UNDP/GEF/YS/RWG-F.3/7
Date: 26 September 2006
English only

Third Meeting of the Regional Working Group for the Fisheries Component
Weihai, China, 25-28 October 2006

Report of Fisheries Regional Stock Assessment Methods and Suggestions for a Comprehensive Strategy

A comprehensive report on existing stock assessment methods and suggestions for a comprehensive strategy for joint-regional stock assessment was carried out from June to September 2006. The results of the regional synthesis will contribute to the Fisheries Chapter of the Transboundary Diagnostic Analysis (TDA).

The report includes: i) A comprehensive report on current methods of assessing fisheries stocks; ii) A list of the sources of data and information collected throughout the report; iii) A list of major issues and priorities that need to be addressed in the Yellow Sea region; and, iv) A suggested methodology to develop a series of joint-regional stock assessment in the Yellow Sea Large Marine Ecosystem.

A consultant from the Yellow Sea Fisheries Research Institute (China) was contracted to develop this activity, and the last version of the report is attached hereafter. During the 3rd RWG-F Meeting, the consultant will present his results-to-date, highlight the relevant findings and explain the proposed methodology towards a Joint-Regional Fisheries Stock Assessment in the Yellow Sea Large Marine Ecosystem, highlighting the suggested frequency of assessments, potential constraints and the species to be addressed.

After reviewing the report and presentations, participants will discuss the information presented, and suggest how certain notable data and information could be included in the fisheries section of the TDA and eventually for the Strategic Action Programme.

The members will be invited to consider necessary revision, edition and publication of this document.

UNDP/GEF PROJECT ENTITLED "REDUCING ENVIRONMENTAL STRESS IN THE YELLOW SEA LARGE MARINE ECOSYSTEM"

UNDP/GEF/YS/RWG-F.3/7
Date: 04 October 2006
English only

Development of joint regional stock assessment methodology

Comprehensive report on existing stock assessment methods and suggestions for a comprehensive strategy for joint-regional stock assessment

by

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Third Meeting of the Regional Working Group for the Fisheries Component

Weihai, China, 25 - 28 October 2006

TABLE OF CONTENTS

1 GENERAL ISSUES

Based on the tasks listed in the Statement of Work issued by the Project Management Office (PMO) of UNDP/GEF project "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem" (Contract Code: F-I-stockassess-JX-1201No), under the sub-objective A "Stock Assessment" of the Fisheries Component, the major tasks is to develop methods for joint regional stock assessment for the Yellow Sea Large Marine Ecosystem. [1]

1.1 Background

One of the problems common to each country highlighted by a Preliminary Transboundary Analysis of the Yellow Sea Large Marine Ecosystem (Feb, 2000) is the "inadequate capacity to assess the ecosystem and perform basin-scale assessments". The approved Implementation Plan of the UNDP/GEF Yellow Sea Project, "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem (YSLME)," lists one of the activities of the Fisheries Component as 'developing a common methodology for joint-regional stock assessment for the Yellow Sea' that will ultimately enable researchers to determine the condition of stocks and manage fisheries in the future.

The major objective of the task is to develop recommendations for future stock assessments for the Yellow Sea for integration into the YSLME Strategic Action Programme (SAP) and National Yellow Sea Action Plans (NYSAPs). It is hoped that this process of joint-regional stock assessment will contribute to continue the development of regionally agreed methods for observation, monitoring and sampling of the marine environment in the Yellow Sea, enhanced co-operative mechanism for regional monitoring and observation; upgrading of skills in basin-wide observation and monitoring; a better scientific understanding of the basin-wide marine environment/ecosystem status; and an increased mutual understanding and trust amongst the participating institutions.

The immediate objectives of this task are to collate information on methods currently used for assessing fisheries stocks in the Yellow Sea, comparing them with methods used in other regions and for different aquatic systems, where possible filing gaps and providing improvements and developing a set of best-practice guidelines for stock assessment using adequate tools for assessing the condition of stocks in the Yellow Sea.

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[1] Geographic Scope: The Yellow Sea Large Marine Ecosystem is defined in this Project Document as the body of water delineated at the south, by a line connecting the north bank of the mouth of the Chang Jiang (Yangtze River) to the south side of Cheju; at the east, by a line connecting Cheju Island to Jindo Island along the coast of the ROK; and to the north, a line connecting Dalian to Penglai (on the Shandong Peninsula).

