Report for Appraisal Step

for deliverable D7.4

short version

<Mar Piccolo of Taranto>

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WT 5 ESE COMPONENTS

GENERAL

1. General Description

Mar Piccolo is a shallow, nearly enclosed estuary of 21 km^2 consisting in two basins separated by an intruding promontory (Fig. 1). The basins are referred to as Seno I and Seno II and have maximum depths of 13 and 10 m, respectively. The exchange with the larger semi-enclosed bay of Mar Grande occurs through a primary artificial navigation channel and a small natural inlet. Mar Grande opens into the Gulf of Taranto and the Ionian Sea. The circulation in Mar Piccolo is driven by a positive water balance (runoff + precipitation – evaporation >0) of ~23 million m3/yr. The flushing (~ 2-3 mos), due to the exchange through the inlet is moderate and varies seasonally depending on the pressure differences with the Mar Grande. During summer season a sufficient stratification develops that can induce hypoxia in the lower layer. This causes a decrease of the benthic production. Wind mixing is low due to the limited fetch and tidal-mixing is low due to the limited tidal range of ~ 30-40 cm.

Mar Piccolo is strongly utilized by an intensive mussel commercial fishery, the moorage for the region's fishing fleet, the largest Italian naval base, while the activities of a large heavy-industrial site are located immediately adjacent to the west. The heavy industry and navy docks are two of the main employers at Taranto. The steel industry strongly influences the environmental quality of water and sediments, not only through the emissions into the atmosphere but also through the water-uptake for cooling a power plant. The drainage of agricultural soils and the sewage inputs are also important factors that influence the water and sediment quality. Mar Piccolo is one of the Sites of National Interest for the highly polluted areas.

Changes in resource-use have characterized the city of Taranto in the last decades. Particularly, the heavy industry (stainless-steel, oil refinery, cement manufacture) was established in Taranto some fifty years ago (second half of the 1950s) completely changing the economy of the city and Province, which were primarily based on agriculture, aquaculture, and naval port space. During this period, the population of Taranto grew to over 280,000 inhabitants from 150,000. Severe social problems have arisen recently, especially when the steel industry, which had hired more than 22,000 employees, reduced its employee force to the present level of 8,000. These problems have strongly influenced the quality of life and safety.

These changes have brought about Policy changes in an attempt to better manage the Mar Piccolo ecosystem. During the 2000-2003 interval, much of the sewer discharges were combined and moved to an outfall outside Mar Grande. Concurrent with the lessening of the sewer discharge, a more liberal policy was enacted that allowed mussel farmers to expand the areal extent of their nets. Despite the longstanding reputation of the Tarantine mussel, the production in recent years has been fraught with high variability and declines in the mussel quality. In addition, attention is being focused on problems associated with inorganic pollution, e.g. an initiative to plan an intervention for cleaning sediments and reducing pollution. Regional Programs also include interventions for the characterization and recovery of surrounding sites that may indirectly influence the quality of the basin.

Fig. 1. Image of Mar Piccolo located near the heel of the boot of Italy. The symbols delineate the complexity of this coastal area, i.e. the City of Taranto in the bottom left, the industrial park in the upper portions, the areas used for mussel culture, and numerous discharges, channel outlets, and aquifers.

2. Status of Policy Issues and Scenarios

<u>2.1 Participant Group</u>

In the first two meetings with stakeholders (4th and 17th October 2007) we presented the SPICOSA project and inform that about the role which stakeholders should have had in it. They demonstrated interest in both our meetings and actively participated at the discussions. The stakeholder partners have been identified as follows:

- Regional Environmental Agency of Apulia Region (ARPA Puglia)
- Province of Taranto (Productive Department)
- Province of Taranto (Environmental Department)
- Province of Taranto (Tourism Department)
- Municipality of Taranto (Ecological and Environmental Department)
- Municipality of Taranto (Productive Activities)
- Municipality of Taranto (Culture and Tourism Department)
- Health Board in Taranto (ASL TA)
- Harbour Board in Taranto
- Harbour Office
- Chamber of Commerce (handicraft and agriculture)
- Industrial Handcraft and Agricultural board of trade
- Heavy industry Representatives: oil refinery - Eni Spa
stainless-steel industry - ILVA Spa
- Environmental Associations : "Amm. Michelagnoli" ONLUS Foundation
"Verdi", Political Organization
- Mussel farmers representatives (OPTIMA srl)
- Local Universities representatives (Universities of Taranto and Bari)

In date of 30th May 2008, we held the third meeting and the stakeholders were reduced to the "Partecipant Group" (PG). They were representatives of Public Corporations and Private Representatives were excluded. The main objective of this meeting was to choose the *scenarios* which will be included in the simulation model.

The PG was 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 chosen 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. Thy were more cooperative respect the first two meetings, and they demonstrated to have better understood the aims of the Project. Furthermore, they felt to be more involved respect to the other stakeholders in the strategic choose of the scenarios.

Particularly, 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 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 Conversano, the simulation models are very useful for the health questions. 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.

2.2 Policy Issue.

Of priority for the PG was their concern about the Impacts related to the decline in quantity and quality of mussel aquaculture. Framing this concern in the broader context of ICZM resulted in a Policy Issue of *"How to include mussel culture in a management plan for the sustainable use of the Mar Piccolo resources?"* Implicit in this Issue is the question of whether it might be possible to compromise between economic, social, and ecological costs and benefits, which is of course an excellent objective for the SAF.

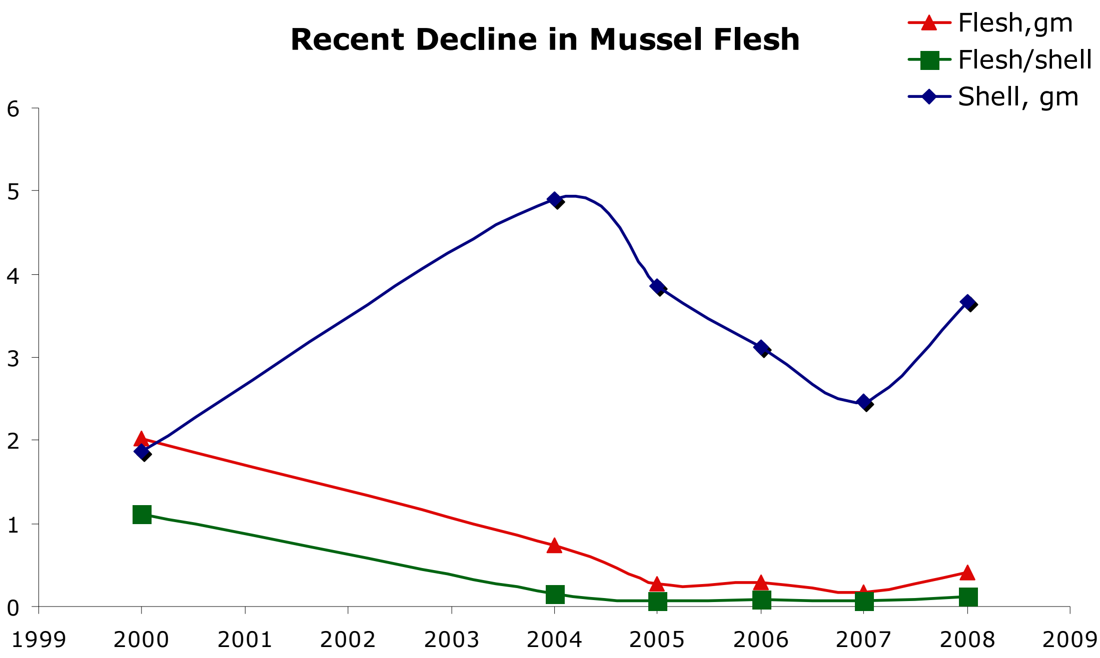


Fig. 2. The plot illustrates changes in the mussel flesh and its shell in grams together with the flesh/shell ratio, which is an indicator of mussel quality. Recent trends in the decline in quality relative to the healthy level existing prior to 2000 coincide with the policy changes concerning waste discharge and mussel farming practices. *Note, the only comparative data is actually from the 70s long before the policy change.*

2.3 Scenarios. The simulation analysis and model construction are focused on three main scenarios, each of which have several scenario options.

1 What are the environmental conditions that control or are causing the mussel decline?

1a. To what extent would optimal environmental conditions reduce the costs of mussel culture and increase socio-economic benefits for employees?

1b. What would be optimal forms of mussel farm: cooperatives or consortium?

1c. What kind of indicators can we use to estimate the mussels growth based on different types of food?

1d. What would be nutrients target ratio in order to optimize MP primary production?

1e. To what degree are contaminant substances or organisms inhibiting or endangering the mussels' growth?

2 What would be the costs and benefits derived by enacting the measures needed for sustainable mussel growth?

2a. Are there other uses preventing better environmental conditions for mussel culture?

2b. What technological options or policy strategies are available to mitigate these damaging effects?

2c. What would be the Cost and Benefits of a Depuration Plant? What would be optimal type of Depuration Plant: Traditional or Natural?

2d. What are the socio-economic consequences of these options or strategies?

3 What are the potential benefits derived from a healthier ecosystem achieved through an improved waste management plan and cleaner shores, and more public facilities connected with the Mar Piccolo?

3a. Health and exposure to pollution.

3b. Shoreline park with accommodations.

ECOLOGICAL COMPONENT

1. Conceptual Diagram of model organization.

1.1 Conceptual Diagram.

The conceptual diagram helps in visualizing the function of the primary components of the ecosystem and their connection with human activities and links to socio-economic dynamics to be considered (Fig. 3).

