Scientific Report for Formulation Step

SSA 14 Mar Piccolo of Taranto Version 1.0 <D7.3>

Mar Piccolo of Taranto (Southern Italy)

Caroppo C.[1], Giordano L.[1], Rubino F.[1], Trono A.[2], Forleo M.[3], Bellio G.[2], Bisci P.[1], Palmieri N.[3], Ribera d'Alcalà M.[4], Siano R.[4]

[1] - Insitute for Coastal Marine Environment, CNR
[2] - University of Salento, Department of Social Sciences
[3] - University of Molise, Faculty of Economy
[4] - Stazione Zoologica Anton Dohrn, Naples

23rd December 2008

1 Input Approximations and Transformations

Natural Component
In the input table of the Natural Component, reported in the Documentation Report of the 7.14 Study Site, we have considered the Mar Piccolo Basin as a component of a more complex system, represented by:

- Weather (atmospheric)
- The Mar Piccolo Basin
- The Mar Grande Basin
- The environmental components

Concerning the **weather** variables such as rain, wind, air temperature, cloud, deposition, relative humidity have been considered. All these variables have been furnished by Regional Sources, such as AssocodiPuglia and Istituto Idrografico and covered a period of ten years (from 1996 to 2005). The frequence of the observations (Delta t) is usually of one day, but in some cases (2002, 2003, and 2004) it is of 3 hours (as reported in the input table). We fill data gaps by using Extend program, as reported in the Formulation guidelines (pag. 14).
All the meteorological data are collected at one station (Taranto – Le Marine), nearest to Mar Piccolo and situated at a distance of 10 km SE of Mar Piccolo and at a height of 100m over the sea level. These data are would be considered as the best approximation of the real data referred to Mar Piccolo.

For the "**Mar Piccolo Basin**" and "**Mar Grande Basin**" blocks variables related to the circulation, the submarine springs ("Citri"), evaporation, sediments and bathymetry were considered.
Some data (temperature and salinity) have been collected by IAMC-CNR throughout the years bi-monthly. These data have been approximated to daily values, by filling the gaps by mean of the Fourier analysis. To know the batimetry of Mar Piccolo we used maps of Italian Navy. The other data connected to the "Mar Piccolo" and "Mar Grande" blocks, were empirically calculated. Particularly, we have used *formulas* and calibrations from data available in literature.
Concerning Mar Piccolo we have considered it as an unique environment, to simplify the model, even if the two Inlets of Mar Piccolo will be in the next simulation considered as two different ecosystems. As regards Mar Grande, it has been considered to better understand the circulation and functioning of the Mar Piccolo.

Environmental data have been collected by IAMC-CNR throughout the years with a variable frequency. The first kind of elaboration is to fill the gaps to make uniform the abiotic data with biotic data. The gaps, when small, were filled by using Extend program, when they were great, with more complex statistical analyses (e.g. Fourier).
Among the considered data, oxygen concentration measured by multi-parametric probe hasn't been calibrated correctly with (Winkler) chemical method: the calibration has been done by considering the surface sample, which is the most variable and instable also for the ship engines. For such data we have done a correction by using literature data. Another problem has regarded nutrients, which have been determined only for a limited period of analyses. A correction will be made taking into account data of the interstitial waters of sediments, reported in some studies of the IAMC researchers.
By considering all these problems we consider SPICOSA exercise as a guide to a better organization of the environmental samplings in Mar Piccolo.

Economic data
In the input table of the Economic Component we have considered the mussel farm as a component of a more complex system represented by catch and mussel market. In particular, the data of the economic model comes out partly from the balance of company (the official date even if not complete) and partly from estimates collected through interviews with operators in the sector. Moreover, the interest rate, percentage of reserve, etc. Comes out from official date. The problem will be to transform the annual data in monthly data.

Social Component
In the input table of the Social Component, reported in the Documentation Report of the 7.14 Study Site, we have considered:

- the Mussel culture farmers of the Mar Piccolo
- the Public Perception.

Concerning the **Mussel farmers** variables, we have considered all about these workers: the legal and the illegal number and the percentage of tarantine and outside mussel

farmers, the legal and the illegal income and their main expenses (travel, sanitary and family costs). The legal number and the legal income have been furnished by INPS (National Institute of Social Security) just for the last year, 2007, because the data for the last years are not available. But, in our previsions, we have hoped to have them for 5 years. About the illegal number and income we have based our model on empirical data (illegal number) and calculate data (illegal income). The frequency of the observations (Delta t) is usually of one month. It will be impossible, instead, to know where the all mussel farmers live and consequently how much they spent for the route that they cover everyday to arrive to works because of the privacy. We'll try to obtain this data and the family cost through interviews. About sanitary costs pertain to their type of job, we'll try to use data furnished by ASL (Local Sanitary Company) to cover a period of 5 years. The frequency of the observations (Delta t) ought to be of one month.