1.2 Description of Activities

- Prepare a comprehensive summary of methods used for assessing fisheries stocks in the Yellow Sea. The summary should include:

  a. A description of the contemporary and historical techniques/methods used to assess and model stocks in this region.
  b. A description of methods used for regular, multi-species, stock assessment in other large marine ecosystems and/or in other aquatic systems.
  c. A description of the types of data and information collected, and used in the analysis, for all these methods.
  d. A description of the analytical and statistical methodology utilised in each model or technique.
  e. A description of the benefits, drawbacks and difficulties of each method.
  f. A description of the knowledge gaps in the current method of Yellow Sea stock assessment, and the barriers to obtaining data.
  g. Recommendations for the most practicable and appropriate method for regular, multi-species, stocks assessment in the Yellow Sea with suggestions on how to fill knowledge/data/information gaps in the future.

- Prepare <u>recommendations for a comprehensive guideline for annual, multi-species, joint-regional stock assessment</u> for the Yellow Sea comprising of:

  a. Instructions for jointly-carrying out a reiterative series of multi-species stock assessments for the Yellow Sea;
  b. Recommendations for the acquisition of data – methodology, type, etc;
  c. Recommendations for the analysis of data – analytical and statistical models;
  d. Recommendations for outputs – charting and graphical display of resultant data;
  e. Recommendations on how data should be archived or managed; and
  f. Recommendations on where final results should be published, integrated into global databases and how the public can access these data and guidelines.

  The guidelines should take into consideration: i) Existing national agreements; ii) Temporal changes in climatic regimes; and, iii) The geographic parameters of the Yellow Sea Project.

- A presentation of the results-to-date at a Meeting of the Regional Working Group - Fisheries, reviewing the preliminary results with all members of the RWG-F and the Project Management Office.

- Based on the comments of the RWG-F, revise the guidelines and provide a comprehensive proposal or list of recommendations for joint-regional stock assessment (highlighting the major barriers to stock assessment, and indicating the species to be assessed) to the next Regional Working Group – Fisheries meeting, for finalisation.

1.3 Expected Outputs/Results

The final product should be a set of reports as listed below:

i. A comprehensive report on the current techniques used to model carrying capacity both locally and internationally and comparing with other methodologies, describing data types, analytical methods, highlighting the differences, benefits, drawbacks and major barriers;

ii. A list of data and information sources to indicate the sources of the data and information collected in item (i), location of these data and information centres, conditions of access to data and information by different users;

iii. A recommendation for undertaking an regular, multi-species, joint-regional fisheries stock assessments in the Yellow Sea Large Marine Ecosystem, highlighting the suggested frequency of assessments, potential barriers and the species to be assessed;

iv. Project progress and final reports as requested by the PMO.

2 METHODOLOGY

Methods used to carry out assignment:

- Data and information collected during the YSLME initial data/information collection activities were referred;
- Existing locally and internationally, accomplished through internet searches, telephone interviews, library research, visits to/communication with national fisheries offices, research institutions, government agencies and related NGOs, compare methodologies and fill in gaps in knowledge.

2.1 Current methods of assessing fisheries stocks: Regional & International

The objective of management of marine fisheries resources is desirable to obtain maximum sustainable yield (MSY) based on scientific advice, which is based on an evaluation of the state of the stocks defined by its abundance at a specific time, together with the mortality and growth that control its development from stock assessment. It is often essential that advice should be given, with explicit statements of its reliability where necessary, especially when a fishery is developing rapidly. Stock assessment is presently based on two major sources of data: from fisheries and scientific surveys. Historical stock levels and the rate of removals by fisheries from most stocks are in most cases obtained from analyses of commercial fisheries data by Virtual Population Analysis (VPA) or other stock number at age based models. The present state of stocks is most commonly assessed by scientific surveys.

The stock assessment by scientific surveys is required at all stages of the development of a fishery, but the need for accuracy and precision is different. In an undeveloped fishery all that is generally required is a rough measure, but the requirement of accuracy and precision will increase with developing of fisheries. In a very intense or overexploited fishery, estimates with high accuracy may be necessary to provide proper management advices.