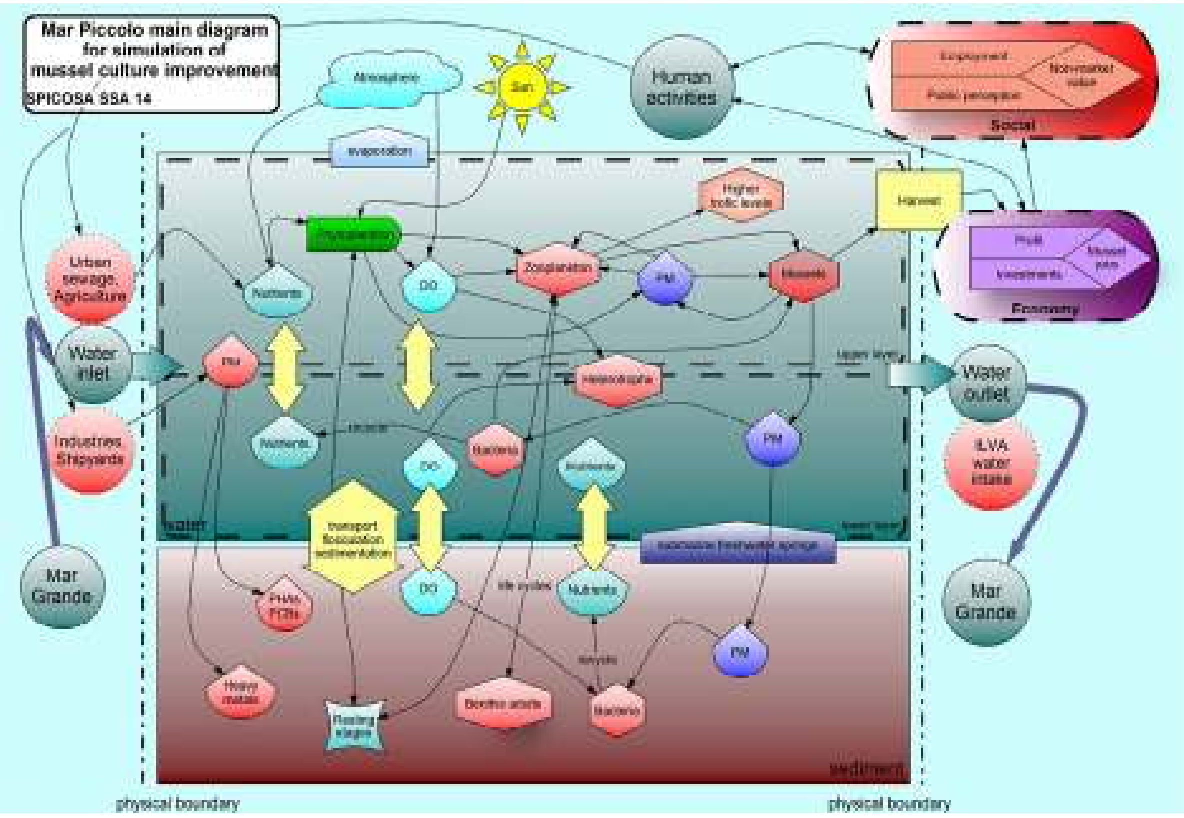


Fig. 3 This diagram represents the VS functionality with regard to the Impact (reduction in mussel size) and the causal set of environmental conditions driven by its waste discharges. Connections to the socio-economic components are shown and further discussed below. *Note. This diagram needs some modification to accommodate recent changes.*

1.2 Ecological Model Organization.

From the Conceptual diagram, we have constructed an Extend model, the organization of which, follows the functional cause & effect chain by identifying clusters of processes that represent a larger discrete function within the modeled system. These we refer to as functional components and they are expressed in the software as Hierarchical Blocks (HBs). The following paragraphs provide brief descriptions of these HBs in order to explain the relevance and formulation of the HBs as numbered left-to-right in Fig. 4.

The model is deterministic in the sense that it is driven by its external inputs of meteorology, light, external salinity variations. The land runoff, nutrient, and organic loading are calculated using available observations of these and of the river and aquifer flows. The representation of the phytoplankton community is based on observed data. The model will be calibrated over an extended period (2002-2004), over which there are reasonable data, to provide credibility for shorter-term prognostic scenario runs. If this is successful, the model will be extended back to include the policy changes of 1998-2001 period.

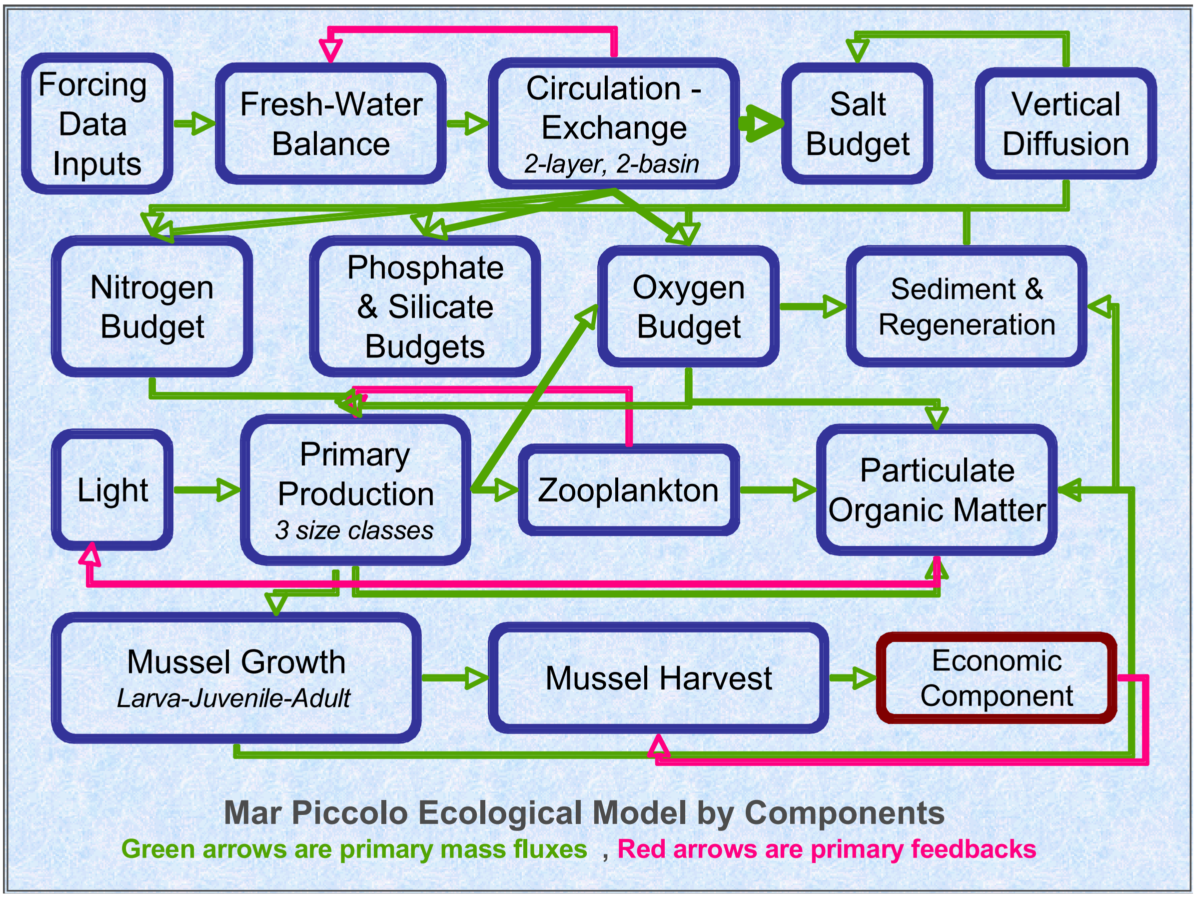


Fig. 4. The major components of the Ecological Component model for the Mar Piccolo. Only the primary interactions are shown.

2. Describe the scope and function of model.

2.1. Scope.

The model is constructed to determine the potential Mussel harvest in Carbon based on the photosynthetic capacity, which in turn is driven by the nutrient discharges and controlled by the available light and the circulation. The mussel harvest is the main link with the economic component. The ecosystem health is a direct connection to the social component through public perception and an indirect (through harvest) and a direct connection to the social component.

The Mar Piccolo has two basins, which could be treated as a single basin or two interacting basins. After the construction of the Ballpark model and the organizing of data, we decided to construct sub-models for each basin mostly because there is a small but significant difference in the mussel harvest from the two basins. By so doing, we would be better positioned perhaps to understand how the differences in environmental conditions influence the growth of the mussels. The Social and Economic Components, for the most part, do not make this differentiation.

2.2 Purpose.

The purpose of the model is to represent the productive capacity of the Mar Piccolo in response to the specified scenarios, primarily having to do with nutrient discharges. This will involve predictive simulations of the primary and mussel production as result of the WWTP options. Future predictions will use a mean-weather as input and variations on the relative discharges. Weather-event predictions will use historic data with events or trends superimposed. All of the ecological response information will feed the economic assessments concerning the costs to change the discharges against the benefits gained by the mussel farming and by the city through improved shoreline use and water quality. Further explained in Socio-Economic Components.

3. Functional Component descriptors.

3.1 Input & Calibration Data.

Input Data*.* The input data gives the model most of its time dependence. In a simulation, it represents the connection of the system to the outside world. For the ecological model the main inputs are:

a. Meteorology. wind, air temperature, relative humidity, cloudiness, and precipitation.

b. Light. Surface light radiation.

c. Marine. Salinity, and nutrients external to Mar Piccolo.

d. Fresh Water. Fresh water runoff derives from numerous sources, including small streams, aquifers, and discharges both channels and outfalls.

e. Substance discharges. Nutrients, BOD, PAH.

These data were mostly in the form of annual averages and none in dailygauged values or from all sources. Simulation of daily values is explained below. In case of missing data, values were used from similar sources.

Calibration Data*.* Calibration data for most of the primary variables was available from oceanographic observations.

a. Salinity & Temperature. Biweekly data were available from vertical casts at several monitoring stations within each basin of MP. These had to be edited for errors and averaged to the corresponding layer depths. Station location and quality varied such that horizontal averages were not always taken from the same set of stations, but they were always from the center of the basin.

b. Nutrients. Only surface values of N and P were available, making the indicative of time trends and rough values for the concentrations.

c. Oxygen. The dissolved oxygen was sampled similarly with the temperature and salinity. The data quality was not entirely adequate but sufficient for rough calibrations.

b. Chlorophyll & Organic Matter. These samples were also only taken at the surface, similar to the nutrients.

Status & Comments. The above data have be treated for gaps and errors and are available in xls files to be sent to WP9 after final calibrations and inclusion of the data from the first basin.

3.2 Fresh Water Balance.

Description. The freshwater balance represents the sum of the rain on the estuarine surface, the land runoff, and the evaporation from the surface. The observed rain is used. The evaporation is calculated using the water-vapor pressure and temperature differences, and the surface wind. The runoff is estimated (below). In this block, the FW in both the layers is calculated. Reference salinity is chosen to be a deep value in the Gulf of Taranto. The actual value is immaterial except that it is numerically better to avoid negative values for the freshwater content. Consequently, the inflow will inevitably import some freshwater to the bottom layer.

Approximations. The annual mean values were available for most of the river and aquifers. Although not for the same year, these values served as a basis for simulating the daily time series for the land runoff. For the rivers, a value for the base flow was selected ~25% and the remainder were based on the rainfall, the recharge area, and the yield. These last two parameters were estimated but were adjusted to match the annual mean flow normalized to the annual precipitation of the current year. The thus calculated runoff was redistributed in time to a running, lagged Gaussian distribution, amounting to a peak delayed skewed over 1-3 days (Fig. 5). A similar approach was used for the aquifers. For the estuarine land surface runoff an area and yield was also estimated. These were important in the sense of sources of nutrients and contaminants. These approximations provide better resolution in time for the model, which is necessary to capture runoff events, such as storms. This variability is very important to both the physical and biological dynamics of the Mar Piccolo system.

Comments. Inevitably, there are uncertainties in the total FW Balance. These are treated as one of the unknowns in the salt balance of the estuary. In the calibration mode, the total amount of FW can be adjusted to match the observed salt in the system. This confirmation greatly assists in calibrating the exchange but leaves some uncertainty concerning among the individual runoff sources of fresh water.

