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Geographic Information Systems as an Integration Tool for the Management of Mariculture in Paraty, Rio de Janeiro, Brazil

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1. Introduction

Worldwide, the exhaustion of marine living resources, due to the degradation of the environmental quality and to overfishing has driving efforts to aquaculture as an alternative to the production of protein rich food. A FAO report of 2004 (Food and agricultural organization, 2004) has pointed out that for a total of 132 million tons of aquatic food in 2003, 31.7 % was produced from aquaculture, a rate that increased 22.8 % in the six preceding years (25.8 % in 1998). Although marine aquaculture contributes with only 12.6 % of the whole 2003 production, it experienced an increased production of 24.4 % since 1998. Furthermore, marine fish capture has reached peak values in the year 2000 (86.8 million tons), but afterwards it showed a consistent decrease (81.3 million tons in 2003; Food and agricultural organization, 2004).

Although aquaculture has been seem as a major alternative for the threat of reducing stocks of fish worldwide, its insertion among the other coastal uses has shown to present significant environmental issues. Troell et al. (2003) analyzed peer-reviewed papers published in the literature of mariculture and identified a number of findings and techniques that provide new approaches for the sustainability of the activity. It is clear from Troell and colleagues' article that integration of the activity within the coastal zone management is the only way that can lead to a long term sustainability. On the other hand, Focardi and Corsi (2005) observed that the techniques to manage mariculture are still complicated and demand adaptation for each environmental condition, and is unaffordable for coastal populations in developing countries. The lack of sound management techniques drive fish-farmers to use chemicals that improve production, or to work with fed cultures and exotic species that impact the water quality, and affect ecosystems. Among the 10 future actions reported in Troell et al. (2003), the last one concerns the transfer of technology from researchers to producers, constituting the most challenging task for the sustainability of the activity.

Considering the complexity of uses in the coastal region and the possibility of conflicts that compromise the sustainability of the different activities, it is largely agreed that the application of geographic information system (GIS) modeling to determine the boundaries of the activities

is helpful. However, when applying GIS, comprehensive strategies are necessary in order to identify the most important variables and parameters that will more reliably reduce the conflicts and warrant the sustainability. For instance, Mason Bay in Eastern Maine, US was studied by Congleton Jr et al. (1999) that gathered informations obtained from sediment characteristics, infra-red satellite images and hydrodynamic informations to establish suitable areas for mariculture of the soft-shell clam. In their work, focusing at the hydrodynamic characteristics, the authors were able to establish the parameters that would favor seeding juvenile shellfish. They also suggest that the system would be able to determine areas for suitable growth of the shellfish, but no GIS maps could be presented.

Geographic information system were also applied using algorithms that overlaid variables that were important for mariculture, like salinity, current velocity and wave height (Comert et al., 2008; Saitoh et al., 2011; Windupranata and Mayerle, 2009). When applied with special softwares, this methodology could generate comprehensible maps that rate suitability for mariculture. In a recent article Saitoh et al. (2011) develop a model that was coupled with IPCC (2007) previsions of climate warming presented rates ranging from 0 (totally unsuitable) to 8 (very suitable) for the cultivation of the japanese scallop in Funka Bay (Japan). The maps provided by the authors show the different scenarios according with the increase in global temperatures.

Mariculture has been developed in Brazil since the late 1970's, when the first experimental oyster cultivations were installed in Arraial do Cabo, Rio de Janeiro (Muniz and Jacob, 1986). Throughout the decades of the 1980's and the 1990's the development of the activity was still shy, for there was not a clear perception among investors of the restricted loading capacity of commercial and artisanal fisheries in the Brazilian coast (Magro et al., 2000; Rossi-Wongtschowski and Cergole, 2001). With the considerable contributions of the REVIZEE project (see some results on http://www.mma.gov.br/revizee/capa/menu.html) on the knowledge of the living resources of the Brazilian continental shelf, the need for alternative non-extrative procedures emerged. Later, in the early 2000's, the marine farms started to spread throughout the country and together with its development, sustainability problems, as well as conflicts with other uses in the coastal areas emerged and management solutions were demanded. Presently, the state of Santa Catarina is the fastest growing mariculture region in the country and in some areas, environmental problems are starting to emerge. Novaes et al. (2010) made a brief review of the activity in that State and showed how the application of a fairly complex GIS model could contribute to the management and location of the farms. In a participatory process, experts and local shellfish farmers, based on their knowledge and experience decided what were the most important variables allowing for the development of a reliable algorithm. The result of the work was a map presented in the article showing unsuitable areas in red and suitable areas in green.