The scientific survey is an important tool for assessing the present state of most of the commercially important stocks. The indices of abundance are used to tune a VPA or other types of catch at age models (Deriso *et al.*,1985; Hilborn and Walters, 1992, and Patterson and Melvin, 1995).

The results of fish stock assessment will provide:

- An estimate of the current stock status,
- A projection of the yield, total and spawning stock biomass and recruitment for specified scenarios of fishing mortalities, and
- The relationship between the stock status / projection and a number of biological reference points.

These parts are used to formulate biological advice on fishery management, and evaluate whether the stock is within safe biological limits, i.e. productivity (growth, recruitment) is not adversely affected by fishing.

The stock status is defined by the:

- Stock size, the number of fish by age group at a particular point in time,
- Stock productivity, growth, maturity, fecundity and recruitment, and
- Stock mortality, made up of fishing and natural mortality rates.

2.1.1 Population Dynamic Models

To describe the population dynamics, many models have been developed and applied world wide, the main references are the books and/or manuals by Beverton and Holt (1957), Ricker (1958, 1975) and Gulland (1969, 1983). Among the models, most used ones are Virtual Population Analysis (VPA), simple production model (Schaefer model) and Yield per Recruit model (Beverton and Holt model). Multi-species modelling is highly multidisciplinary in nature, including fishery science, fish biology, ecology, hydrography, mathematics, statistics, economics, operations research and computer science, the more extensive the inclusion of such factors, the more complex the models. In the following, the three types of models will be briefly described.

2.1.1.1 Virtual Population Analysis (VPA)

Although there are many mathematical models (including the original and corrected ones) used to do the stock assessment all over the world, the VPA method in fish stock assessment is widely used, and become a standard assessment approach within many international communities and countries, for example, the International Council for the Exploration of the Sea (ICES), CCAMLR, CECAF, Northern Pacific stocks, Australia, New Zealand, South Africa, Argentina, Chile, Peru, etc.

Age-structured data is required by VPA. Fisheries data may provide important information about catch-at-age data from a fisheries statistics and biological samples taken from these catches. The state of the stock at a specific point in time is described by:

- Stock in numbers by age group (cohort)
- Mean weight per individual in the stock by age group
- Mean weight per individual in the catch by age
- Maturity proportion by age group

Virtual population was originally defined by Fry(1957) as the sum of fish belonging to a given year class present in the water at any given time that are destined to be captured in the fishery. The VPA model is developed by Gulland (1965)

$$\frac{1}{N}\frac{dN}{dt} = F + M \qquad (1)$$

Where:

N is the number of fish in a year class

F *is* the fishing mortality, and

M is the natural mortality, which is normally assumed constant during the year. Solving equation (1) for catch gives

$$C = F\,\frac{N(1 - e^{-(F+M)})}{F + M} \qquad (2)$$

Where:

C is the catch in numbers during the year. This model also defines the demographic structure of the stock provided some additional weight at age and maturity at age are given.

The above formulas are general and not subject to any discussion on their validity for describing a fishable population of some species. The term VPA-analysis was developed using the assumption that when a year class (cohort) of fish is almost fished to extinction, an arbitrary value of F could be set to estimate the number of individuals at that age. Then, assuming a constant value of M, the numbers at any age could be calculated backwards in time by the following formula

$$C_t = F_t \frac{N_{t+1}(e^{(F_t+M)}-1)}{F_t + M} \qquad (3)$$

Where:

t is the current year and t+1 is the next year and solving for F. Then the following version of formula (1)

$$N_t = N_{t+1}e^{(F_t+M)} \qquad (4)$$

Will give the current years population numbers and the process may be continued. The error introduced by the arbitrary choice of F at an old age would be negligible when estimating the number at age in the beginning of the life of the year class.

The problems arise when we want to calculate F. F has to be solved numerically either by reference to tables or by iteration. Either methods make the calculations somewhat laborious.