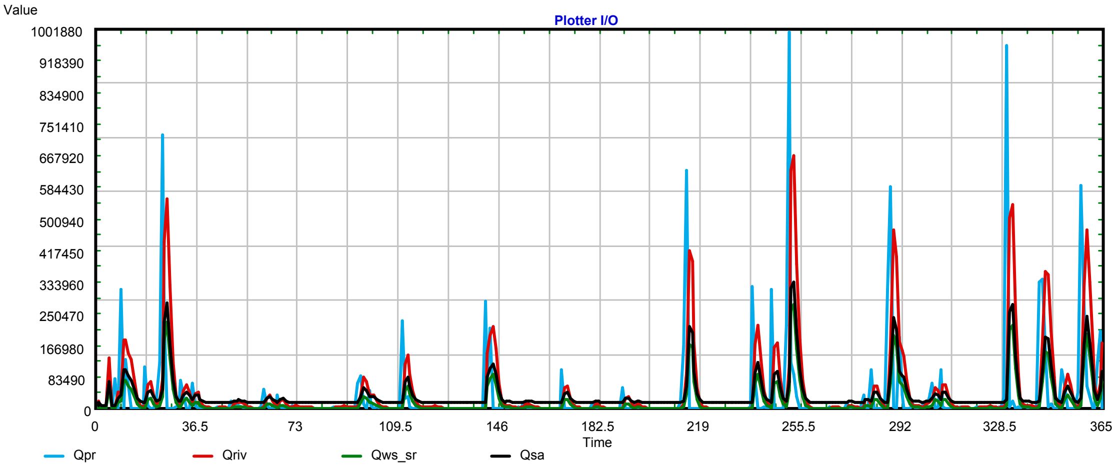


Fig. 5 The various runoff components freshwater input (m^3 d^{-1}) to Mar Piccolo in 2003: rain on lake (blue), rivers (red), peripheral land runoff (green), and aquifers (black). The different components have a lagged response to the rain depending on type; i.e. rain, river, land runoff, aquifer, and discharge.

Status. The model formulation is verified. We have exhausted our potential sources of data concerning the inputs and their substances. We are in the process of connecting the two basins after which the data will ready for archive submission.

3.3 Circulation Exchange.

Description. An approximation of the Thermo-haline Exchange Method (TEM, Hopkins, 1999) is used to derive the formulas used in this panel. The TEM is valid between any two points (areas) of the ocean, sea, estuaries, except that for less enclosed systems there are more degrees of freedom for exchange between two points. This is because the method relies on Continuity (conservation of mass), which is more easily applied to a situation with only one narrow opening. This means that for enclosed seas with wide openings, the method would only calculate the net exchange, i.e. not water re-circulated horizontally through the opening. The Mar Piccolo inlet is quite narrow with a width of 58 m.

The two-way exchange is directly related to the strength of the baroclinic and barotropic pressure gradients that are formed in a semi-enclosed basin when the internal density and the sea level differ from that of the larger adjoining sea. Thus, the exchange can be expressed as a simple draining relation in which these inter-basin pressure gradients determine and the exchange, i.e. the exchange is proportional to the force that creates it. The frictional constraints of the strait or opening to the sea add some additional non-linearity, which can be approximated as an opposing body force to the inter-basin pressure gradient. The baroclinic pressure gradient is always relative to the sill depth separating the estuary from the external sea at locations away from the immediate connecting waters. Simplifications permit formulation of the net inflow and outflow. However, several approximations of this formulation render a simple expression that requires calibration for a particular application through the salt balance (Fig. 6).

Two possible formulations can be used with the TEM, which differ depending on the relative importance of temperature in determining the inter-basin pressure gradient. That is, for estuaries where the temperature difference (outside minus inside) is not negligible requires that the full calculation of the densities must be used. Otherwise, the Fresh Water Height (amount of FW in a water column (cm) can be used as a proxy for the steric height (cm) determined from the density. We have used the former, because there is little observed temperature difference between the Mar Piccolo and the Mar Grande, and because in order to fully use the density version of the method, one must have good meteorological data to generate the surface heat balance of the basin.

Comments. The three control parameters used for calibrating the circulation are those controlling the diffusion, the freshening of the system, and the rate of exchange with the exterior sea. In the model these are expressed as:

a. A diffusion parameter (diffparam) controls the salinity difference between the layers.

b. A constant parameter (alpha) controls the draining efficiency of the thermo-haline circulation, which acts to bring in more salt.

c. An adjustment parameter (FWfrac) controls the amount of freshwater entering the system, i.e. in the event it has been estimated.

In theory if the input data were all well observed, the only two unknowns would be the diffusion parameter and the draining constant, for which the two salinity equations provide sufficient calibration. We have assumed a first guess on the FW runoff and then calibrated the model to the salinities including the FWfrac control. We then correct that discharge, which is the least known of the inputs, e.g. in this case the amount of urban runoff from the city of Taranto.

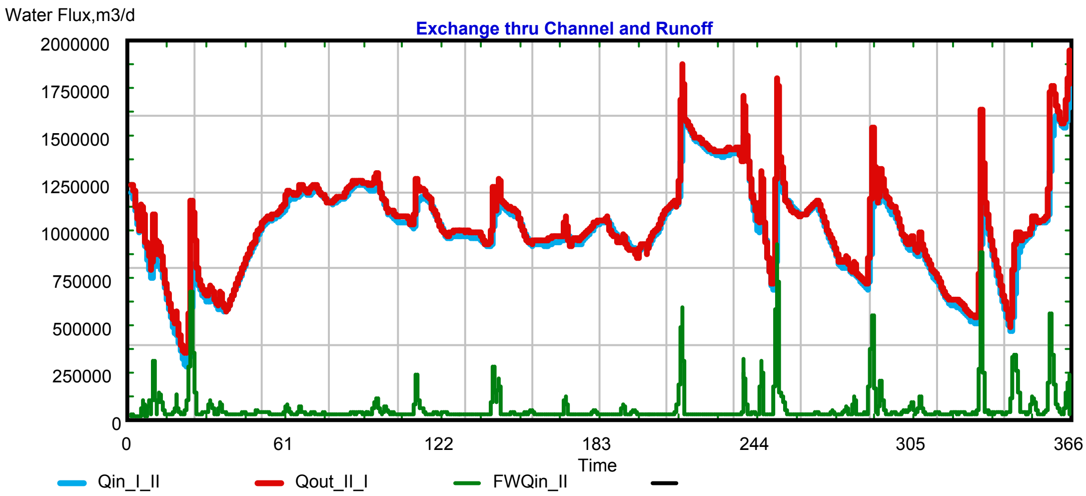


Fig. 6 The inflow (blue), outflow (red), freshwater inflow (green) transport for the test year of 2003. Note, the exchange decreases exponentially with a cessation of freshwater input but increases linearly with pulses of freshwater.

3.4 Salt Budget.

Description. In this HB, both the total salt in the surface and bottom layers are calculated by simply keeping a running account of the amount of salt brought in to the bottom layer of inlet, that diffused up to the upper layer, and that exiting the inlet. Salt is a conservative parameter without internal sources or sinks.

Comments. Over long periods, the mean total salt is relatively stable to the degree that the long-term freshwater balance is relatively stable. In the shorter term, the total salt may vary according to excess, or lack, in the fresh water supply. This variability in the simulation and in the observations is illustrated in the test year shown in Fig. 7. The salinity thus provides a good constraint on the calibration, i.e. an increasing error (in the fit between model and observations) over a long simulation would indicate an error in the formulation of the circulation or in the FW input values.

We note that the model is calculating the vertically and horizontally averaged salinity and the observations are vertically averaged to the same depth (4.5m) but are not comprehensive in the horizontal.

Status. While the model aspect of this component is complete, we are waiting to combine the two basins so that the exchange between them will change these plots slightly, i.e. we are now using observed values in the first basin as input instead of calculated values.

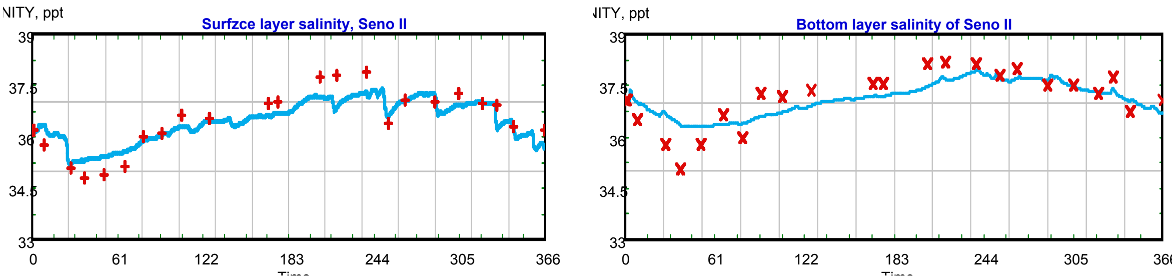


Fig. 7 The surface salinity (left panel) and bottom salinity (right panel) in Seno II, with observations from three centered stations, for the test year of 2003.

3.5 Vertical Diffusion.

Description. In this HB, we simulate the turbulent mass exchange through the pycnocline, in which volume is conserved, but salt is exchanged. The diffusion process itself approximates smaller-scaled processes that consort to cause the diffusive flux. The magnitude is inversely related to the salinity gradient and directly related to the KE available to produce the shear condition at the interface necessary for a diffusive process. Several levels of approximation are possible. Without this process, the bottom layer would have no mechanism to lose salt to the upper layer. It also produces a gain of salt the upper layer along with the process of entrainment. Here we have approximated the KE by using the entrainment velocity to represent the KE and the difference between the surface and bottom salinities to represent the salinity gradient.

Comments. This diffusion coefficient is parameterized using the wind energy, assuming that it generates most of the small-scale KE promoting the diffusive process. Note, this parameterization is not the most rigorous, but it allows us to calibrate the observed vertical salinity gradient with a single parameter. This is a good example, where we are not interested in exploring the actual diffusion process, but only in simulating the mass exchange in the vertical. Obviously, the parameter valid for Mar Piccolo would not be valid for other basins with differing conditions.

Status. This representation is satisfactory for our needs. However, we would recommend that it be used only as a tutorial example for the Model Library.

3.6 Oxygen Budget.

Description. The oxygen is modeled because hypoxia is a concern with respect to mussel growth, and it is a key indicator of several essential processes, which help considerably in calibration. For the surface layer, the main sources are those due to photosynthetic production, diffusion from the atmosphere, entrainment from the bottom layer, respiration from phytoplankton, mussels, and other heterotrophs (constant), and due to diffusive loss to the bottom layer. Note, net benthic production is considered to be in balance with its respiration. For the bottom layer, the sources are those of diffusion, advection (from Mar Grande and aquifers); and the losses are those of entrainment and respiration (benthic and pelagic).

Comments. The available observations are of only marginal value for calibration, however, enough observations do exist to assure that the oxygen budget remains within reasonable bounds. The calibration curves in Fig. 8 show reasonable agreement. The quality of the oxygen data is somewhat in doubt, however, we don't think that we can attribute the noticeable lack of a strong oxygen gradient to instrumental error. That is, with strong surface production one would expect hypoxia to exist in the lower layer; however, the bottom layer is not isolated by a sill and it receives considerable inflow from bottom aquifers.