The present chapter describes the methodologies that were applied to manage mariculture in the Municipality of Paraty, Rio de Janeiro, Brazil, with the tool of Geographic Information Systems, (GIS). The applied methodology was considered to be the best way to organize the spread environmental, ecological, sociological and political information. The description of the methodology applied to Paraty included how information was organized and presented in a summary map, containing the activities and themes that effect mariculture.

The chapter presents a general scheme of the developed GIS, showing sources of information and how the system should be interfaced with the society and with local authorities. A series of parameters and variables are also suggested that were considered suitable for future monitoring programs that would support the management programs on a long term basis.

2. Methodology

2.1 Study area

The Municipality of Paraty is located 236 km South-West of the city of Rio de Janeiro and is a tropical region within the geographic coordinates of 44.4° and 44.8° W, 22.9° and 23.4° S. The region is known for its outstanding natural scenic and cultural richness, underlined by the pristine environmental conditions. Most of its coast is located in the Ilha Grande Bay, a leaked embayment protected from waves by the Grande Island (Figure 1). The geology of the region was described by Muehe (1998), who included it among the Northern Crystalline Slopes. The steep relief characteristics of the region with heights of 1600 m is the result of the seaward drift of the Brazilian Coast Chain that dives into a very rugged coastline, with countless embayments and small islands. These characteristics are very favorable for mariculture, because waves and currents are not too strong, facilitating navigation and installation of fish-farm apparatus.
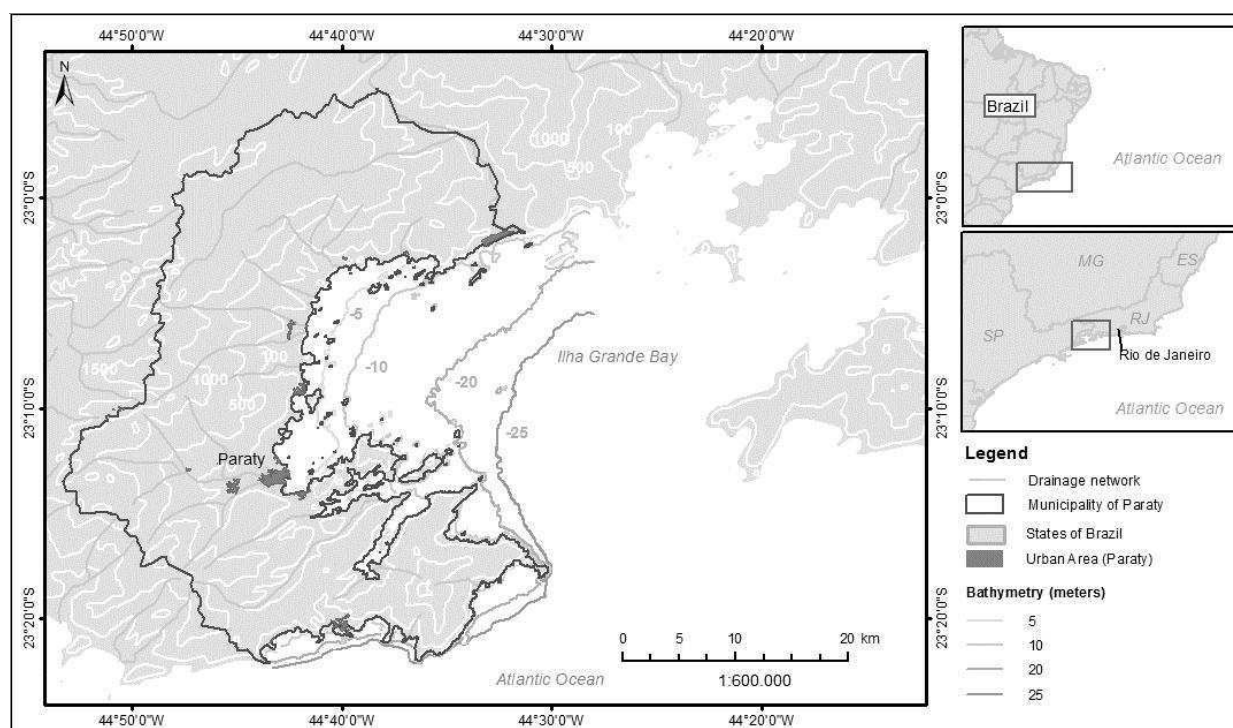