Pope (1972) proposed a method to overcome these problems by assuming that catch of each age group is taken exactly half way through each year.

$$N_2 = N_1 e^{-\frac{M}{2}} \rightarrow N_1 = N_2 e^{+\frac{M}{2}} \quad N_3 = N_2 - C \quad N_4 = N_3 e^{-\frac{M}{2}}$$

Therefore: $N_4 = N_1 e^{-M} - C * e^{-\frac{M}{2}}$ or $N_{t+1} = N_t e^{-M} + C_t e^{\frac{M}{2}}$

Then: $N_t = N_{t+1}e^{M} + C_t e^{\frac{M}{2}}$

When we take N_{t+1} as present. This means that we consider a year class from the last year it is present in the catches and work-out backwards in time. As in the Gulland's VPA N_{t+1} has two possible forms. In the first form C_{t+1} refers to as the catch in year t+1 only, in this case

$$N_{t+1} = \frac{C_{t+1} * Z_{t+1}}{F_{t+1}(1-e^{-Z_{t+1}})}$$

The second form of N_{t+1} is when C_{t+1} refers to catch in year t+1 and subsequent years. This is usually the case with a completely fished year class. Then

$$N_{t+1} = \frac{C_{t+1} * Z_{t+1}}{F_{t+1}}$$

We also need a formula to calculate the F_t

We can use $N_{t+1} = N_t e^{-(F+M)}$ or $e^{-(F+M)} = \frac{N_{t+1}}{N_t}$

Therefore $-(F+M) = \ln\frac{N_{t+1}}{N_t}$ or $F = \ln\frac{N_t}{N_{t+1}} - M$

If we start at age 6 we can go backwards as follows:

$$N_5 = N_6 * e^M + C_5 * e^{\frac{M}{2}}$$

$$N_4 = N_5 * e^M + C_4 * e^{\frac{M}{2}}$$

$$N_3 = N_4 * e^M + C_3 * e^{\frac{M}{2}}$$

The VPA analytical model has been expanded to include multispecies interactions (Magnusson 1995, Sparre 1991) that assumed the natural mortality mainly caused by predation in the ecosystem. Therefore, multispecies VPA (MSVPA) includes estimation of the natural mortality from predator consumption. Natural mortality is separated into two components $M = M_p + M_o$, where M_o is a (small) constant while, M_p is calculated from the estimated stock sizes and stomach contents. This method has been used in a few areas due to data limitation.

2.1.1.2 Schaefer model

Assuming an equilibrium relation between catch and population biomass, the rate of change in biomass can be written

$$\frac{dB}{dt} = G(B)$$

The Schaefer model is taken this function as

$$G(B) = Bk\frac{B_\infty - B}{B_\infty} = Bk(1 - \frac{B}{B_\infty})$$

Where:

B_∞ is the maximum biomass under equilibrium and k is a constant. This equation describes the logistic growth curve.

Since F = fq, where F is instantaneous rate of fishing mortality, f is fishing effort and q is a catchability coefficient, when a fishery occurs, $Y = FB = fqB$, then

$$\frac{dB}{dt} = Bk(1 - \frac{B}{B_\infty}) - fqB$$

or $$\frac{1}{B}\frac{dB}{dt} = k(1 - \frac{B}{B_\infty}) - fq$$

Under conditions of equilibrium the growth is zero and the equation becomes

$$0 = (1 - \frac{B_e}{B_\infty}) - fq \quad \text{and} \quad B_e = \frac{B_\infty}{k}(k - fq)$$

Where: B_e is the equilibrium biomass.

The equilibrium yield is $Y_e = fqB_e$ or $Y_e = fq\frac{B_\infty}{k}(k - fq)$

Then, solving this equation, the maximum yield can be obtained.

$$Y_{e\max} = \frac{k}{4}B_\infty \quad \text{and} \quad f = \frac{k}{2q}$$

If we have an equilibrium situation, this can be fitted by plotting catch per unit effort (u) against

f : $$u = \frac{Y}{f} = qB_e$$

The model in non-equilibrium situations (Walter, 1975) is: $U_{i+1} = A - Cf_i$

$$Y_{\max} = \frac{k}{4}B_\infty = \frac{k^2}{4a} \text{ for } f = k/2q \text{ or } Y_{\max} = \frac{A^2}{4C} \text{ for } f = A/2C$$

Where:

$$a = \frac{k}{B_\infty}, \quad A = \frac{kq}{a} \text{ and } C = \frac{q^2}{a}$$

2.1.1.3 Beverton and Holt Model

Another popular used prediction model is the *"Yield per Recruit"* model developed by Beverton and Holt (1957). The starting point of this type of model is the individual fish, compared to the Schaefer type of model which regards the total stocks as the basic unit.