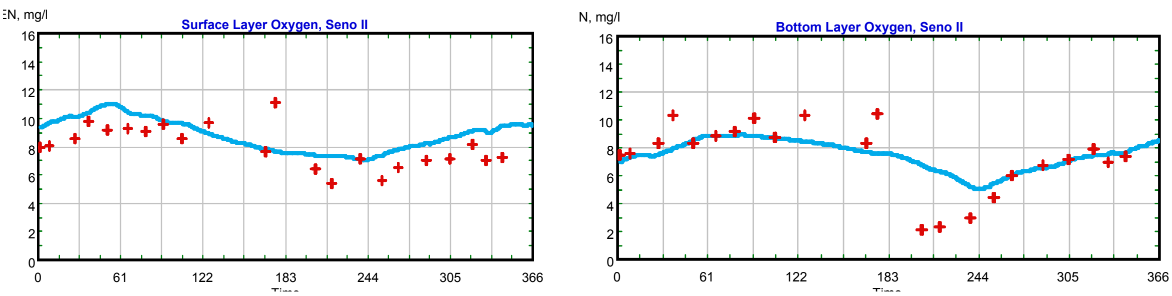


Fig. 8 The surface (left) and bottom (right) layer concentrations of oxygen for the test year of 2003. The red crosses are the observed data points.

Status. The oxygen component is not quite finished. We need to insert some estimate of the combined oxygen use of the bottom sediments. We will use rates from comparable shallow, eutrophied seas in the Mediterranean. In addition, the oxidation rates do not yet have a temperature dependence, which undoubtedly would reduce the bottom DO during the summer.

3.7 Nitrogen.

Description. In constructing the N budget, we assume that only the nitrogen stored in the top layer is available for photosynthesis and that not all of this nitrogen is immediately available for primary production, i.e. some might be of terrigenous origin. Restricting production to the top layer is based on annual observations, which return the same mean depth (+ 1 m) for the Secchi disc as with the pycnocline depth (5 m and 4.5 in Seno I and II), respectively. It exists benthic production but this is almost entirely restricted to the depths less than the 4.5 m surface layer.

The surface layer receives inputs from the atmospheric deposition, the land runoff, the surface discharges, and from the bottom layer, via entrainment and diffusion processes. The surface layer loses nitrogen through phytoplankton uptake, advective outflow, and sinking to through the pycnocline. The bottom layer gains N from regeneration, advection, and it loses N to the upper layer through the same entrainment and diffusion processes and through burial (in the form of POM). These Nitrogen processes are formulated as follows:

a. Entrainment, as an upwelled flux of bottom water;

b. Diffusion, as proportional to the vertical N-gradient using the same diffusion coefficient as Salinity;

c. Uptake, as the amount available up to the saturation value (associated with each of the three phytoplankton classes);

d. Sinking, calculated as a constant percent of the surface POM sinking to the bottom layer and converted using the weight N:C ratio. The sinking rate takes into account the opposing upwelling rate of entrainment.

e. Regeneration, calculated through a conversion algorithm between POM produced by phytoplankton with stechiometric ratio of N:C while sinking out of the surface layer at rates increasing with temperature. A contribution due to ZP grazing is also added. However, the regenerated N produced locally in the second basin or the organic nitrogen excreted by the mussels is not yet included. There were no observations available to calibrate the bottom N, which is ~3.5 times that of the surface N values. As an option we will compare the final bottom N level with the excess amount of N in the bottom layer relative to that in the supplying inflow.

f. Advection, as the flux of inflow or outflow times the N concentration;

g. Sediment burial, as approximately equal to literature values for similar deposition rates in estuaries, e.g. ~10% of new N inputs (ibid.);

h. Denitrification, as proportional to the bottom oxygen values and calibrated to satisfy the total N budget. For the current model the percent denitrified is 45% of the external inputs (runoff, discharges, etc.).

Comments. The nitrogen values for both layers are shown in Fig. 9. The observations used for calibration were only sampled at the very surface and might represent an underestimate for the surface layer; and there are no observations to check the bottom layer concentrations. The total new N reflects the seasonality of the rainfall and at a shorter time scale the larger runoff events. The regenerated total N is low and gives an average f-ratio of 0.85, which is low because our formulation is not complete.

Status. We are improving the regenerated balance by including the PON contribution from neither the mussels nor the re-entry of bottom regenerated N produced in the surface. These changes will decrease the f-ratio to levels comparable with other Mediterranean coastal seas, e.g. as the Northern Adriatic ~0.67 (Hopkins, 2001). Also, we expect the connection with the first basin will alter this N budget.

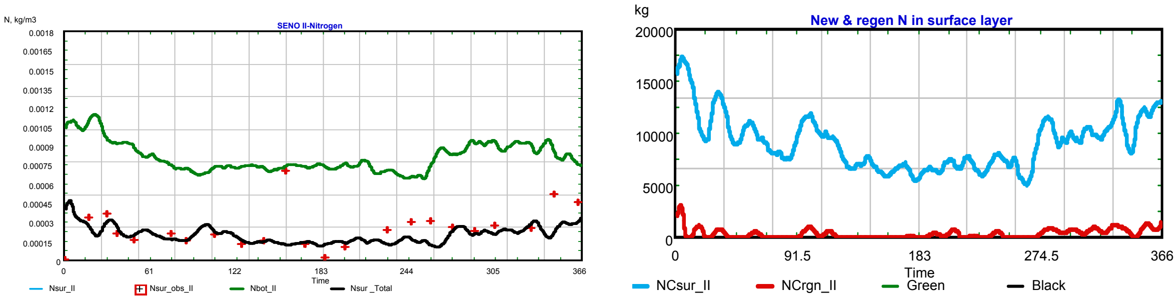


Fig 9 The left panel shows the total N of the surface layer (black) and the total for the bottom (right) using concentrations in kg m^{-3}. The red crosses are the observed data points. The right panel shows the total N in kg of new N (blue) and regenerated N (red).

3.8 Phosphorus & Silicate.

Description. The purpose of modeling the phosphorus and silicate concentrations is to retain information concerning any threshold limits with respect to the N concentrations as controls for the growth and community structure of the Phytoplankton classes. The processes formulated are:

- P uptake, as dictated by Redfield ratios;
- P regeneration, as a percentage of the phytoplankton biomass, assuming rapid regeneration, in the surface layer; and as a percentage of the POC in the bottom layer; and
- P burial is considered negligible.

Comments. We have ballpark representations of these components, but have not included them in our current model because of uncertainties in their role as limiting nutrients and how to formulate these, e.g. to express the very short and longer time scales for P regeneration. There are also large uncertainties in the P input values, e.g. for those connected to agricultural runoffs.

Status. When we will have confidence in our model and know better how and if these nutrients can be limiting, we will add them during Appraisal Step. In addition, we need to explore better to WWTP options for providing an option for nutrient management.

3.9 Particulate Organic Matter.

Description. POM eventually is consumed or settles to bottom layer is buried or respired. Our purpose in simulating this is that it constitutes the food source for the mussels. However, its composition and trajectory through the system is complicated to be represented. We focus on the POM produced by phytoplankton within the system as likely the most important component. This component is taken as equal to the mortality component of the phytoplankton production, i.e. due to natural death excluding grazing. The sinking rate is slowed by the opposing upwelling speed. Both surface and bottom layer accumulations are budgeted similar to the nutrient budgets except that diffusion is not considered significant for particulate matter. That is, the surface layer receives POM from all the FW inputs (except from the aquifers) and from entrainment from the bottom layer; and it loses POM through sinking and some oxidation and advection into the first basin. The bottom layer has losses due to entrainment, oxidation, and burial. The oxidation is calculated in the oxygen budget and the burial rate is taken from the literature.

Comments. Detrital POM can be also important in the diet of mussels and is included by converting the BOD observations in the various discharges and FW runoff, however, that from terrestrial origins of POM in these discharges is considered less labile and, consequently, less valuable as food for the mussels. We therefore diminish the observed BOD by a fixed portion dependent on its principal origin, with the exception of untreated sewage discharges. In fact, the rather constant contribution from sewage component, prior to the re-location of the main outfall, is considered as part of the reason for the decline in mussel production.

The plots in Fig. 10 show lower than expected surface values, because the observations were taken at the very surface and are therefore likely lower than the vertically integrated values would be. The failure to produce the peak in POM during the late summer needs to be understood and resolved. The bottom values are not calibrated because of lack of data, but we hope to find some way to check their magnitude.

Status. This component is not complete particularly with regard to the respiration, consumption, and with the budgeting between the layers. We expect the adjustments to be completed soon, this year.

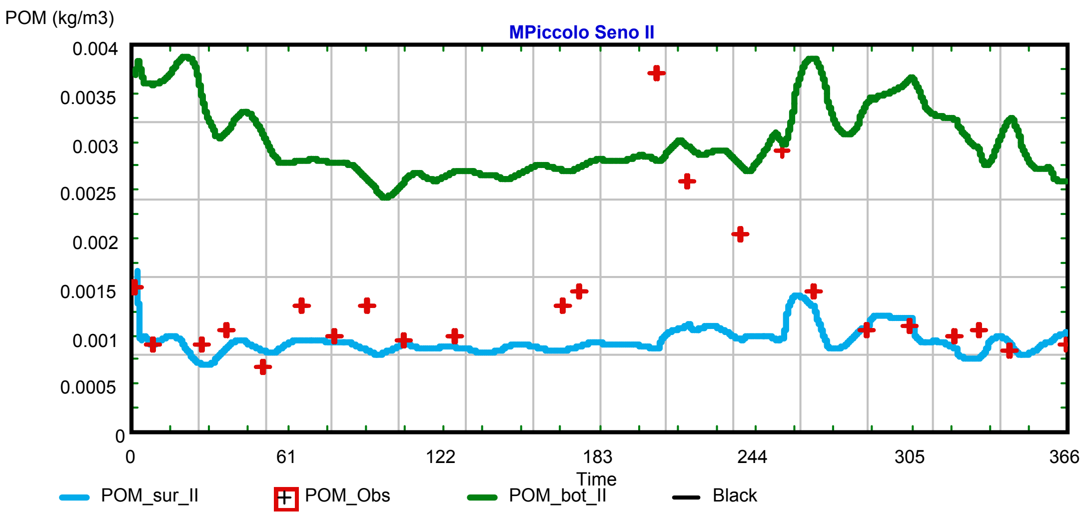


Fig. 10 The surface (blue) and bottom (green) layer concentrations of POM for the test year of 2003. The red crosses are the observed data points.

3.10 Phytoplankton.

Description. The PP block follows the formulation of the Villefranche model (Paul Nival). The purpose is to represent three major plankton size groups (e.g. diatoms, dinoflagellates, and nanoplankton) in order to simulate seasonal succession in these groups relative to their relation to assimilation and growth of mussels (Fig. 11).