The **Public Perception** of the local economy and of own quality life, is calculate through questionnaires and interviews, and they haven't a specific duration or a specific frequency because they will be sporadic.

For all the components, to provide for the lack of data and lack of time-series or the presence of data not updated, it will be used, if possible, documentation and bibliography of the past to understand the changes happened in the last years.

2 Description of Policy Issue Scenarios and Interface

In date of 30th May 2008, in the library of the IAMC-CNR of Taranto we held a meeting with the Partecipant Group of the stakeholders to choose the *scenarios* which will be included in the simulation model.

They were represented by :

1. Regional Environmental Agency of Apulia Region - ARPA Puglia – Dr Damiano Calabrò
2. Province of Taranto (Productive Department) – Dr Luca Conserva
3. Health Board in Taranto (ASL TA) – Dr Michele Conversano
4. Italian Navy – Capitano di Fregata Nicola Mancini
5. Harbour Office - Sottotenente di Vascello Antonia Lenti

In the first part of the meeting the SSA team presented the conceptual models which simulated the ecological, and socio-economic features of the Mar Piccolo, obviously linked to the choosen Impact (**The reduction of the productivity and the quality of the mussel culture**). After the explanation of the utility of a mathematical model to give answers to simple question related to the improvement of the "mussel resource" in Mar Piccolo, we involved the participant Group in another important choice: the *scenarios* which would be included in our simulation model.
Two scenario themes were proposed by the researchers of the Study Site team to start the discussion:

1. The best use of the Mar Piccolo resources
2. The reduction in the negative impacts caused by discharges into the Mar Piccolo.

All the Participant Group expressed their interest in both the themes, and underlined that many aspects were common to both of them.

Particularly, Dr Calabrò (ARPA-Puglia) underlined the necessity to work together, CNR and ARPA, to organize an environmental data base available to all the people involved in the environmental management. All the efforts would be directed to have data *in continuum* on the chemical and biological contaminats of Mar Piccolo, due to both the discharges and also to the atmospheric *fall-out*. Also Dr Conversano, appreciate the opportunity to exchange informations with the SPICOSA researchers, mainly because many sanitary problems would be better solved throughout the ecological knowledge of the studied environment. According to Dr Conversano, the simulation models are very useful for the health questions. Dr Conserva, confermed us that mussels of the Mar Piccolo represent an important socio-economic source for Taranto, and it is auspicable to undertake studies to improve their quality. In its opinion, the ESE approach proposed by the SPICOSA project, could help more Politics to solve the management and the improvement of the local marine resources. CF Mancini and STV Lenti offered the availability of their data and informations for the SPICOSA purpose. Particularly, STV Lenti would furnish data on the mussel culture concessions and farmers.

At the end of the discussion, the Policy Issue was chosen: **"Including mussel culture in a management plan for the sustainable use of the Mar Piccolo resources"**. Connected to this Policy Issue three *scenarios* were also defined:

A. evaluating the environmental conditions controlling mussel growth
B. evaluating the measures and costs needed for sustainable mussel growth
C. evaluating the effects on human health, deriving from the exposure to hazardous levels of contaminants or microrganisms;

and nine baby-*scenarios*:

A1. To what extent would optimal environmental conditions reduce the costs of mussel culture and increase socio-economic benefits?
A2. What kind of indicators can we use to estimate the mussel growth based on different types of food?
A3. What would be nutrients target ratio in order to optimize MP productivity?
A4. To what degree are either contaminant substances or organisms inhibiting or endangering mussel growth?

B1. Are there other uses preventing better environmental conditions for mussel culture?
B2. What technological options or policy strategies are available to mitigate these damaging effects?

B3. What are the socio-economic consequences of these options or strategies?

C1. What are the implications to human health due to mussel uptake of hazardous substances or microorganisms?
C2. What are the health costs following the exposure to these contaminants?

By considering the three *scenarios* we have hypothesized that the price is due to the quality of mussels, evaluated by the condition index. This index has been calculated by means of a *formula* which combines the weight of the mussel and the length of the shell. The improvement of the mussel abundance and quality would be responsible for an increase of the local economy. The economic advantages will reflect also on the quality of life of farmers and of other categories of workers depending on the mussel selling.