Fig. 1. Study area showing altimetry (100, 500, 1000 and 1500 meters), bathymetry (5, 10, 15, 20, 25 meters) and main drainage.

The coastal hydrography was classified as dendritic and the rivers follow the geologic alignements in the direction NE-SW and NW-SE (Figure 1). Due to the steep relief, the rivers are not very long and drainage basins are relatively small. On the other hand, the incidence of heavy rain events, mainly during winter periods yield a significant fresh-water input to the bay. In spite of thee significant fresh water inputs, the water of the bay is not very colored because of the thick vegetation cover observed in the continental portion (BRASFELS, 2005).

Most of the population of the Municipality is located in the small flat coastal plains, trapped between the sea and the steep vegetated mountains, a very favorable situation for touristic activities, generating potential conflicts with mariculture. Due to its pristine conditions, the

region is still populated with traditional communities like "Caiçaras" (ancient fishermen groups of Portuguese and Indian origin), "Quilombolas" (black communities of ancient slavery refugees) and Indians. These groups have developed, through time, traditional and sustainable fishing techniques, but today, overfishing is threatening their way of life and mariculture may be one of their options of economic activity (Diegues, 2004).

The population of the Municipality of Paraty was estimated in 2006 to be circa 33.7 thousand inhabitants, which are mostly located in the rural areas (52% of the houses; IBGE, 2009). After the construction of the road BR-101, the connection with the great cities of Rio de Janeiro and São Paulo pulled the occupation and increased touristic predatory activities in the region. As established by Instituto Brasileiro de Geografia e Estatística (2000) the rate of occupation of the houses is quite low (72%) and among these, only 43% is perennially occupied. On the other hand, touristic rental of houses, house construction and services are the main economic activities of the Municipality GDP (TCE, 2003). The significant increase of the occupation without the due increase in sanitary infrastructure is generating eutrophication and uncontrolled pollution that also tend to conflict with fish-farms.

The maritime portion is characterized by a flat bathymetry, that reaches 25 meters in the edge of the Ilha Grande Bay (Figure 1). Wherever emerged areas are steep, the bathymetry is also locally steep and in these areas depths 20 meters may be observed 200 or 300 meters from the coastline. These areas are very suitable for mariculture because there is no depth limitation and the installations are very close to land.

2.2 Regulations for mariculture in Brazil

The Regulation number 06/2004 from the Brazilian Government established the driving lines for the ordainment of the mariculture and introduced the National and Local Plans for the Development of Mariculture (PNDM and PLDM respectivey), that constituted a reference document for the delimitation of mariculture parks and farms. Besides aiming to promote the organization of the mariculture initiatives, the document is intended to promote mariculture that offer an alternative income for artisanal fishermen, during periods of low productivity of the extractive fisheries. Nonetheless, the PNDM also aims to provide conditions and regulations for the commercial mariculture, wherever conflicts between artisanal communities and fishermen occurs. The Regulation number 06/2004 in its local approach (PLDM at the State or Municipality level) describes in detail the type and structure of the studies that are necessary to bind the mariculture areas. The approach presented in the document can be seen as a guideline for a generic Environmental Impact Assessment (EIA) for mariculture activities, including cultivation structures, transportation structures, processing and commercialization facilities.

The Local Plans for the Development of Mariculture (PLDM) should be carried out by expert interdisciplinary groups, which define the broadness of each PLDM as a function of the already installed farms and forthcoming activities associated. The work that was done in Paraty is part of the activities of the experts interdisciplinary group of the state of Rio de Janeiro.