The population balance of growth (nutrients & light), respiration, death, and grazing, in the following form:

dPP/dt=PP_dia*(MU_n+MU_reg+Light*Kl)-(Kr+Km)*PP_dia*PP_dia
Kg*PP_Population;

All calculations are expressed in grams of carbon and grams of carbon per area

a. Light. The input considers observed light corrected for cloudiness. Its value for the euphotic zone (surface layer) is a vertical integral of the light using a linear attenuation function with an absorption coefficient (Kl) dependent on POM concentration through a conversion table.

b. Nutrients. Nutrients are assimilated considering a specific absorption function (Michaelis-Menten) for each group taking into account the assimilation of new-nitrogen (Nitrate) and regenerated-nitrogen (Ammonium). We considered the fact that each group-specific has its nutrient assimilation ability, which allows diatoms to grow faster in presence of new-nitrogen and nanoplankton in presence of large amount of regenerated nitrogen. By this we obtain two growth rates (MU) of each group, one based on nitrate and one on ammonium which, when summed, give us the total assimilation. The growth rate in presence of regenerated nitrogen is also temperature dependent.

c. Respiration and Mortality. These are simulated using a quadratic dependency with constant death (Km) and respiration rates (Kr).

d. Grazing by Zooplankton. These are simulated as a linear proportion of the total population through a constant grazing coefficient (Kg).

c. Sinking. The phytoplankton sinking out of the surface layer are accounted for in the POM component.

d. Grazing. Zooplankton grazing is simulated as a linear proportion of the total PP population through a constant grazing coefficient (Kg). Grazing by the mussels is by a population dependent linear function, which is calculated by considering the absorption rate to be a function of PP % in the total POM and an Ingestion rate that is directly a function of the POM.

Comments. The results of this component have not yet been calibrated. We intend to make some proxy calibrations using observed cell counts and surface Chl *a* values for the three groups. The succession of the three groups indicates that diatoms prevail in the spring (with high runoff) and nanoplankton increase during the summer (with higher ammonia values) and dinoflagellates remain quite constant throughout the year. The total production is maintained also fairly constant during the year, with the implication that if mussels grow best with the larger phytoplankton then they could be undernourished during the summer (low runoff) period.

Status. This component still needs some modifications dependent on the mussel component and it needs some form of calibration.

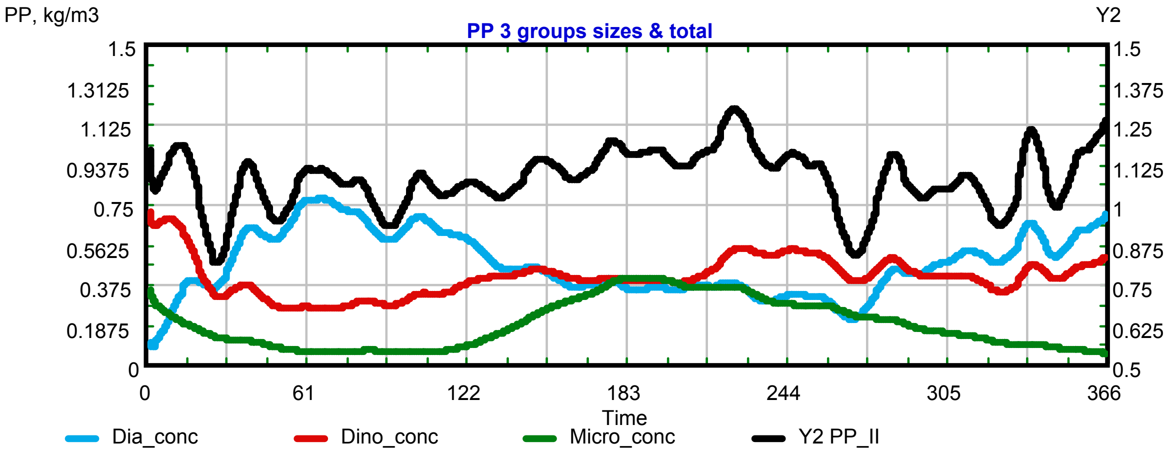


Fig. 11 The modelled results of the three phytoplankton groups: diatoms (blue), dinoflagellates (red), and nanoplankton (green), and the total (black, left scale). This plot does not include the influence of mussel grazing.

3.11 Mussel Growth.

Description. The model is divided into 2 separated boxes that allow to simulate two generations of mussels, the first one was considered as the "mother" generation sown in January while the second is the "daughter" generation that come from the spawning (e.g. 25 % of the total amount of first generation) of the previous that happen in late autumn of the first year of simulation. All the calculations are expressed in kg of Carbon to be compatible with the whole model units (Fig. 12).

The growth equation for Mussels follows a bioenergetics model of Von Koijiman et al. (2003) and it is based on the assumption that mussel food is POM mainly constituted by Phytoplankton and Detritus; we simulated a feedback on these components including food absorption efficiency as suggested by Navarro et al. (1996). Other important factors for growth are respectively the three rates of filtration, ingestion, and absorption expressed empirically from laboratory experiments (Corriero et al., 2001). The filtration rate and the ingestion rate are considered as function of the mussels length. Three absorption rates for the three plankton groups were used: i.e. 45% for diatoms, 30% for dinoflagellates, and 25% for nanoplankton.

Shell length and Condition Index (expressed as single mussel wet weight divided by cubic length) has been simulated using a typical equation fitted on historical Mar Piccolo mussels biometric data-sets (Matarrese et al., 1993; Corriero et al., 2001; Pastore et al., 2003).

Mortality rates for the two generations are expressed as rates (time-dependent) proportional to mussels carbon. Mussel oxygen consumption is function of shell length.

Status. This version is also under refinement to improve the POM–N interactions and find ways to calibrate the biomass of mussels.

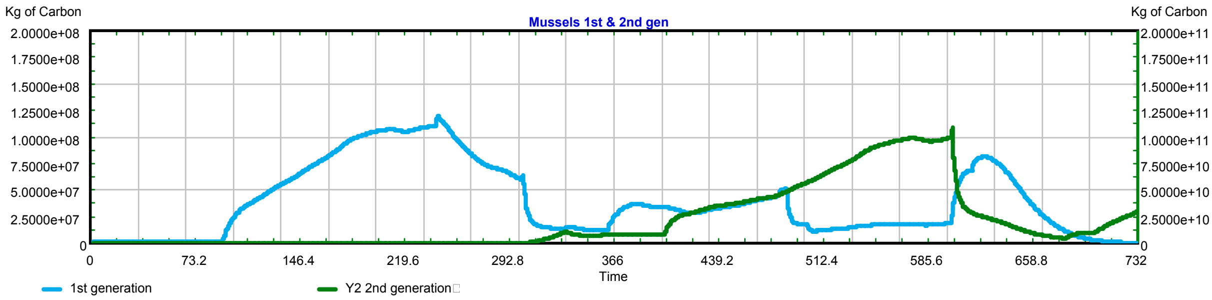


Fig. 12 The mussel biomass of two age classes of a 2003 -2004. One harvest event is shown in June after whom little growth occurred due to the declining phytoplankton production associated with decreases in runoff and new nitrogen, and a second one in late October allowing the younger class to profit from the increased availability of phytoplankton.

3.12 Mussel Farm & Harvest function.

Description. The purpose of this component is to help in simulating aspects of the aquaculture practices that influence the growth and harvest of the mussels. Since the mussel growth model is a community (as opposed to an individual) model, aspects that affect the growth, i.e. the closeness of the lines, their location/orientation, the separation distance must be taken in consideration. The timing of the harvest becomes important if the meat decreases with long periods of no new nutrients. Likewise, the timing of the seeding depends on the concurrent phytoplankton production. Of course, from an economic point of view, the harvest timing should consider market price variations too (Economic Component model). The quantity of the harvest is simulated by considering the volume (surface area per depth) of the mussel nets relative to the volume of MP in order to get harvest estimate. This will also provide a calibration constant; i.e. the amount of photosynthetic carbon produced dictates the maximum carbon assimilated by the mussels per unit volume.

The Extend model contains a user option to vary the dimensions of the lines, distance and mean weight of nets to better understand the role of spacing in the mussel growth. These dimensions are: the line length, the number of lines, the wrap distance, and the wrap length. We intend to demonstrate this feature at the next meeting of the Participant Group.

Comments. Most of this has been constructed, although it is slowed by a lack of information. Most prominently, we have no "real" data on the annual catch, which would allow us to calibrate the harvest. We have increased our engagement of some stakeholders from the mussel culture and we are expecting more information about their procedures and relative catch abundances. We are also optimistic about providing some guidance through model runs on limits to be adopted for the number and exposure of nets to optimize access to POM.

Status. Some elements are completed but the remainder will be done as a non-interactive addition to the simulation model.

ECONOMIC COMPONENT

1. Conceptual Diagram of model organization

1.1 Conceptual Diagram.

The conceptual diagram (Fig. 13) evidences the economic flow of the mussel harvest and management options for revenue distribution. In this figure the initial layout of the supply chain analysis and its link to the social sub-component expressed as employees benefits is shown. It illustrates an important conclusion: the ultimate dependence on actions (subsidies or pollution reduction) that must be taken external to the mussel management itself. For this reason the SSA Team expanded its scenarios to include benefits (see social component) derived from an improved ecological health of the system (Fig. 14).

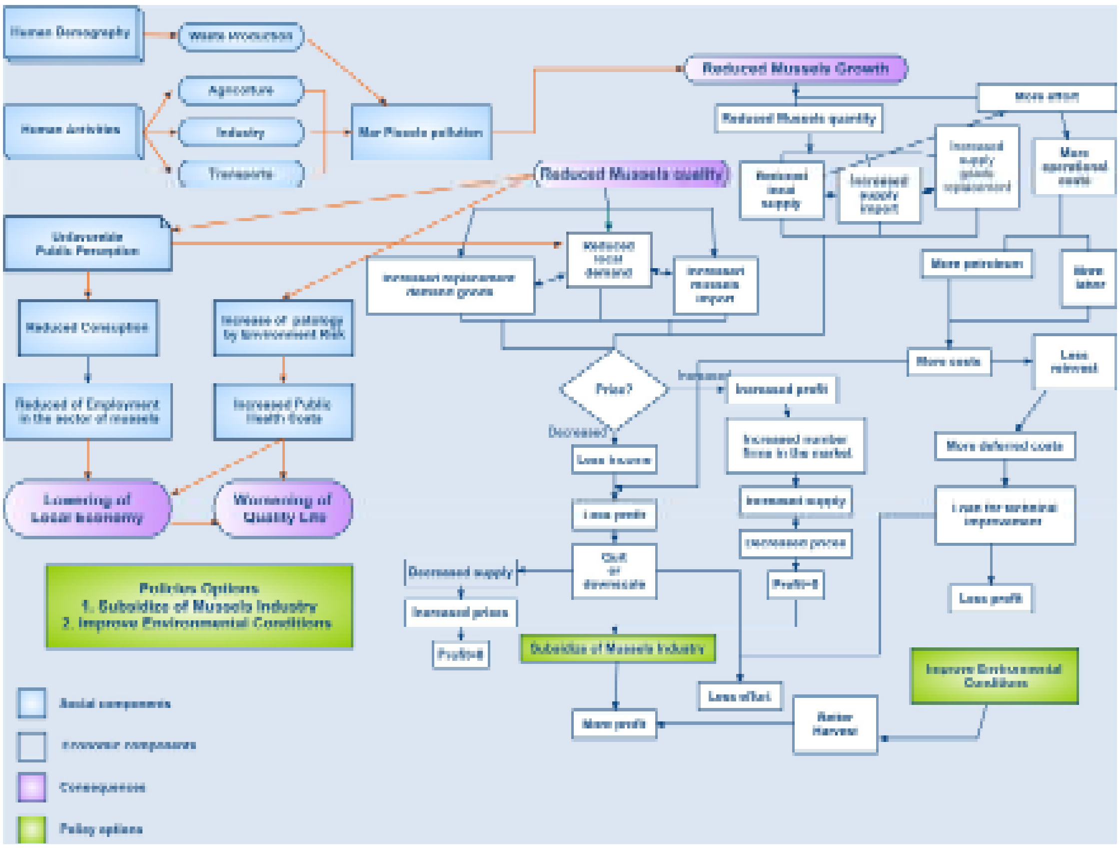


Fig. 13 This flow diagram illustrates the responses to the impacts of reduced quality and quantity in Mussel culture.