Economic scenarios

The objective the economic model is to reproduce the economic conditions in which the mussel farm occur. This is done by carrying out simulations, starting from the current situation and analysing the behaviour of the mussel farm under different economic conditions. The two economic scenarios are:

Scenario 1: increase subsides and reduction of catches. In this scenario we will try to calculate how changing the income of a mussel farm when the catches are reduced and increase subsidies.

Scenario 2: reduction in tax; in this scenario we will try to calculate how changing the income of a mussel farm when the catches are reduced and tax are reduced.

In particular, the harvest is due to the function growth which determines the quantity as well as the quality of mussels. We have hypothesized three period with different percentage of catch, where each catch has a different price due to the quality level. We have determined the market price by using a formula which combines the quality index (conversion index) and the mean price. The revenue is given by multiplying the price and quantity of each catch; and the total revenues were referred to the real cash money period. We have assumed that revenue are 90% for cash while the remaining 10% are loans to customers. Customers debts will be transformed in cash in sixty days while debts to suppliers will be paid in sixty days. If the budget bank is positive we will have an active interest rate bank, on contrary we will have a negative budget with passive interest rate bank. The capital is given by the reserve, new contribution and part of profits reinvested and it can reduced by loss.
Moreover, we have considered the total costs borne by the mussel farm; which were referred to the real disbursement money period. We have also considered the possibility to immediately bear 90% of costs and to pay the remaining costs through debts to suppliers. Total costs are inclusive of trade costs (given by total revenues legal and revenues tax) maintenance costs, labor costs, insurance, daily costs, interest loan amortization share (if applicable), equipment costs, passive interest bank and VAT. In

particular the financial costs are given by multiplying the interest rate and the amount of the loan. The mussel farm can ask loans in case it has not exceeded the maximum amount the bank can grant. The maximum amount is a combination of both invoicing and the maximum percentage of loan granted by the bank. As for the loans we have taken in to consideration the amortization plan of the capital borrowed.

3 Scope and Methods for the interpretive Analyses

All details, relative to the mathematical formulation of the model, are shown in the DR. Here we are reporting only a summary of this formulation, by considering all the components.

Natural Component
In all the model, variables are calculated and updated at each time step using different equations. The whole model regarding the MP ecology, detailed in the DR, is reproduced considering the following processes, reproduced by considering different model blocks: **FRESH WATER CONTENT, ESTUARINE INFLOW and OUTFLOW, WATER VOLUME, OTHER CIRCULATIONS, FLUSHNG TIMES, INTERFACE DIFFUSIVE EXCHANGE, SALT BUDGET, NITROGEN, OXYGEN, PHOSPHORUS, PRIMARY PRODUCTION, POM** and **MUSSELS GROWTH.**
Among these blocks in this Report, we have chose the biological models, which better represent the link with the economic and social components.

1. **PRIMARY PRODUCTION: -** Three phytoplankton groups are simulated as in Lewis, 2005. Each has a different Growth curve, and different grazer population. The grazers are taken as proportional to the PP biomass. This will change when a ZP population is incorporated. Other changes to be made: observed radiation with absorption, and specific mortality rates. Light values are from observed irradiance - but KI is constant for all species. Grazing by mussels is considered depending on mussels' model.
2. **POM:** it will be soon available
3. **MUSSELS GROWTH:** Model Structure: 5 boxes (1 for Larvae, 2 (shell&meat) for Juvenile class, 2 (shell&meat) for Adult class. Mussels' larvae are considered like plankton and their preferred food is Microplancton. Larvae mortality rate is higher than juveniles and adult. No difference between shell carbon and meat carbon. Larval stade is 60 days. Mussels juvenile class growth is considered as a cycle lasting 65 days & dimension between 21 and 37 mm. The initial carbon content from larvae is equally divided between shell & meat. Mussels adult class growth is considered as a cycle lasting 240 days & dimension above 37 mm .Feedback on Primary Production by means of mussels grazing. Selective Feeding considered only for larvae. Shell growth was predicted using an empirical equation fitted on Mar Piccolo Mussels growth data (Corriero et al

2001). Meat growth (Temperature and POM dependent) was predicted using a growth equation as in Gangery et. Al. 2004. Carbon content per mussel as in Nalepa et al. 2003. Mussels physiological parameters as in Gragnery et al. 2004.

Economic Component
In the economic simulation we have hypothesized the whole Mar Piccolo as a one mussel farm. We considered one farm because mussel farm in Mar Piccolo are rather homogeneous (the same technology, the same production cycle, etc), being differentiated only by the size of the system of cultivation.

