappropriate for estimating TACs. The workshop recommends that all countries exploiting the stock should follow the same unified procedures.

The methodology endorsed by the five Caspian states and currently applied by Azerbaijan, Kazakhstan, the Russian Federation and Turkmenistan is an improvement compared to the method described in the 2004 FAO review. Since the 2004 report, real progress has been made. The first progress was seen in the 2006 interstate agreement which defined standards of the survey and updated the estimation of TACs. The second improvement was the document presented by the Russian delegation which offered an improved methodology fully consistent with international practice. Parts of this procedure have already been integrated into current methodology.

The Workshop participants recommend that the Commission on Aquatic Bioresources continue improving the methodology by reviewing a methodology that includes all relevant data and calculates stock status and biological reference points.

The Workshop recommends that as far as possible a full technical description of the methods is produced.

The Workshop recommends that two technical workshops for specialists be organised with FAO support:

1) Workshop on survey estimation methods for sturgeons of the Caspian Sea.
   This workshop will include both survey design and the analysis of the resulting data.

2) Workshop on the application of modern methods for stock assessment and TAC estimation for sturgeon species of the Caspian Sea.

[3] For specific recommendations by the two experts please refer to Appendix C

APPENDIX A

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APPENDIX B

Independent Experts

Robert Mohn – Dr. Mohn is a Research Scientist with the Canadian Department of Fisheries and Oceans based at the Bedford Institute of Oceanography, Nova Scotia. With the exception of a brief period of consulting, he has worked for DFO since 1977. He has been responsible for the assessment of various fish, invertebrate and mammal populations. Most of his work has been in the modelling of populations and management scenarios. He has also addressed methodological issues in stock assessment with emphasis on diagnostics and the quantification of uncertainty. His recent work has increasingly been focused on ecosystem modelling with particular attention on the seal-cod interaction and a more complete analysis of cod natural mortality. Dr. Mohn is and has been a reviewer for several organizations including: The Centre for Independent Experts' (CIE), The Southern Bluefin Tuna Commission, The Pacific Halibut Commission and The International Council for the Exploration of the Sea (ICES).

Alexei Sharov – Dr. Sharov is programme chief at the Maryland Department of Natural Resources, USA. He is currently directing the Stock Assessment and Analysis Program to provide the quantitative evaluation of Chesapeake Bay and Atlantic coast fishery resources. He participates in interstate and federal assessment activities as a member of striped bass, Atlantic menhaden, dogfish, summer flounder, stock assessment and multispecies technical committees of the Atlantic States Marine Fisheries Commission. He serves as an advisor and reviewer for the New England Fisheries Management Council Science and Statistics Committee and North East Fisheries Science Center.

He works with the analysis of fishery dependent and fishery independent data and the development of population dynamics and stock assessment models that address single and multi-species management issues and their interpretation. He also designs survey sampling programs to collect important fisheries information, and reviews and evaluates federally funded research proposals, interim and final reports on research activities conducted by Fisheries Division staff. He has also analysed the population dynamics and restoration success for sturgeon species in Caspian Sea.
Dr. Sharov is a member of: American Fisheries Society; Tidewater Chapter of AFS; Atlantic States Marine Fisheries Commission; International Council for the Exploration of the Sea; Atlantic States Marine Fisheries Commission; Chesapeake Bay Stock Assessment Committee; New England Fisheries Management Council Science and Statistics Committee.

APPENDIX C

Specific recommendations by Dr. Mohn and Dr. Sharov

Current methodology for stock assessment

The methodology applied by the Islamic Republic of Iran as described in the review by FAO (2004) is not considered acceptable by international standards. However, it must be underlined that no delegation from Iran attended this workshop and that it was not known if any progress has since been made in Iran. This Appendix is therefore exclusively about the methodology, which has been applied by Azerbaijan, Kazakhstan, the Russian Federation and Turkmenistan and is hereafter referred to as "*the existing methodology*".

The existing methodology of sturgeon species stock assessment in the Caspian Sea is based solely on trawl surveys that are conducted twice a year (summer and winter). Sampling is based on 450 fixed stations distributed along the predetermined equally-spaced transects supposedly covering the principal areas of sturgeon distribution in all five Caspian countries. But, it appears that no analysis has been completed to determine a number of stations that are needed to achieve a certain level of precision. Although transect-based fixed stations are utilized in other areas of the world as well, random stations are preferred when practically possible.