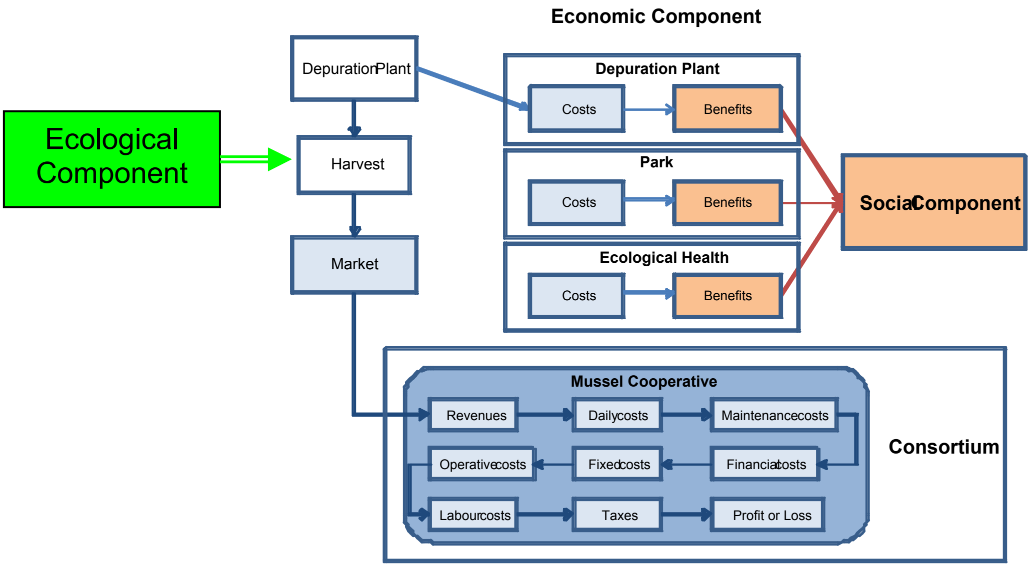


Fig. 14 A broader set of scenarios that provide options both for the mussel culture management and for urban planning.

2. Describe the scope and function of model/analysis.

2.1 Scope

The scope of the Economic Component is to evaluate several methodologies that are directly or indirectly linked to the Ecological and Social Components. The expansion of the original set of scenarios is aimed to illustrate the flexibility of the simulation analysis and prepare the SSA Team for a deeper understanding of the SAF methodology. Three methodologies are demonstrated:

a) *Supply chain analysis:* it illustrates the conversion of harvest to profit and the potential consequences to employees. There is a direct connection with the Ecological Component (mussel culture management) and another indirect with the Social Component .

b) *Management comparison* between the profits derived from individual cooperative *versus* consortium. The connection with the other components is indirect.

c) *Cost-benefit analyses:* concerning the installation of WWTP options to reduce management costs and optimize the carrying capacity of the Mar Piccolo. The connection with the other components is direct.

2.2 Purpose

2.2.1 Harvest Profit.

The link between the biological and economic model is the harvest. The harvest takes place every year during the period May-September. According to ISMEA data the total harvest of mussels in Taranto is equal to 30,000 tons of which the 80% is collected in Mar Piccolo.

In order to link the ecological model (growth function referred to18 months) with the economic model, we have hypothesized to cover the costs of the first year with the income of mussels derived from another site. On the other hand, the cost of the second year and onwards (after 18 months) were covered by the income of the mussels grown in Mar Piccolo.

So, the improvement of water quality in Mar Piccolo is directly connected with the increase of the mussels harvest.

The life quality of the employees is considered in the Social Component model.

2.2.2 Cooperative & Consortium.

We propose two different forms of mussel farm: cooperatives and consortium. Actually in Taranto there are only cooperatives so, we have analyzed all costs and revenue derived from a "cooperative". Moreover, the possibility of merging more cooperatives into a Consortium of three or more cooperatives, has been foreseen in our model. The Consortium respect to a Cooperative go back out to put the entire harvest on the market and cut some costs. In other words, the consortium will ensure promotion and sale of the product, at a single market price. In our model we have considered that in Mar Piccolo of Taranto there are 31 Cooperatives. Only three of these cooperatives are consortium members and each cooperative employs 30 workers.

2.2.3 Waste Treatment and Water Quality.

The demonstrated methodology is an initial Cost-Benefit Analysis (CBA) of the sewerage management. To improve the quality of the mussels we assumed the presence of a sewage treatment plant. The costs and benefits of both traditional and natural depuration plants has been evaluated. The costs (investment, energy and employees' training) should be the same, even only in theory for the lack of data for these depuration plants. The benefits of a natural plan respect to the traditional one are mainly connected to the improvement of the water quality, and of the shoreline, and to the creation of a public park.

Particularly, the costs for a shoreline were due to the analysis and mapping of the wastes, and their removal, disposal, etc. The benefits are the reduction of the health costs. So, the social benefits are greater than the costs.

Finally, we have taken into consideration the building of a public park to improve the wellbeing of *Tarantini*. A park for the city of Modena has been taken as an example. In particular, the considered costs were those for the creation of a greenbelt, of a parking lot, an info point, an eco-market, an outdoor cinema etc. The benefits are: the energy saving, greenhouse effect mitigation, decrease air pollution and the increase real estate market.

We conclude that also in the second case the social benefits are higher than the costs.

3. Functional Component descriptors.

3.1 Input & Calibration data

Input data. In economic model the main input are:

a) Total costs and total revenues of cooperatives;

b) Total costs and total revenues of consortium;

c) Costs of traditional and natural depuration plant;

d) Costs of ecological health;

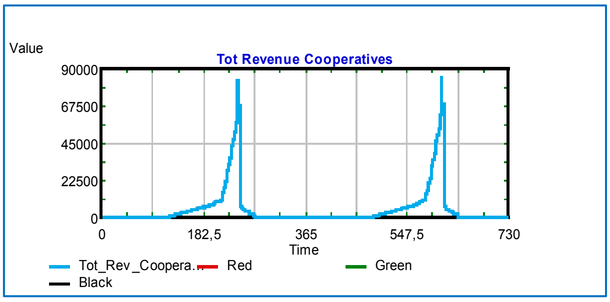
e) Costs of public park.

Calibration data: The budget of Cooperatives and Consortium and the costs of traditional and natural depuration plant aren't available; while the costs of ecological health are available to city of Taranto. The costs of public park are referred to Modena example.

3.2 Revenue

Description and comments.

Total revenues were calculated by multiplying the market price for the amount collected (Fig.15.a,b).The average market price (ISMEA data) was assigned to the price charged by cooperatives, while the price of the Consortium was calculated by using the price of the Cooperative as a percentage of 30% (usually determined by the State of the Consortium).



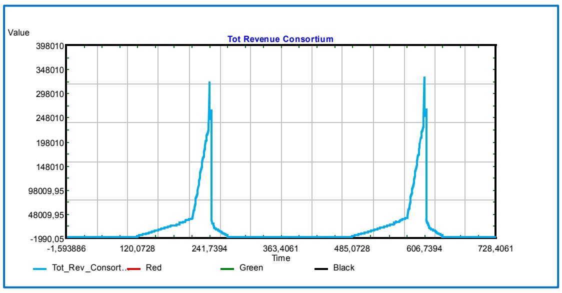


Fig 15. Total revenue of Cooperative (a) and Consortium (b)

3.3. Costs.

Description and comments.

Total costs. Total costs are the sum of all costs of the cooperative, in particular, we considered blocks of costs such as labor, INPS, INAIL, the daily costs, maintenance, insurance, advertising, equipment, VAT, ICI and IRAP.

Labor. Specifically, the cost of labor has been calculated as a worker of 6th level (according to the national collective agreement), with no annual increase, without family allowances, overtime without compensation, with annual bonuses and with a basic salary of € 1168,99. Usually a Cooperative Member is classified as an associate worker and such relationship is considered equal to that of an employee. For this reason we have also considered the monthly wage of an employee with deductions of:

a) IRPEF (to 23%);

b) ADDIZIONALE REGIONALE (1.4%) and COMUNALE (0.8%);

c) plus a part of INPS equal to € 8,84.

The mussel cooperatives are made up of a minimum of 9 members, our model takes in consideration the presence of 30 employees working at a minimum wage.

INPS. The cost of INPS to be paid the cooperative was established at € 34.47 a month, having simulated the cost of a worker rearing fish in freshwater and / or marine and lagoon.

For INAIL however, the cost of the Cooperative (due 16th February of each year) was calculated by multiplying the gross annual salary of each employee by a percentage of risk INAIL for small-scale fishing industry and fisheries inland is equal to 65 ‰.

The DAILY COSTS, MAINTENANCE, INSURANCE AND ADVERTISING considered for mussel cooperative are entirely hypothetical, as the official accounts of mussel cooperatives are not yet available.

The cost of DIRITTO CAMERALE is paid by the Cooperative, is paid annually (by 16th June) at the Chamber of Commerce and is equal to € 88,00.

The COST OF EQUIPMENT, however, is treated as purchases made by the cooperative during the year and therefore taxed at a rate of 20% VAT.

VAT: For this reason, it was necessary to calculate every 90 days even VAT liquidations at the head of the Cooperative, as a simple difference between the amount of VAT on purchases and the VAT on sales. In particular, the VAT on the sale of mussels is equal to 4%, while the VAT on the purchase of equipment is equal to 20%. Furthermore, we have also suggested the possibility of higher VAT on purchases compared to that (the VAT) paid on production sales.

Other costs for the cooperative is the amortization, in particular it has been suggested to amortize the boats purchased in previous years at an annual rate of 20% for a maximum period of 5 years.

ICI. Other costs considered for the cooperative are that ICI is paid for the possession of remises (purchased in advance and already fully amortized) and for the possession of the body of water.

IRAP TAX. The regional tax on productive activities is a value-added product that affects the wealth at the stage of its production.

The property of a cooperative is made up of the sum of the initial contribution of members, the mutual fund (which includes an annual payment of a share of profits to mutual funds for the promotion and development of cooperation, the extent and manner provided for in law, or 3% of earnings), the accrual of profits to reserves (20%) and finally some of the profits reinvested. When a cooperative has a loss during the business year, we have hypothesized the possibility to cover this loss through a reduction in capital.

The cooperative may apply for bank loans (including losses) or sums of money for which the cooperative shall undertake to repay a gradually increasing share of interest .