Social Component

Because of the difficult to apply mathematical *formulas* to the Social Components, we have could simulate only a little part of SC doing a very simple model with only one block and without equation. but with calculate, such as:

- The effective **number of employees** was calculated in base of the mq given in grant using the constant "employ_area" .
- To **calculate travel cost** for all the employees for each type of farms, we multiply the distance to work for tarantine employees and for outside employees for the km cost and we sum them.
- To have **total costs** we have to sum the total mean family costs, total mean sanitary costs and total travel costs in mean for every type of farm (small, medium and large) and summed each other.
- To calculate the **income**, that represents the **labour cost** of Economic part, we sum the mean legal income and the mean illegal income and multiply for every category of farms.

4 Representation of System Function

Respect to the Design Step, we have made some changes in our Conceptual models. Particularly, they have been make more simple, by taking into account that many data aren't available (natural, economic and social). Furthermore, taking into account the complexity of the ESE system, we prefer to have a simple model which would be implemented with other blocks and new data.

5 Description of ESE Linkages

The main linkage between the **NC** and the **EC** is represented by the quality of the mussels, which has its effect with the prize; but mussels represents also the linkage with the **SC**, because they represent the matter of working for the farmers. The link between the **SC** and the **EC** is determined by the income of mussel culture farmers that represents the labour cost of the Economic model. Moreover, calculating the route that

mussel culture farmers cover everyday to arrive to works from their house, we have a link also between the **NC** and the **SC,** in fact we'll consider the environmental impact of the long commute.

The link between the biologic and economic model is determinated by the quantity and the quality of mussels. . We have hypothesized three period with different percentage of catch, where each catch has a different price due to the quality level. We have determined the market price by using a formula which combines the quality index (conversion index) and mean price.

6 Description of Hindcast Results

Concerning the NC, we have choose as time duration **10** years, taking into account an event which occurring starting from 2000. In the past, the sewage pipes of Mar Piccolo were 14 (5 at the First and 9 at the Second Inlet), coming from the northern area of Taranto and from 8 nearby towns and they weren't subjected to depuration. These wastes amount to about 18,272 m^3 d^{-1} (of which 85% at the Second inlet), with organic matter equal to 6,767 kg d^{-1} of BOD_5 (Cardellicchio et al., 1991). The daily input of nitrogen and phosphorous were 17,2 t d^{-1} and 0,3 t d^{-1}, respectively.
Starting from 2000 the number of sewage pipes has been reduced to the actual 5 (1 at the First and 4 at the Second Inlet) and are all subjected to depuration. The levels of organic matter, nitrogen and phosphorus have been drastically reduced. The quantification of such a reduction of the sewage input will be done by using the rare data collected by the Provincial Environmental Office, after the necessary statistical and mathematical elaborations to fill gaps.
The effects of such a reduction are evident by considering the first level of the food chain, phytoplankton. The features of this planktonic component seemed to have influenced the quality of the mussels in Mar Piccolo. Such a modification have its effects on the EC of MP, based on the mussel culture and on the SC, represented by the farmers and all people depending on such economic source. For the EC and SC, we have chosen as time duration **5** years, because in this last period the problems connected to these Components have been becoming more urgent.

7 Assessment Plans for ESE Components

In order to evaluate the system's response to the selected Policy Issue, which foresee the inclusion of the mussel culture in a management plan for the sustainable use of the Mar Piccolo resources, some simulations will be undertaken. These simulation will be carried out the *scenarios* and baby-*scenarios* chosen by both the researchers and stakeholders. All these scenarios include the ESE components and particularly the first *scenario* mainly comprises the Natural Component whereas the second and third the Economic and Social Components.

Natural Component

The main environmental factor which would be considered as the responsible for the decline of the mussel biomass and quality, the latter expressed as a reduction of the condition index, is the reduction of organic matter input in Mar Piccolo. In fact, until 2000 in Mar Piccolo there were 14 sewage pipes coming from the city of Taranto and from 8 nearby towns. In a gradual way the number of the sewage pipes has been reduced and today they are 5 (Fig. 1 reported in the DR).

The result is a reduction of **NUTRIENTS** and a changing N:P:Si ratio which is responsible for a changing of the **PHYTOPLANKTON** physiognomy in Mar Piccolo. Particularly, by considering data of the previous ten years, it has been observed that the nanoflagellates abundance is growing respect to diatom abundance. The quality of the main food resource for **MUSSELS** is changed. We know by the literature, that the main food source for mussel in brackish and enclosed ecosystems, is phytoplankton. But mussels can use also other resources, such as **POM** and **ZOOPLANCTON**. In fact, some recent studies aimed to investigate on the phytoplankton contribution to the mussel diet on the basis of the fatty acid analysis, evidenced that mussels collected in the Mar Grande of Taranto feed very little on phytoplankton.