The calculations are best made in terms of the yield of a single year-class of fish throughout its life, which will be, in the steady state, the same as the yield in one year from all year-classes present in the fishery. In a stock the whole life span can be divided into periods. For each period the number alive, the number caught, the number dying of natural causes, and the number surviving to the beginning of next period can be calculated, and the yield in weight can be calculated if the number caught and mean weight of individual fish is known.

This process can be calculated mathematically. The parameters of the stock concerned are given below.

N_t = number of fish at age t
W_t = average weight of fish at age t
R = no. of recruits, or no. of fish alive at time t_r
M = instantaneous natural mortality coefficient
F = instantaneous fishing mortality coefficient

We first consider a time period before fishing operates. If

t_r = age at recruitment and t_c = age at capture

then $t_r < t < t_c$

The number (N_t) alive at time t , can be given as $N_t = \mathrm{Re}^{-M(t-t_r)}$

The number (R') alive at first capture, can be given as $R' = \mathrm{Re}^{-M(t_c-t_r)}$

Therefore,

$$N_t = R' e^{-(F+M)(t-t_c)}$$

$$N_t = \mathrm{Re}^{-M(t_c-t_r)-(F+M)(t-t_c)}$$

The yield in weight is proportional to fishing mortality (F), stock size in number (N_t) and mean weight of an individual at age t ($\overline{W_t}$).

The yield in weight caught in a short interval $\frac{dy_t}{dt} = FN_tW_t \quad dy_t = FN_tW_tdt$

The total weight caught throughout the life span of a cohort (t_c = age at first capture, t_λ = maximum age) is then $Y = \int_{t_c}^{t_\lambda} FN_tW_tdt$

W_t can be expressed in the form of von Bertalanffy's growth equation $W_t = W_\infty(1-e^{-k(t-t_0)})^3$

Where *k* is the growth constant of the species concerned. This equation can be written as

$$W_t = 1 - 3e^{-k(t-t_0)} + 3e^{-2k(t-t_0)} - e^{-3k(t-t_0)} \qquad W_t = W_\infty \sum_{n=0}^{3} u_n e^{-nk(t-t_0)}$$

$u_0 = 1, u_1 = -3, u_2 = 3, u_3 = -1$

Therefore yield can be expressed

$$Y = \int_{t_c}^{t_\lambda} FR' W_\infty e^{-(F+M)(t-t_c)} \sum_{n=0}^{3} u_n e^{-nk(t-t_0)} dt$$

writing $t - t_0 = (t - t_c) + (t_c - t_0)$ and rearranging

$$Y = FR' W_\infty \sum_{n=0}^{3} u_n \int_{t}^{t_\lambda} e^{-(F+M+nk)(t-t_c)} e^{-nk(t_c-t_0)} dt$$

Integration gives $Y = FR' W_\infty \sum_{n=0}^{3} \frac{u_n}{F+M+nk} e^{-nk(t_c-t_0)} (1 - e^{-(F+M+nk)(t-t_c)(t_\lambda-t_c)})$

If t_λ is sufficiently large, the last term can be neglected. The yield equation becomes

$$Y = F\,\mathrm{Re}^{-M(t_c-t_r)} W_\infty \sum_{n=0}^{3} \frac{u_n e^{-nk(t_c-t_0)}}{F+M+nk}$$

Because the recruitment is unknown and often variable, the yields etc. are normally calculated as yield etc. per recruit.

$$Y/R = Fe^{-M(t_c-t_r)} W_\infty \sum_{n=0}^{3} \frac{u_n e^{-nk(t_c-t_0)}}{F+M+nk}$$

This model assumes that the stock is in the steady state, or equilibrium condition, and that recruitment is independent of parent stock size.

2.1.2 Bottom Trawl Survey

For demersal fish, bottom trawl surveys may provide better indices of abundance than the CPUE indices from the commercial fishery. Bottom trawl survey is a traditional and the most widely used method for the assessment of demersal fish stocks. At presently, otter trawls and beam trawls are two major types of bottom trawls used in scientific surveys. The density of fish is estimated by swept area method.

$$d = \frac{D}{a} q$$

Where:

a is the area swept by the survey trawl, is often assumed to be the area swept by the trawl's wings or doors during a standard tow, and

q is the catch ability coefficient which is affected by target fish behaviour and gear operation.