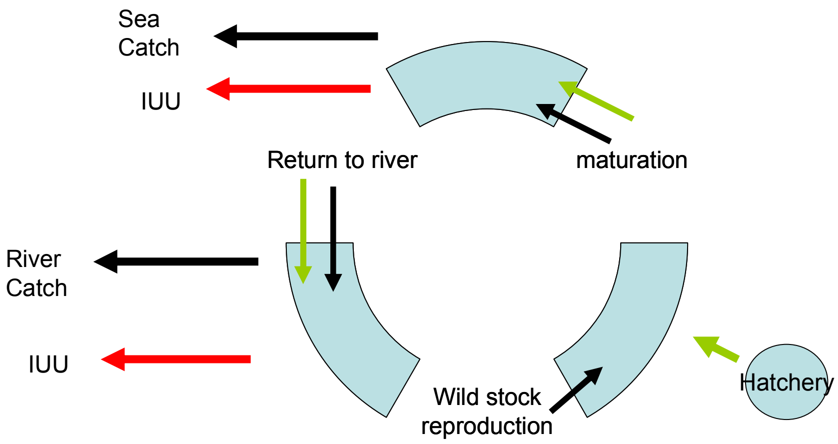
The major deficiency of fixed station surveys is potential bias in the estimates of fish density due to non-randomness in the selection of sample stations. However, the direction and magnitude of such bias is hard to predict. With large number of stations covering the whole area of stock distribution the issue of bias may not be as severe as in other cases. Large areas of the sea were not sampled, primarily due to depth under the assumption that sturgeon densities in those areas are low or very low. However, some areas at suitable depth were also not sampled due to obstructions on the bottom. In addition, workshop participants indicated that Iranian waters were not sampled in the last year or two due to vessel repairs. All these factors contributed to the incomplete spatial coverage of the stock abundance survey and are likely to lead to biased estimates of population density.

The advantages of randomized survey design are unbiased estimates of fish density and quantification of the uncertainty involved. Stratifying the Caspian Sea according to sturgeon distribution or habitat characteristics would certainly be useful. Maps of sturgeon distribution show a high spatial variability. In such cases, the use of stratified survey design most likely leads to more reliable estimates for mean population density.

Major deficiencies of current approach

No error estimates (i.e. standard error of the mean, coefficient of variation) are currently reported for the density estimates (CPUE), and the reliability of gear efficiency estimates for all sturgeon species is currently unknown. No documentation has been made available to the experts or to FAO on how trawl catchability was estimated, and no uncertainty estimates were presented. It appears that the values currently used were "determined" based on a number of studies, rather than objectively estimated. The basis for this approach is not clear. It was reported at the workshop that gillnet and hydroacoustics data were collected and used for estimating trawl catchability coefficients and subsequent absolute abundance, but no details were available for evaluation. The gear catchability coefficient is notoriously difficult to estimate. According to the FAO review (2004), the estimates produced for sturgeon in the Caspian Sea varied by more than an order of magnitude. The catchability coefficient is affected by a variety of factors such as depth, visibility, trawl speed, length of weirs, fish size behavioural aspects, etc. Consideration of uncertainty involved in the gear efficiency is very important. Absolute estimates of population size are extremely sensitive to bias in the catchability coefficient, especially when the coefficient value is small.[4] For that reason, survey-based abundance estimates should be used primarily as a relative index. However, the methodology used by the Caspian countries treats the survey estimate as absolute population abundance without consideration of measurement error and associated management risks. It is even more troubling that in some cases extremely low numbers of fish were caught in the survey and those numbers were used to produce absolute abundance estimates. For example, the 2002 spring survey caught only 19 belugas in 450 stations[5]. Less than half of them were adults, and the 2004 winter survey caught eight belugas, seven of which were juveniles. Based on these numbers, one would conclude that either trawls are very inefficient in catching beluga or the population was at extremely low levels and an immediate rebuilding programme would have to be initiated. Yet these numbers were used to estimate absolute abundance for the Caspian Sea and to set TAC. The authors of the report went even further and described the spatial distribution of the juvenile and adult sturgeons in different areas based on the 19 fish. Estimates of total and exploitable population size in hundreds of thousands of tonnes scaled up from less than 20 fish or even 10 caught in the survey are absolutely questionable.