By using our model, we'll simulate a variation of chemico-physical variables and the nutrient input in the basin to evaluate both the effects on the abundance of the primary feeding source for mussels (phytoplankton, POM and zooplankton) and their growth. Also the quality of the food, expressed as phytoplankton species composition will be modulated to simulate the effect of the quantity (biomass) and quality of the mussels. Particularly, the length/weight ratio (conversion index) of the mussels will be considered as an index of their quality.

This kind of simulation is enclosed in the first of our *scenario*: "**Evaluation of the environmental conditions controlling mussel growth",** and particularly in the **A2** ("What kind of indicators can we use to estimate the mussel growth based on different types of food?") **and A3** ("What would be nutrients target ratio in order to optimize MP productivity?") baby-scenarios. Concerning to the **A1** baby-*scenario* ("To what extent would optimal environmental conditions reduce the costs of mussel culture and increase socio-economic benefits?"), it will be enclosed in the simulation model of the Economic Component.

The main results which we would obtain is the knowledge of the best theoretical nutrient-ratio for improving the mussel growth. All the possible alternative strategies to obtain such objective will be also considered. If the solutions wouldn't be applicable to the Mar Piccolo ecosystem, other alternative uses of the basins will be considered and simulated under the integration of the socio-economic analysis.

Economic Component

We will try to use models of environmental accounting of mussel farm to know the business profitability and environmental sustainability. This analysis will measure the economic and environmental effects of mussel farm; in fact we will reclassify the costs and revenues to understand the environmental sensitivity of the various mussel farm (see Regazzi D, 2005). We will identify the mussel farm more efficient and then we will take it

as an example for better economic and environmental management of other mussel farm in Mar Piccolo.

Social Component

At the end of the discussion of 30th May 2008, were defined three *scenarios* and the first one and the second one are still now valid, whereas the third one, the social scenario, is changed because of difficulty to find several data.

The current scenario is the "**Evaluation of the level of quality life of mussel farmers".**

The social context of Taranto and in particular of mussel culture in Taranto is characterized by a high presence of the underground economy and a high presence of illegal cultivation of mussels causing complex economic dynamics. The result is a general worsening of the level of quality life.

By using our model, we'll simulate the route that mussel farmers cover everyday to arrive to works, the environmental impact of the long commute and the repercussions in the market. In fact, if the most part of mussel farmers don't live in Taranto, they're going to spent their money elsewhere, putting away the wealth from one's local economic system and will produce an environmental impact, too. Moreover we'll calculate the most important costs for the employees (travel, sanitary and family costs) that influence the quality of their life.

The main results which we would obtain is the knowledge of the best theoretical typology of mussel farmer and the possibility of embark on a new enterprise: the "mussel-tourism". It consists in a type of tourism that advantages the mussel culture permitting to people the knowledge of the methods of mussel growth. It could permit, also, constant income for the admin that could reinvest in the improvement of the structures.

References of the Economic Component

Lleonart J, Maynou F, Recasens L, Franquesa R. *"A bioeconomic model for Mediterranean fisheries, the hake off Catalonia (western Mediterranean) a case study"* SCI MAR 2003, 67(Suppl.1): 337_351.

Regazzi D. *"Acquacoltura sostenibile: Strategie, vincoli ed opportunità per allevamenti in acque interne in Emilia-Romagna e Toscana"* Franco Angeli 2005.

Boatto V, Pellizzato M "La filiera della vongola: Tapes phippinarum in Italia" Franco Angeli 2005.

Idda L "Pesca ed Acquacoltura in Sardegna: Competitività Sostenibilità Politiche Strategiche" Gallizzi - Sassari 2005.

Mattos S, Maynou F and Franquesa R *"A bio-economic analysis of the hand-line and gillnet coastal fisheries of Pernambuco State,North-Eastern Brazil"* SCIENTIA MARINA 70 (2) June 2006, 335-346, Barcelona (Spain) ISSN: 0214-8358

Tibor Neugebauer *"Bioeconomics of sustainable harvest of competing species: a comment"* http://129.3.20.41/eps/othr/papers/0503/0503012.pdf

Antonelli G, Bischi G.I and Viganò E. *"La sostenibilità nel settore della pesca. Modelli, politiche, esperienze in un'area del litorale romagnolo-marchigiano"* Franco Angeli 2005.

Spagnolo M. *"Modelli bioeconomici per la gestione della pesca in Europa"* Rubbettino 2008.