2.3 GIS data

From the analysis of the available environmental data, it is clear that although scattered and scarce, oceanographic and biologic surveys are reliable for the construction of a local plan

for the development of mariculture. Most of the works were obtained from university research programs (mostly master dissertations or doctorate theses) or constitute part of Environmental Impact Assessments and monitoring programs from logistics or industrial enterprises recently installed in the region. The objectives of these surveys were very distinct from those of mariculture and therefore the approach is frequently inadequate, but data is reliable and the information is suitable for the aims established in the present work. The spatial distribution of samples is normally focused on the studied problem, for instance, an EIA for a nuclear power plant from Ilha Grande Bay (Rio de Janeiro) is focused on the dispersion of pollutants in the case of accident. In this case, the hydrodynamic model (MRS, 2007) was constructed with a grid that is not adequate for the location of the farms. The simulation of the dispersion of hot water from the plant is also useless for the fish farmers. Furthermore, due to the fact that there is no articulation between these works, analytical methods, and units are sometimes incompatible, and it is difficult to correlate studies carried out in various periods. It is undeniable that an integrated program supported by the stakeholders and mainly the government is necessary, overcoming political, economic and social instabilities. Besides, the institutions responsible for this monitoring program should be strengthened, regardless its political colors.

For most mariculture areas, hydrodynamic data are scarce and circulation numeric models should be developed. Transport (dispersion) models may help to determine areas where water quality is more suitable for mariculture and may also help to determine loading capacity values for the activity (Alves and Wasserman, 2002). These hydrodynamic models may contribute to a better understanding of the oceanographic processes that dilute and disperse contaminants and therefore subsidizing the choice of better areas for mariculture. The dispersion models mentioned above are particularly interesting when evaluating the impact of coliform bacteria from domestic sewages on the cultivation stands.

In the state of Santa Catarina (Brazil) an expert group has developed a GIS system with a considerable number of variables that were thoroughly discussed by scientists and stakeholders (Novaes et al., 2010). Their system showed a reliable distribution of "suitability for mariculture" within the Baía Sul (Florianópolis), the determined variables and parameters cannot be applied elsewhere, heavily depending on the characteristics of the activity in each location.

The construction of a long term plan for the mariculture in the studied area depends on reliable monitoring programs, however, considering the present development of mariculture in Brazil, it is not possible to expect a broad and comprehensive set of data and the first management programs must be based on secondary information. Nonetheless, this management program must be the basis for a perennial monitoring of the environmental and social conditions, that will be constantly up-to-dated. This management program, in the form of a Geographic Information System will provide a dynamic process that follow the evolution of the knowledge, the evolution of the occupation of the spaces and the activity itself (Cicin-Sain et al., 1989).

In a generalist approach, Table 1 reports variables that should be considered as reference and should certainly be included in a monitoring program. However, for each location, some adaptations are necessary, including or excluding specific variables as a function of their own particular characteristics.

1. Municipal limits and hydrographic basins
2. Detailed hydrography
3. Bathymetry
4. Water parameters (at least temperature and salinity)
5. Sediment contamination (metals, organic matter, hydrocarbons, pesticides, nutrients)
6. Classified coastal line (beaches, rocky coasts, mangroves, dumping areas, coastal vegetation)
7. Roads, railways and other accesses
8. Conservation units
9. Mariculture parks and areas
10. Fishermen and fish farmers associations, communities
11. Fish and shellfish processing units
12. Maritime uses (navigation paths, nautical tourism, nautical leisure, anchoring areas, marinas, harbours, fishing areas)
13. Reef areas, rocky and sandy banks,
14. Restricting areas (regulation)
15. Soil uses and cover of the continental adjacent area (with the LCC – Land Cover Classification of FAO)

Table 1. Suggested variables for monitoring programs of mariculture areas.

Finally, an important point that has also to be discussed is the scale. When the parameter do not affect directly the activity like coastal vegetation, municipal limits, etc, smaller scales should be used (1:50,000). For parameters that directly influence mariculture like depth and sediment characteristics, bigger scales should be used. The problem is that sometimes available data grid is not tight enough to allow bigger scales. Another problem is that data variation is such that very tight sampling grid is not enough and a temporal series is necessary (that is the case for temperature or salinity). Even if the environmental parameters can only be represented in small scales (up to 1:50,000), the location of the marine farms must be precisely set (1:10,000) because overlapping of the areas should cause conflicts between farmers.