The repayment installments are conventionally calculated in Extend and determined as follows:

$$R = A * \frac{i}{1-(1+i)^{-n}}$$

Where

R = rate;

A = debt to repay;

i = interest rate;

n = number rate;

In particular, the debt provided by banks cannot exceed 80% of the Cooperative turnover the previous 5 years. If the requested loan is lower than the value, the bank can still grant funding; *viceversa* if the loan reaches its maximum value, the cooperative will be forced out of the market.

The costs and revenue for each type of mussel farm (cooperative and consortium) have been analyzed, the results evidenced that the consortium is more profitable than the cooperatives (Fig.16).

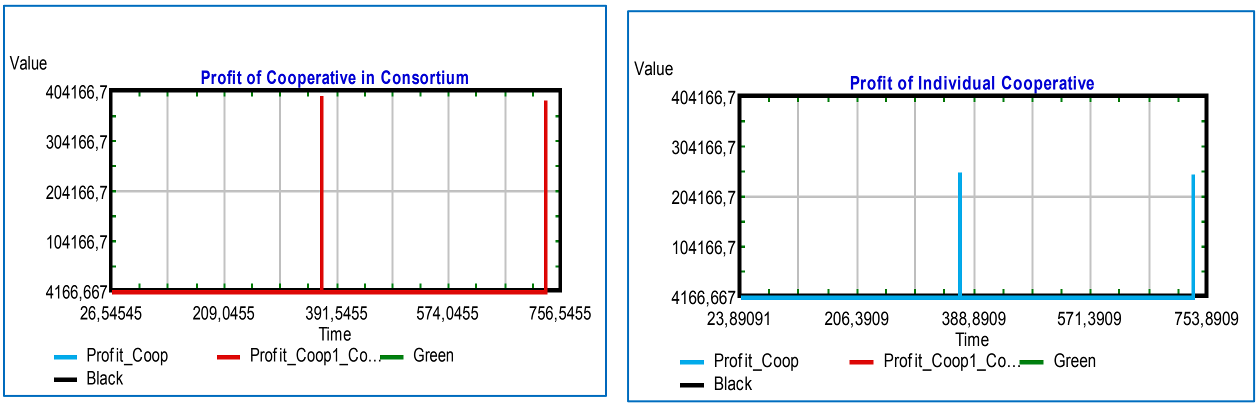


Fig. 16 The left figure primarily represents the annual profit of individual Cooperative, and the right figure represents that of a Cooperative in a Consortium.

3.4 Sewerage Management

<u>Description and comments.</u>

The demonstrated methodology is an initial Cost-Benefit Analysis (CBA) of the sewerage management. The natural depuration plant has been compared to a traditional one (Fig. 17). Difficulties has arisen when costs and benefits (market and non-market assessments) has been compared for both the aquaculture enterprise and the city of Taranto.

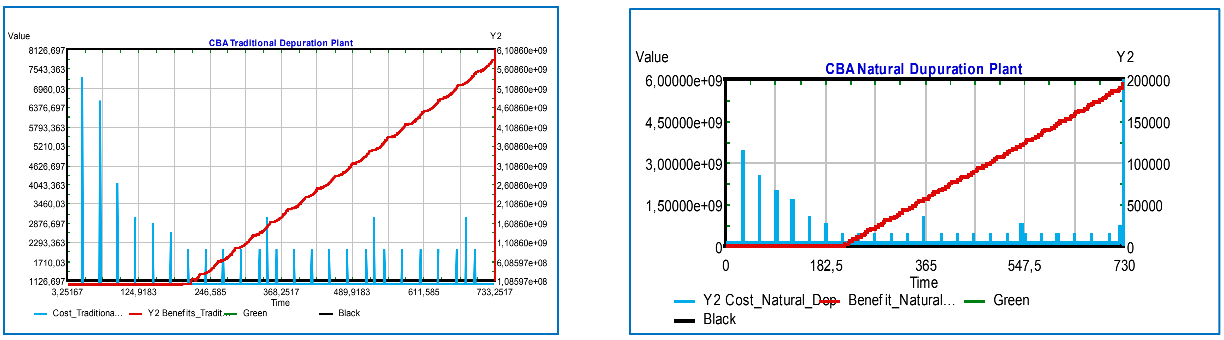


Fig. 17 The left figure primarily represents the Cost Benefit Analysis of Traditional depuration Plant, and the right figure represents the Cost Benefit Analysis of Natural depuration Plant.

3.5 Ecological Health and Park

Description and comments.

At this point, in order to improve the ecosystem of the Mar Piccolo, we have thought to improve the Ecological Health of the shoreline and to create a public park.

In the first case, we have considered all costs such as the analysing and mapping of waste, removal and disposal of waste etc. The benefits are those of reducing health care costs, better water quality and the willingness to pay. The result is that the social benefits are greater than the costs (Fig. 18).

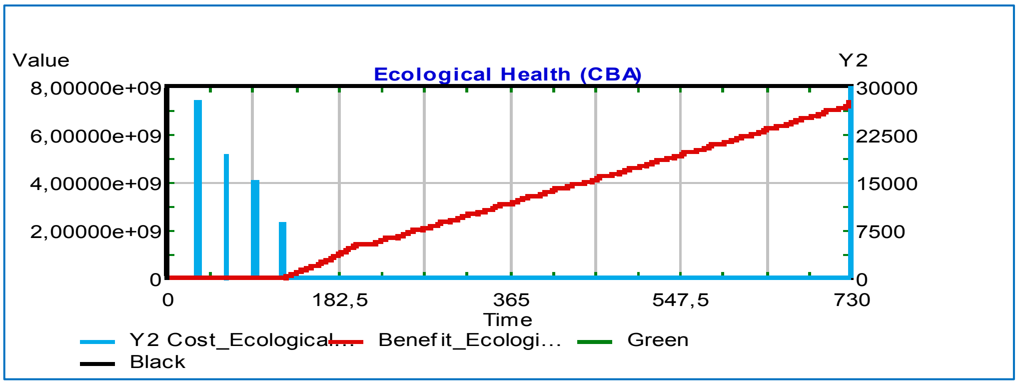


Fig. 18 The figure represents the Cost Benefit Analysis of Ecological Health

However the park costs include: building an eco-market, parking space, info-point park equipment, cinema while the benefits we have considered are: the energy saving, greenhouse effect mitigation, decrease air pollution and the increase real estate market. We conclude that also in the second case the social benefits are higher than the costs (Fig. 19).

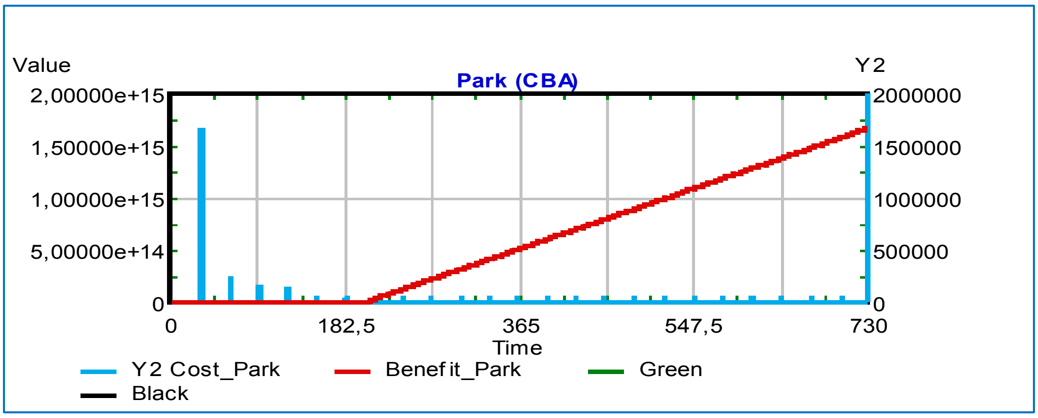


Fig. 19 The figure represents the Cost Benefit Analysis of Park

SOCIAL COMPONENT

1. Conceptual Diagram of model organization

The Social part of the conceptual diagram in Fig. 13 is directly linked with Economic part and shows the effects that the life's quality of mussel farmers have on the market. We have assumed that an unfavourable public perception has consequences to the local demand. The unfavourable public perception, that we'll calculate using questionnaires and interviews would cause a lowering of local economy and then a worsening of the life quality.

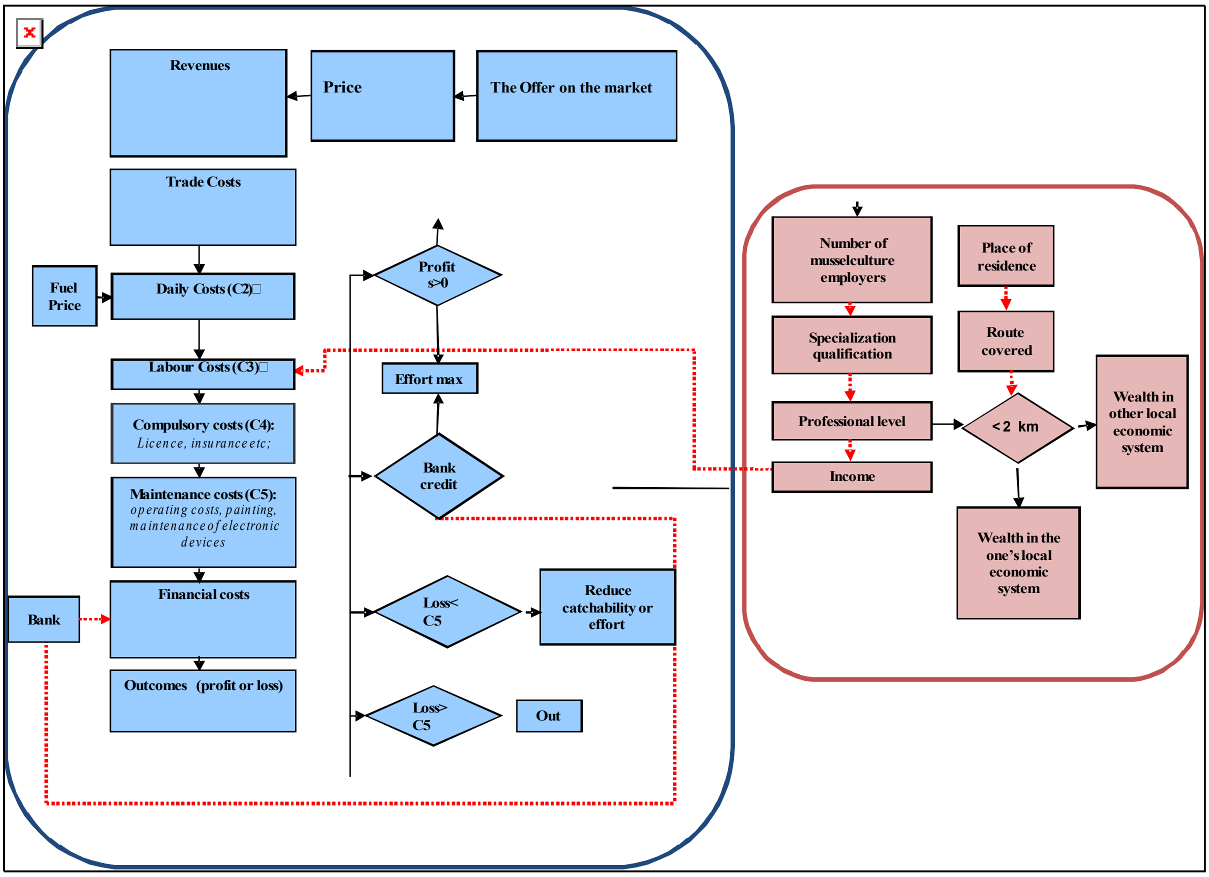


Fig. 20 This flow diagram illustrates the consequences of financial investments to life's quality of mussel farmers.