Current stock estimation relies exclusively on survey data and makes no use of catch statistics, size and age structure of specific populations, effort information, etc. No modern methods of stock assessment based on catch statistics are currently being employed. No past or current estimates of fishing mortality are being produced. Methods that would allow catch and survey data integration should be considered.



An operational model is needed to capture, at least in a crude scale, the major special attributes of Caspian Sea sturgeons. It could be used for the evaluation of various harvest, management and stock enhancement scenarios. Biological reference points and harvest control rules would be improved if they included the special attributes of the Caspian Sea rather than be just the standard fisheries science models. We are told that poaching is a major source of mortality; scenarios could be developed with

[4] For example, currently used catchability value of 9 m trawl for beluga is 0.04. This means that only 4 percent of the fish in the path of the trawl are actually retained. Obviously this coefficient was estimated with some error. Suppose it is reported that trawl catchability for beluga is somewhere between 0.03 - 0.06, which would be considered by most people as quite precise range. However, a change of this value from 0.04 to 0.03 will lead to increase of population size estimate by 25%. A change from 0.04 to 0.06, being small in absolute value, will result in 50% reduction of stock size estimate.

[5] The actual numbers of fish are often not presented; they are disguised as densities per trawl, so it was necessary to reconstruct the numbers by multiplying average catch per trawl by the total number of trawls made.

explicit amounts of poaching to assess its effect on the rest of the system and the estimation of the wild stock component. Figure 1 demonstrates the concept, but it would have to be further developed by people who are familiar with the system.

As an alternative or an addition to estimation of mixed Caspian wide stock size, river specific stock estimation can be considered, given that in the modern history, stocks were primarily exploited in their native rivers. It appears that corresponding stock specific information on size, sex and age structure of the spawning stock and catches has been collected, at least in some countries. If so, variations of cohort analysis methods could be employed to estimate river specific population size and fishing mortality level.

Long term dynamics need to be evaluated both for the development of biological reference points and as a basis for developing long term production and recovery potential. As a specific example catch curve analysis could be carried out on early and mid 20th Century landings (either as age or length disaggregated catches) to get a feeling for the total mortality (Z) at time relative to estimates from current analysis. Naturally, this suggestion is contingent upon the existence of such data.

There is a need for more complete error analyses. Bayesian posteriors are becoming more widely produced internationally. It was encouraging to see the thoughtful discussion of error estimation and examples using bootstrapping in the document provided by the Russian delegation (Babayan *et al*. 2006).

TAC estimation

The method for determining TACs suggested by the Interstate Document (2006) incorporates an index of abundance and a harvest rate:

$$TAC = F (b\ I/q)$$

Where *F* is the applied fishing mortality, *b* is the survivorship of the estimated stock size from the current year to the year for the TAC. *I* is the index of abundance and *q* the catchability of the survey. Each of the four components in the equation lacks supporting documentation. The index of abundance is from one year for a TAC two years in the future. It is updated once so that there are apparently only two observations included. The survivorship (b or something conceptually similar) used in the prediction was not documented. The F came either from Malkin's method or the yield per recruit[6] (it was not clear from the discussions which one of the methods is currently used by Caspian states). The final component q is the conversion from the index to true biomass. Adequate documentation must be provided for any session to deal with these technical issues in the future.

The most important issue with TAC determination is that the harvest control rule uses only one reference point of target fishing rate. No consideration is given to the development of a threshold fishing rate. More importantly, no target and threshold levels of the spawning biomass are used. With no minimum biomass defined, the exploitation will be taking place even if only few fish are left in the population. This means that the current harvest control rule is incapable to maintain the long-term sustainability of the fishery, which is the most critical point in the current procedure of stock management and TAC determination. Without the

[6] Babayan et al. 2006

definition of the target and minimum spawning stock it will not be possible to maintain natural and artificial reproduction at the required level.

The seminar concluded that it was best to use methods which integrate both fishery and survey information. The approach described in the document provided by the Russian delegation (Babayan *et al*. 2006[7]) which uses Russian sturgeon as an example shows one way in which this may be done and is generally consistent with the assessment methodologies currently utilized internationally. The document demonstrates a very good knowledge of modern techniques of defining the stock status (i.e. the use of the Control Rule and biological reference points) as well as challenges presented by specifics of sturgeon biology and fishery. Adoption of this or a similar approach by the Bioresources Commission would be a significant step forward towards improvement. Babayan *et al*. (2006) nicely integrates catch and survey and it could be a vehicle to incorporate other information as well. For example if tagging information became available it would help determine the absolute population size and in turn the survey catchability. Secondly, the incorporation of the hatchery component of recruitment could be useful as a tuning index, especially for stocks for which it is the major component, and give insights into mortality from release to capture.