A broad range of information was obtained from academic studies, environmental impact assessment reports, management plans for the neighboring protected areas, municipal master plans and other sources. Furthermore, *in situ* observations, interviews and participatory mapping with stakeholders enriched the work. Cartographic information from the mainland were based on the topographic maps of the region (1:50,000), supplied by the Brazilian Institute of Geography and Statistics (IBGE) and the Directorate of Geographic Service (DSG – Brazilian Army). The cartographic information from the marine area was based on the bathymetric map (1:40,000) from the Directorate of Hydrography and Navigation of the Brazilian Navy (DHN).

The data was introduced in the software ArcView 9.0®, ESRI Software, and the approach was based on the concept of indicators that are variables recognized as significantly affecting the water quality or constituting elements of conflict with other activities. These variables were classified into production indicators and constraining indicator. Among the production indicators were temperature, salinity, depth, wind, currents, wave parameters, sediment characteristics, nutrient concentrations, chlorophyll-a concentrations, natural beds of seaweeds and eelgrass bank locations.

The constraining indicators surveyed were grouped into: 1) Restricted Areas (Law protected areas, leisure boating areas; anchorage distance from beaches – 200 m and from rocky shores – 50 m), 2) Activities with Potential Conflict (boat channels, diving areas, nautical tourism areas, and other activities related with Tourism, and existing marine farms) and 3) Pollution (areas of direct influence of rivers and streams, effluents from urban centers). This indicators, were also identified in other studies presented in the literature (Ferraz, 2006; IED-BIG, 2001, 2002; Perez-Sanchez and Muir, 2003; Scott, 1998) and were considered relevant for the study area.

Furthermore, buffers considering distance from routes (streets and roads), distance from urban centers, distance from traditional communities (Caiçaras) and distance from marinas and airports were included. Although the evaluation of the reach of effluents from urban sewages is tentative, a buffer was included in the mouth of rivers and channels that were considered contaminated. The Figure 2 is a brief outline of mariculture production indicators and of constraining indicators.
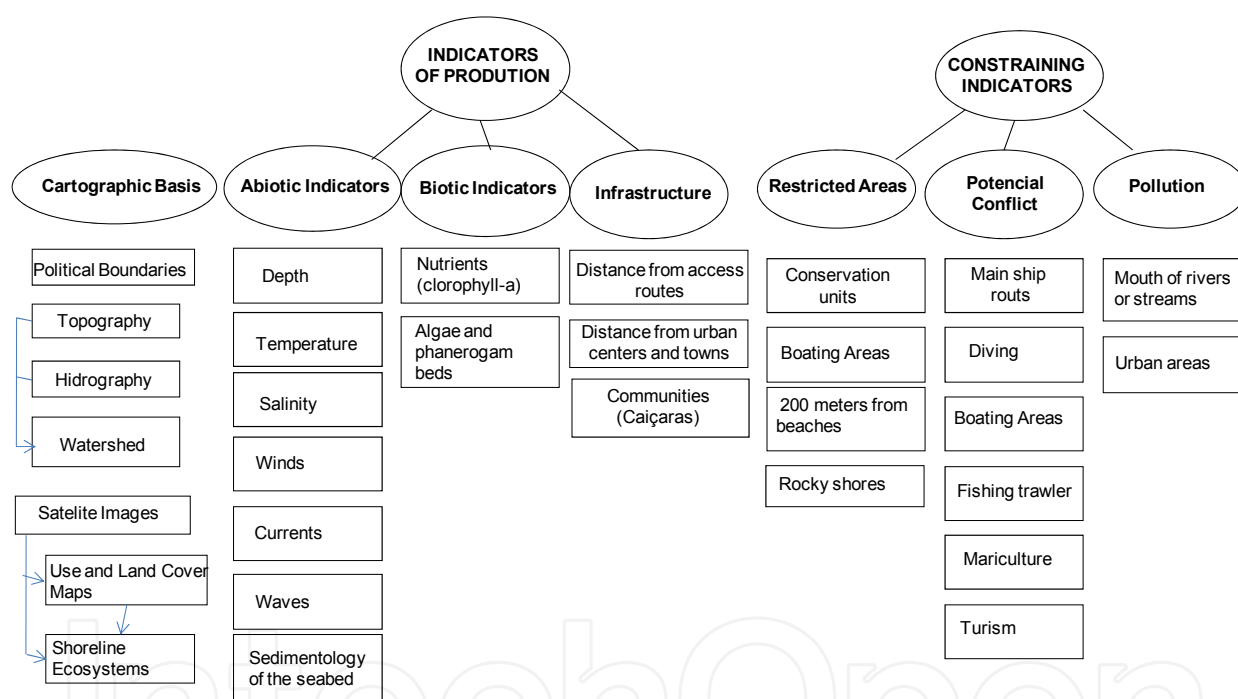