Before survey starts, sampling design should be well-defined that will increase the precision of the survey. For example, stratified sampling is usually used, i.e. the area is divided into several strata of more uniform fish density and the mean and the variance for each stratum is separately estimated before combining them into a whole assessment.

2.1.3 Acoustic Survey

The pelagic fish stocks are mostly estimated by acoustic surveys, which usually give a absolute abundance/biomass after survey. During the acoustic surveys, catches from bottom and pelagic trawl samplings are used to identify species for judging the acoustic recordings and supply information on size composition needed for converting the reflected energy to actual fish densities.

The estimates of abundance obtained from the acoustic method rely on the recorded reflected energy from fish as a measure of biomass density (acoustic back scattering cross section). The basic acoustic relationship is usually formulated as.

$$s_A = \rho \cdot \sigma$$

Where:

s_A is the acoustic index (the area back scattering coefficient (m^2 /n.mile^2), ρ is the area density of fish, and σ is the average back scattering cross section per fish (conversion factor).

For acoustic surveys, σ relates the acoustic signals to fish density and is correlated with the size composition of fish, which normally is established from trawling. Instrumentation in acoustic surveys thus includes the electronic instruments as well as the gear used for sampling the recorded fish.

2.1.4 Tagging – Recapture

Conventionally, the metal tags are implanted in the abdomen, dorsal fin etc. of the fish. Recaptures are obtained from scanning catches mostly from the commercial fleet. If the mortality caused by tagging is known or assumed and the tagged fish are evenly distributed in the stock, the tagged fish can be treated as a sub-population with the same population dynamics characteristics as the stock, e.g.

$$N : T = C : R$$

Which imply that the relationship between total numbers caught in the fishery (C) and number of tags found in this catch (R) reflects the relationship between the total (N) and tagged (T) populations.

With the develop of techniques, active acoustic tags or new data storage tags were used, a detailed picture of an individual fish's vertical and horizontal migration can be obtained, but this method need expensive equipments and manpower.

2.1.5 Egg and Larval Survey

Egg and Larval survey is another important method to conduct stock assessment. The total number of eggs and larva produced per year is estimated by survey, and divided by the number of eggs spawned per female to produce the number of fish in the spawning stock, then:

$$p = \frac{E}{FR}$$

Where:

p is size of spawning stock;

E is total annual egg and larva production in the survey area; F is mean annual fecundity per adult female; and R is the sex ratio. The accurate of the estimate is influenced by the mortality at egg and larval stages, and the fertilizing rate, except for the sampling problems.

2.1.6 Ecosystem Model

Since the complex marine ecosystem, many of single species (stock) management strategies has been failure, ecosystem-based fisheries management have been stressed recent years. Therefore, more and more ecosystem models are developed, among them, Ecopath with Ecosim (EwE) is probably the most widely used model (Christensen, et al, 2004), and is designed for straightforward construction, parameterization and analysis of mass-balance trophic models of aquatic and terrestrial ecosystems. Focus is on using the models for fisheries management, and a suite of tools are included for this aim.

EwE has three main components:

- Ecopath is a static, mass-balanced snapshot of the system, and is used to organize historical data on trophic interactions and population sizes;
- Ecosim is a time dynamic simulation module and builds dynamic predictions by combining the data with foraging arena theory;
- Ecospace – a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas.

The Ecopath software package can be used to

- Address ecological questions;
- Evaluate ecosystem effects of fishing;
- Explore management policy options;
- Evaluate impact and placement of marine protected areas;
- Evaluate effect of environmental changes.

The basic Ecopath equations are:

- Production = catches + predation mortality + biomass accumulation + net migration + other mortality
- Consumption = production + unassimilated food + respiration

In the Yellow Sea Ecosystem region, stock assessment, many traditional models have been applied to analyze the population dynamics, however, for stock assessment, the VPA method has not been used as a standard approach in providing the scientific advices to fisheries management. Scientific surveys, including bottom trawl survey, acoustic estimation, tagging and recapture method, egg and larval survey have been conducted, but mostly, only a part of the major stocks are sampled due to the less coverage, and all surveys were conducted by individual countries. Ecopath model has been tried to be built in recent years.