Specific Recommendations

Information dissemination

Openness and transparency are the norm of international practice and important critical elements in multi-jurisdictional fisheries management. **A detailed description of all methods used in stocks' abundance estimation, development of reference points and TAC calculations should be produced and made available to range states representatives and other parties involved**. Details should be sufficient for the readers to understand all steps of calculations.

[7] A few technical observations about Babayan et al. (2006) seem warranted. The residuals show a strong pattern following the (about) 1984 year class. Was this a major recruitment event that the separable model could not handle? Traditional separable models as were used for this study often have difficulty dealing with cohort specific events (as opposed to year or age effects). Secondly the differences between the population and the corrected survey in Figure 12 are a little surprising. The contours in Figure 2 show that the survey index is far and away the most important source of information in the fitting process. It is expected then that the survey points shown in Figure 12 would balance nicely around the population estimate, with perhaps larger positive residuals if they are logged. Here all the residuals but one are negative. It is further surprising how well these residuals (after some unspecified transformation) fit the indices of IUU in Figure 13, thereby suggesting all the error is due to IUU.

Also, the stock status suggested by Table 1 (SSB in 2004 is less than 2 percent of that in 1985) seems to be severely depressed. However, the HCR and projected status (Figure 8) suggests rebuilding in about five years to a regime of full exploitation. It is further noted that this point on the HCR is about twice the current level. In other words, the stock would be rebuilt to a level supporting full exploitation at about 4 percent of the 1985 SSB. And finally on the HCR, having only two zones provides no obvious consideration for the preservation of native stocks. Arguments were made that defining minimum spawning biomass is not needed because hatchery production currently substituted natural one. This is only true for beluga. The proportion of naturally spawned Russian sturgeon and stellate sturgeon is currently estimated as 45 and 55 percent, which are still high numbers. Maintaining natural reproduction is extremely important for preservation of complex population structure and genetics. This would be important for beluga as well. Hatchery needs for spawners is also part of the minimum spawning biomass that should be maintained.

Improvements of the existing survey

1. **Error estimates of population density should be calculated for existing annual estimates of the mean catch per trawl by species**. These errors should be used to characterize the uncertainty in population density estimates and further used in the risk analysis for management purposes.

2. **Mean catch per tow from the trawl survey should be treated as an index of relative abundance**.

3. **If absolute abundance estimates are produced based on survey results, uncertainty in those estimates should be used in risk analysis**. [8]

4. **When determining stock status, trends in CPUEs time series should also be considered rather than a single annual value.** Knowing that the particular stock numbers were going down or up would help ensuring appropriate management decisions.

5. **Detailed report or scientific paper describing the data, methods and the results of the trawl catchability experiment should be developed**. Trawl catchability estimates for each species should be reported with associated errors and those errors should be used in calculating confidence limit intervals for absolute abundance estimates if such calculations will be continued in the future.

6. **Previously collected data should be analyzed to detect whether stocks distribution changes over time**. Subdivision of sample area into strata with more homogenous CPUE values will lead to significant improvement in the precision of mean CPUE (reduction in uncertainty). The analysis of the existing data can answer the question on the required sample size for a given precision and optimum allocation analysis can help to optimize the number of samples (trawls) to be completed in each stratum.

7. **Stratified random survey design should be considered as an alternative to the existing fixed stations design.**

8. **The size of the bias in the estimate of mean CPUE arising from ignoring the areas that were not surveyed due to obstructions on the bottom or for other reasons should be quantified.**

Further improvement of assessment methodology.

1. Current stock abundance estimation relies exclusively on survey data, ignoring catch statistics, size and age structure of specific populations, effort information, etc. **Methods that allow catch and survey data integration should be considered.**

2. **Estimates of fishing mortality should be calculated for the past and present, using variable methods starting with simple catch curves.**

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[8] For example, if the spawning stock biomass is estimated to be 100,000 tons ± 40,000 tons, while the minimum biomass level established is 80,000 tons, the question could be posed: "What is the chance of the population size to be above the minimum biomass level? How much risk can we take for a population to actually be below the biomass threshold?