Fig. 2. Flowchart of the indicators used for the delineation of potential areas for mariculture in Paraty.

3. Results and discussion

The study area was divided into areas of direct and indirect influence. The former (ADI) includes the aquatic marine area of the municipality of Paraty, located between the coastline and the isobath 25 meters. For practical reasons, these limits considered the distance from the coast, because the costs with diving apparatus, fuel, risk of theft and risk of navigation increase for farther operations. The area of indirect influence (AII) corresponded to the watersheds that contribute with freshwater and effluents from rivers and human activities into the ADI. (Figure 3)
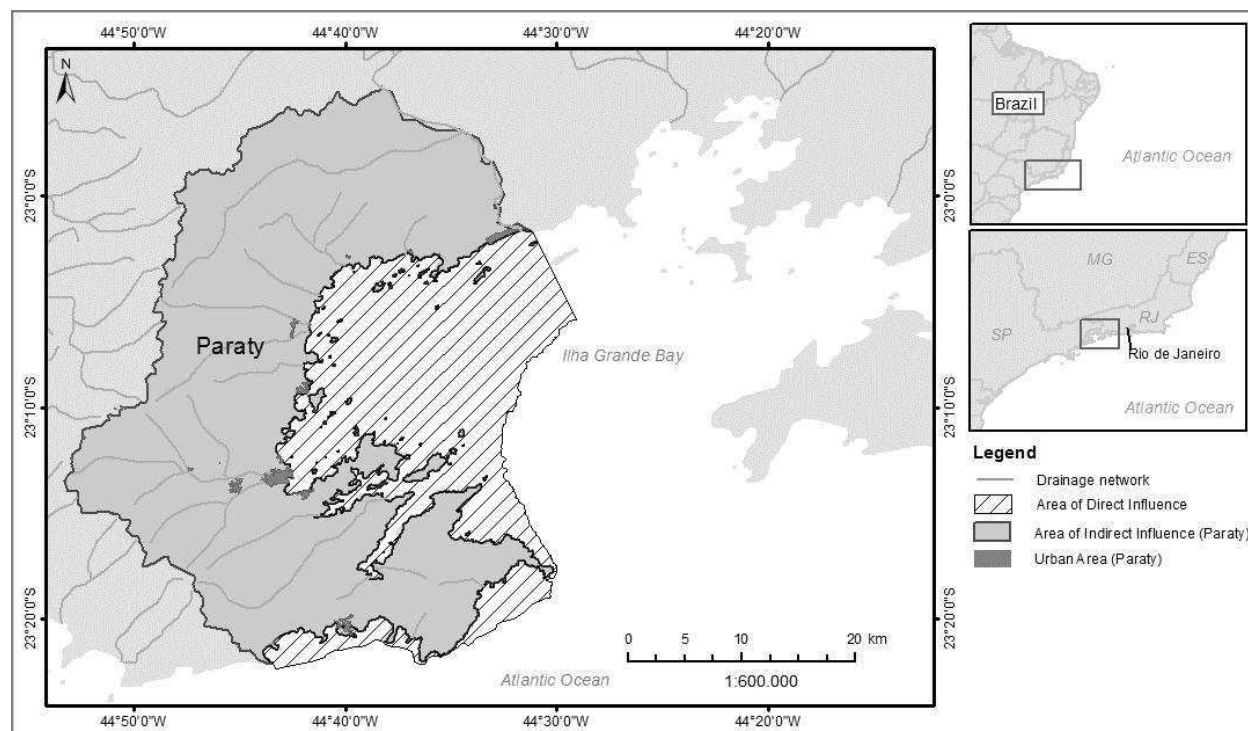
Fig. 3. Location of the Area of Direct Influence (ADI) and Area of Indirect Influence (AII).