2.2 Location of data & info and access to each site by the public

- FAO Yearbooks of Fishery Statistics
- FAO Bulletins of Fishery Statistics
- FAO Fisheries Circulars
- FAO Handbook of fishery statistics
- FAO Fisheries Reports
- FAO Fisheries Technical Papers

- China Fisheries Yearbook
- China Ocean Yearbook
- Korean Yearbooks of Fishery Statistics
- http://www.fao.org/fi/
- http://www.cnfm.gov.cn/
- http://www.cafs.ac.cn/
- http://www.ysfri.ac.cn/
- http://www.eastfishery.ac.cn/
- http://www.china-fishery.net/
- http://www.ifishery.com.cn/
- http://www.china-fisheries.org/
- http://www.nmdis.gov.cn/
- http://www.ouc.edu.cn/
- http://www.qdio.ac.cn/
- http://www.momaf.go.kr/
- http://www.nfrdi.re.kr/
- http://kodc2.nfrdi.re.kr:8001/home/eng/main/index.php
- http://www.pknu.ac.kr/eng/

The data sources include fisheries dependent data (fisheries) and independent data (scientific surveys).

The fisheries data may be found from fisheries statistics, mostly catch statistics by major species and total landings in whole country and total fishing effort, some by fleets, the area fished is not usually specified. The multi-species inhabited and multi-fleets operated in the Yellow Sea Large Marine Ecosystem bring out more difficulties in getting accurate figures and sufficient fisheries data for the stock assessment.

The survey data are not available to public, it is impossible to access to any kind of survey data on stock assessment. However, the final results from surveys can be found from publications from both countries and international journals and books.

3 MAJOR ISSUES AND PRIORITIES

In the Yellow Sea region, currently, three countries (China, South Korean, and DPR Korea) fished there with multi-gears by different types of fishing boats. Japanese fishing boats were also operated in this area with high landing in last century. It is the fact that there is no closely cooperative work on the stock assessment in this region, although a lot of signs indicate that many stocks are overexploited. Management measures have been taken by individual countries without strong scientific information support.

The **major problems** in stock assessment in the Yellow Sea today are:

a. Lacking of agreed methods such as ICES uses VPA tuned by survey data;
b. The availability of data at regional level is limited, insufficient data, both fisheries data and survey data;
c. Different coverage of survey resulting in insufficient knowledge of distribution and status of major species;
d. Different methods and gear used in scientific surveys without calibration leading to different results;
e. Different objectives of surveys leading to focus on different target species;
f. Different target species in catch statistics;
g. Different standards in catch statistics.

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Data quality and the methods used to integrate them may result in imprecise and inconsistent stock assessments. Therefore, there is a lot of work to be done before conducting stock assessment to the whole ecosystem. To overcome these barriers, priorities are suggested as below.

<u>First step</u> is to establish several scientific working groups, such as

- Fisheries data WG responsible for collection of fisheries data, data standardization, etc.
- Survey methods WG responsible for comparison of survey methods by different countries and calibration, looking for consistent survey methods to estimate the biomass of stocks; development of better observation tools and survey strategies.
- Fisheries biology WG responsible for collection of fisheries biology data, data standardization, biological characteristics of major species, e.g. growth, mortality, migration and distribution, spawning, feeding, wintering, etc..
- Stock assessment WG responsible for selecting adequate mathematical models to the fish stocks in the Yellow Sea ecosystem, prediction of stock size of commercially important species, providing allowable biological catch (ABC) and total allowable catch (TAC) for fisheries management.

<u>Second step</u> is to establish exchanging mechanism of survey data and fisheries data.

<u>Third step</u> is to establish a joint survey mechanism based on analyzing all historical individual surveys by countries from the working groups.

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4 RECOMMENDATIONS

Suggested methods for reiterative series of joint-regional stock assessment. The quality of stock assessment depends on:

a. The quality of the assessment methods and the associated strategies;

b. Understanding of dynamics of the ecosystem, including species interaction, relationships between environment and biology;

c. Human activity effects;

d. Reliable data, both fisheries and survey data;

e. Reliable models chosen;

f. Knowledge of ecosystem uncertainties.