1.2 Social Model Organization.

Because of the difficult to apply mathematical formulas to the Social Components, we have decided to work with two types of Social Analysis: the first one is a traditional analysis and the second one makes use of the Extend model (directly and stringently linked with Economic model).

From the Conceptual diagram in Fig. 20, we are realizing the interpretative analysis that we will do with the aid of questionnaires and interviews, as mentioned before, to mussel farmers and administrators divided into the 3 different type of farms, based on the dimension (small, medium and large). Our goal is the knowledge of the best type of mussel farm. We will try to establish a link between the data. It will use, if possible, documentation and bibliography of the past to understand the changes happened in the last years. The conceptual model considers, as parameters to value the level of life's quality of mussel farmers, the specialization/qualification from which derive the professional level of an employee and his income. The income of mussel farmers represents the Labour cost of the economic model. Moreover, it wants to evaluate, considering where the employees live and the route that they cover everyday to arrive to the working destination, the environmental impact of travelling and the repercussions in the market. The route that they cover is calculated by considering the space between their home and Mar Piccolo. By means of the questionnaries, we'll know however the employees go to work. The travel cost is obtained by the gasoline cost multiplied to the covered kilometres, if the employee travels by car and alone. Instead, if the employee travels by car but with other colleagues, the cost will be divided between the people. If the employee travels by bus, the cost will be represented only by the ticket cost. About the environmental impact, it will be calculated by using as parameter the quantity of equivalent CO_2 emitted during the travelling.

Instead the Extend model derives from the CBA of Economic part (like already discussed in the Economic part) and involves the benefits of Cost Benefit Analysis. It has been necessary to give a money value to non-economic components.

2. Describe the scope and function of model/analysis.

2.1 Scope

The scope of the model was already explicated in the Economic part.

About the Social part, we can add that the Tarantine musselculture is characterized by the old age of musselfarmers. The mean age of employees increases progressively because of failed generation turnover that has been rendered the tarantine musselculture an economic sector with strong family tradition. The social context of Taranto and in particular of mussel culture in Taranto is characterized by a high presence of illegal cultivation of mussels causing complex economic dynamics. The result is a general worsening of the level of quality life. This represents an important restriction to possibility to maintenance during the time the vitality of this sector and its production capacity.

2.2 Purpose

The purpose of the Social Component is to improve the quality life of musselfarmers, and more in general, of the Tarantine citizens. We have imagined to built a depuration plant (moreover we are considering two types of depuration plants - the first one is a traditional plant and the second one is a natural plant - to establish what is the most advantageous) which discharge supply to the mussels the necessary quantity of nutrients. Moreover we have hypothesized to realize a land reclamation of the shoreline that would permit the realization of an Urban park around the Mar Piccolo. In this exercise, the social component involves the benefits of the Cost Benefit Analysis (CBA) of these public works. About the depuration plants, the included benefits are the improvement of the water quality, and the increase of the willingness to pay to build around the Mar Piccolo of Taranto. Particularly we have calculated the value of the water like the sum between the damn spared by the absence of discharges and the value based on the services offered by wetlands. The benefit of the land reclamation of the shoreline is directly connected to that of the park and of the depuration plant: the increase of value of real estate market. About the park the benefits considered are the increase of value of real estate market, mitigation of greenhouse effect (uptake of CO_2), decrease of air pollution (vegetation filters a part of pollutans).

3. Functional Component descriptors.

3.1 Benefits of Traditional Depuration Plant

Description. The first benefit considered is the decrease of sanitary expenses, the second benefit is the improvement of the water quality that has been calculated like the sum between the damn spared by the absence of illegal discharges and the value based on the services offered by wetlands. The last benefit considered is the willingness to pay to have a mussel quality.

a) Sanitary expenses

We have calculated the expenses percentage of the National Sanitary System for diseases like the cancer and about this disease we have hypothesized that a percentage is caused by heavy metals.

b) Water quality

We have considered the value of the water like a damn spared. Following the study of two legislators (*Maglia-Tredanari*), we have used:

1) the administrative sanction based on the Italian Environmental Law (to quantify the environmental damn to the water according to the Law, the legislators have multiplied for 3 times the maximum economic sanction established, by D.Lgs 152/2006, in 78,000 euros)

2) the quantify of damage to agriculture (It has been multiplied the agriculture surface area around the Mar Piccolo (175 ha) with the value of the annual use of water diluted on the time of emission of the pollutant [(3,682€/ha : 365) x 2]= 20,17€/ha)

3) the quantify of damage to fish fauna (It has been used the Protocol of Province of Piacenza to value the damage to the fishery fauna (1999). It calculates the mean cost for each square meter).

Therefore, the International Report of the WWF "*The Economic Value of the World's Wetlands*", establishes the mean Economic value for each year based on the services offered

4) Fish nursery (mussels)

5) Fishing

6) Resort (entertainment area)

7) Intrinsic value of Biodiversity

8) Water forniture (to ILVA, for example)

c) Mussels quality

Through the use of questionnaires we want to calculate the Willingness to pay of Tarantine citizens to have a mussel quality. It is calculated like a percentage out of market price and we have considered several groups.

Comments The results of the comparison of the benefits with the costs are represented in the Economic part.

Status The data of sanitary expenses are not yet real data and the questionnaires to value the WTP aren't yet dispensed.

3.2. Benefits of Natural Depuration Plant

Description. In addition to all the benefits of a traditional depuration plant, we have considered also in the *water quality* **the production of fertilizers and the lack of costs for the waste disposal and the transport of the mud produced, instead, by the traditional depuration plant.**

Comments The results of the comparison of the benefits with the costs are represented in the Economic part.

Status The data of sanitary expenses (as mentioned before) and the data of production of fertilizers are not yet real data; the questionnaires to value the WTP aren't yet dispensed.

3.3 Benefits of Ecological Health

Description. Represents the land reclamation of the shoreline and it is calculated like the sum between the value of the water, the sanitary benefits and the WillingnessToPay to build around Mar Piccolo of Taranto. We have hypothesized that the benefits about the land reclamation of the shoreline are the improvement of the water quality, the decrease of sanitary costs for heavy metals diseases and the increase of the real estate market around the MP.

The first two components are already calculated inside the two types of depuration plants.

The willingness to pay to build around the Mar Piccolo is calculated like a percentage out of actual market price; this percentage derives by a verbal of a Municipality near Modena that demonstrates that the presence of a park, realized after a reclamation of the shoreline, increases of 35% the real estate market price, that amounts for the area around the Mar Piccolo of Taranto to 600 €/mq. We have hypothesized to have a house of 70mq.

Comments The results of the comparison of the benefits with the costs are represented in the Economic part.

Status The data of sanitary expenses are not yet real data (as mentioned before).

3.4 Benefits of Park

Description. We have assumed that we are going to realize a park that has a surface area of 20,000 mq. If we want to plant "live oaks" (native plants), they need 8 meters of distance each other (64 mq all around themselves) and for this we'll have 312 trees. The life of these trees is about 800 years.

About the park we have considered as benefits the increase of value of real estate market and all the benefits deriving from trees: the energy saving (less use of air conditioner), the mitigation of greenhouse effect (uptake of CO_2) and the decrease of air pollution (vegetation filters a part of pollutans).

a) Total_Energy_Saving According to a study of *Nowak (1999)* is established that 1 tree equals to 5 air conditioners that are switch on 20 hours for each day. Actually the mean power of an air conditioner is 1,5 kwh and the price of energy amounts to 0,20 €/kwh.

b) Mitigation of Greenhouse_Effect According to a study of *Giordano (1989)*, we know that 1 tree can absorb, during all its life, 2,5 tons of CO_2. The *Protocol of Kyoto* establishes a market price for each ton of CO_2 emits to the atmosphere equivalent to 20 €.

c) Decrease_of Air_Pollution According to a study of *McPherson, Simpson, Peper, Xiao (1999)*, 1 tree have fixed during one year 4,5 kg of air pollution. To value this benefit, we have used the costs for the reduction of emissions in the Chicago city equivalent to 30,42 €.

d) Increase_of eal_Estate_Market As already specify, a verbal of a Municipality near Modena demonstrates that the presence of a park increases of 35% the real estate market price. Moreover, by several estimates, it results that the value of a real estate market increases also of 1,800 Euros for each 100 metres in proximity to the park. We have established that 600 metres are the maximum distance to the park.

Comments The results of the comparison of the benefits with the costs are represented in the Economic part.

Status All the elements are completed.

RESULTS DISCUSSION *(optional)*

1. General

Concerning the SPICOSA objectives, about the improvement of multidisciplinary and multinational research, our experience with our Partners has been good, until now. Certainly, the exposure and dialogue with city officials, regional environmental agencies, and stakeholders is proving to be a beneficial experience.

The IAMC-CNR is young and has not had much experience with an integrated (internal collaboration) multidisciplinary research. The SPICOSA Project has provided such an example, but until the exercise is completed the peripheral benefits will cannot yet be thoroughly demonstrated, e.g. through publications, increased international collaboration, national and regional grants, etc. Actually, we are looking for new initiatives, both on local and national level to use the experiences derived by the SPICOSA exercise.

2. Specific

SPICOSA approach to the System Science research has evidenced some problems connected to the Mar Piccolo ecological and socio-economic data sets. The next research programs will be positively influenced by these limits and the information's quality improved.

Briefly, some of the aspects related to data/information lacking for the Mar Piccolo SSA are listed.

1) For Meteorological data, no information existed and suitable data were difficult to acquire or were taken land distant form the Mar Piccolo. Certain parameters, i.e. PAR, cloudiness, back radiation, were lacking.

2) Oceanographic data were inadequate in both time and space. Spatial averages in horizontal and vertical were rendered in adequate for accurate model calibrations. Vertical profiles of nutrients were non-existent. Sampling in the Mar Grande had less coverage and no data existed for the adjacent open Gulf of Taranto.

3) Observations were lacking for the fundamental processes of primary production, zooplankton growth and grazing, sedimentation, sediment respiration, sediment burial, sediment phosphate release.

4) Data on the amount and content of the many discharges and of the runoff (streams, drainage canals, and aquifers) is inadequate. So, definition of the inputs has been only done with rough approximations.

5) Regarding mussel cultivation, most of the data was empirical and difficult to retrieve. Regarding observations of in-situ processes, information was lacking on the feeding and excretion processes of the mussels and on the relationship between the detritus composition and the assimilation of the mussels. The information on the catch (tonnage) history was not available.

6) Likewise the statistics on the annual revenue, on employment were not available. Some of the costs involved in the present and past discharge, systems are available.