3. In addition to estimation of mixed Caspian wide stock size, river specific stock estimation can be considered, given the fact that fishing only occurs in native rivers in most countries. It appears that corresponding stock specific information on size, sex and age structure of the spawning stock and catches is available. If so, variations of cohort analysis methods such as VPA or statistical catch at age models could be employed to estimate river specific population size and fishing mortality level.

4. More specific recommendations on models and methods to be tried can be done only if more detailed information is provided on the type of the fishery dependent and fishery independent data available in all countries, including area/river specific catches, fishing effort, size and age structure of fish in the catch and in surveys, total number of the young of the year released by hatcheries, existing estimates of natural mortality, juvenile survival, etc.

Management Control Rule and TAC estimation.

1. **It is strongly recommended to set clear management goals for the fishery and to develop corresponding target and limit biomass reference points. A harvest control rule should then specify detailed pragmatic actions according to stock status of the fishery.**[9]

2. **Target and limit fishing mortality levels should be established for each species**. A modified yield per recruit analysis for each species can be easily done to produce estimates of fishing mortality such as F_{max}, $F_{0.1}$ or F corresponding to a selected percentage of maximum spawning potential (MSP) that can serve as targets and limits for current set of fishing regulations.

3. **Minimum and target spawning stock biomass values for each species should be developed**. Definition of minimum spawning biomass is especially important. This value should reflect a biomass of spawners necessary to fill in all available natural spawning grounds plus the number of fish needed to satisfy the capacity of all hatcheries.

4. **A population rebuilding plan should be developed for each species**. Should the spawning biomass fall below the minimum threshold, actions should be taken to restore the stock within defined time frame.

5. **TAC should be set on a precautionary basis.** Considering sturgeon species life history (high longevity, low natural mortality, low sustainable levels of fishing mortality), target fishing mortality level below F_{MSY} should be applied to the exploited stock. Uncertainty in population size estimates should be used evaluate the risk of stock overfishing.

6. Since the majority of legal fishing occurs in the spawning rivers, **river specific TACs should be considered**, otherwise there is a risk of overfishing river specific stocks using Caspian wide approach only.

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[9] The publication by Babayan et al. (2006) provides an example of how these principles can be incorporated.

7. **It is recommended that a stock assessment working group is established** by member countries that will systematically review the data, models and the results of annual stock assessments and TAC calculations.

8. **It is recommended that member countries invest in professional stock assessment training of young scientists to bring regional knowledge and expertise to the modern level**.

9. **It is recommended that Caspian states convene at least two workshops to discuss ways of improving stock assessment methodology**. One should review the data collected by trawl surveys, discuss gear cathability issues and look at ways of improving survey efficiency. The second one should consider all fishery dependent and independent data accumulated by five states, evaluate available modern assessment methods and their applicability to sturgeons of the Caspian Sea and develop integrated assessment approach that would combine the survey and catch statistics information.

10. It is recommended that any upcoming workshops, including the survey design and assessment methods should be as open as possible that they provide a forum for the exchange of ideas, models and insights. If original data cannot be provided, synopses are still useful. As well as scientists from the member states, outside, independent reviewers should attend.

List of documents reviewed by the experts:

Babayan V.K., Bulgakova T.I., Kotenev B.N., Vasilyev D.A., Khodorevskaya R.., Vlasenko A.D. 2006. Caspian sturgeon TAC foundation in modern conditions. Moscow. VNIRO. 27 p.

CITES (2008) Evaluation of the assessment and monitoring methodologies used for stocks of Acipenseriformes species shared between different range states. Report by CITES Secretariat to the 23rd meeting of CITES. Geneva, Switzerland, 19-24 April 2008.

FAO (2004) Review of the Survey Methodology, stock Assessments and Setting of Total Allowable Catches for Caspian Sea Sturgeon Fisheries. Report by FAO to CITES.

Interstate Programme on Study of the Distribution, Abundance, Stock Assessment, Food supply and TAC recommendation of Caspian Sea Sturgeons in 2007 -2009.

Kaymaram, F. 2008. Some comments and recommendations of the Reports on Results of complex Interstate All- Caspian Sea Expedition on the Assess of sturgeon Species Stocks. Report to the technical workshop on Stock Assessment and TAC methodologies (FAO) 11-13 November 2008.

Kotenev B.N., Babayan V.K. (eds) 2006. Fish Stock and TAC assessment methods. Third international Workshop of the Commission for Aquatic Biological Resources of the Caspian Sea. VNIRO. Moscow