… …

In the Yellow Sea region, the stock assessment is far behind the fisheries, and also far behind the ICES region and northeast Pacific region, for example, the North Sea, the Barents, the Bering Sea, George Bank, etc. although there are many scientists working with this field. At present stage, because of lacking of basis, the methods for the regional stock assessment are recommended as following.

4.1 Collection of Fisheries and Survey Data

The data collected from fisheries and from scientific surveys are the basis, used in various computerized calculation tools and models to assess the states and the trends in the development of the stocks and to predict the catches and the development of the spawning stocks in the short and medium terms.

As known from the models, fisheries data are important (necessary) to fit most models. Therefore, collection system of accurate catch and effort and biological data should be implemented. A fisheries database should be established and upgraded that could provide a time series of stock abundance and composition.

Catch per unit effort (CPUE) is an index of stock abundance and is used to support the prediction models, and may get from either well-defined commercial fleets or from abundance surveys using research vessels. The CPUE values are expressed in numbers-by-age per effort unit. The effort unit can be days-at-sea, trawl hours, search time, etc. Commercial CPUE data are obtained through sampling the commercial fisheries for biological information and linking this information with catch and effort statistics. Abundance surveys using research vessels provide these data directly, often from bottom trawl surveys expressed as numbers caught per hour trawling. It should be noticed that survey data differ from commercial CPUE data.

Biological information is the fundamental components required in the stock assessment, for example the age composition, growth, length-weight relation, prey-predator relation, migration, stomach contents etc.

There are large uncertainties in the ecosystem, therefore, the data related to the fish inhabiting environment are also necessary to collect, such as temperature, salinity, primary production, plankton, etc. Some data is used to fit the ecosystem models.

4.2 Stock Assessment Modelling

- Jointly selecting to find an adequate model from the existing classical mathematical models for reiterative use in stock assessment of the fish stocks in the region after testing.
- Developing new models based on the classical and new models used in other regions.
- Joint prediction of stock size of commercially important species in the region.

… …

4.3 Jointly Scientific Survey

A regular scientific survey is suggested to carry out every year to monitor the state of major stocks in the Yellow Sea. The sampling strategy and survey design should be well-defined. Acoustic-trawl survey is recommended based on the availability of research vessels and equipments in the countries around the region. The frequency of cruise is completely dependent on the available budget because the using research vessel is high cost. The coverage may be large enough to cover the whole distribution of the major stocks.

5 FINAL REMARKS

The purpose of stock assessment aims at fisheries management for sustainable development and resources must be managed sustainably with a long-term view. The ecosystem based fisheries management (EBFM) is discussed in many areas of the world recently, particularly after the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem, held in Reykjavik, Iceland, October 2001. Since fisheries not only reduce the exploited stock sizes, but also affect the interrelated species, which are predators, preys or species in competition with the target species for food resources. It is therefore important to monitor changes in the fish community as well as the exploited stock, to ensure the ecosystem is not damaged by the fishery.

Marine fishes do not respect the boundary delimited by people, fisheries science is very internationally oriented. Therefore, stock assessments in the same region must co-operate each other and work together. When the objective of fisheries management is defined, the method and strategy of stock assessment can be determined based on the presently available data and knowledge in relation to the Yellow Sea ecosystem.

Although there are many methods used in the world, in the Yellow Sea region, stock assessment has to fill its gaps in a more consistent and complete framework for sustainable management in the future. Cooperation can not flourish **without a formalized network** of institutions and scientists that maintain and share the data and knowledge. Firstly, preliminary results concerned the Yellow Sea fisheries resources from different sources can be compared between surveyed areas, assessed stocks, and all parties can directly exploit developments and improvements in assessment methodology done in various areas. Secondly, effort at all levels must be encouraged to establish and to improve stock assessment in a coherent way, it is required that scientists with various areas of expertise form working groups to co-ordinate research projects.

Annex containing:

Persons / institutions / websites visited or interviewed

Dr. Tim Parsons, Institute of Ocean Sciences, Canada

http://www.fao.org/fi/default.asp

http://nrcwg.imr.no/Reports.html

http://www.imr.no/

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