Indicators of production	Classes/ranges		References for the classification of ranges	Data source from the study area
	Ideal	Good		
Depth (m)	5 - 15*	16 - 25	(IED-BIG, 2002)	Bathymetric map (DHN)
Temperature (°C)	18 - 22	15 - 17 and 23 - 25	(IED-BIG, 2002)	(Bormann, 2005)
Salinity	34 - 36		(IED-BIG, 2002)	(Bormann, 2005)
winds (m/s)	x	x	x	BRASFELS (2005)
Sea Current (cm/s)	10 - 60	60 - 70	(Scott, 1998)	BRASFELS (2005)
Waves (m)	< 0,25	0,25 - 0,4	(Scott, 1998)	BRASFELS (2005)
Sedimentology of the seabed	x	x	x	(DIAS et al., 1990))
Nutrients (chlorophyl-a)	x	x	x	(Bormann, 2005)
Distance from land access routes (km)	0 - 5	5 - 10	(Scott, 1998)	Participatory Mapping
Distance from the urban centers and towns (km)	0 - 4	4 - 10	(Scott, 1998)	Land cover and use maps
Distance from Traditional Communities (km)	0 - 2	2 - 5	(Scott, 1998)	Topographic maps from IBGE and *Management Plan from EPA Cairuçú*

Table 2. Range of values of the indicators of production for the cultivation of scallops *(Nodipecten nodosus)* in the study area.

The Areas of Direct Influence were classified into three categories regarding the potential for mariculture of scallops, that is the main mariculture activity in the area: ideal areas, appropriate areas or unsuitable areas. The classification considered the physiological characteristics of these organisms and ability to adapt to changes in the physical-chemical properties of the environment (IED-BIG, 2002; Scott, 1998). In Table 2 are shown the range of values for each indicator, classified as ideal or appropriate. Areas that had values outside these ranges were classified as unsuitable and were not represented on the map.

3.1 Production indicators

According to FAO (1991) the ideal temperatures for growing scallops range between 20°C and 23°C. Temperature is among the main parameters to be monitored in the cultivation of scallops due to high sensitivity to small variations of these organisms In the study area, a more recent study has shown that the ideal temperatures for the growth of *Nodipencten nodosum* range from 18°C to 22°C, not quite different from what has been observed for other species worldwide (IED-BIG, 2002). When adult, these organisms have a regular growth in temperatures ranging between 16°C and 25°C and the marine water temperature in the study area varies between 22.5°C and 26°C in summer and between 21°C and 23°C in winter (Bormann, 2005; IED-BIG, 2002). The optimum depth for scallops ranges between 5 and 15 m (IED-BIG, 2002), but depths of 16 and 25 m are still appropriate. The depth is closely related with the temperature, because in the calm waters of the study area, there is strong thermal gradients.

The adequate distance from the land routes is not farther than 5 km. Beyond this distance, the production becomes expensive and the risk of theft of equipments and of scallops become unacceptable. After reaching the coast, the access to the consumers market must also be considered, due to the need of low temperature containers. In this case, after reaching the routes, 4 km was considered as an ideal distance from consumers centers and 10 km is still acceptable (Scott, 1998). The ideal distance between shell-farmers residences and crops is 2 km, but the distance is still appropriate between 2 and 4 km. Beyond 4 km the daily transportation between their residences and the farm becomes expensive and navigation safety gets compromised (Scott, 1998).

Hydrodynamic indicators like winds, currents and waves were grouped together and represented as restrictions indicators in the southern portion of the study area that is located in the open sea and is exposed to stormy conditions. However, for these areas, farmers can consider the use of fixed structures that resist this extreme oceanographic conditions, as has been done in the neighboring Municipality of Angra dos Reis.

3.2 Constraining indicators

Due to its pristine state, the region has a great number of Conservation Units, that may or may not constitute a constraining factor, as a function of its type: the sustainable use units allows the installation of some few economic activities since it does not constitute any threat for the environment. In the case of the sustainable conservation units of Paraty, the installation of marine farms is allowed. On the other hand, the Integral Protection Units has as main objective the preservation of untouched environments. In many of these conservation units even scientists are not allowed, unless an special authorization is granted by the Brazilian Environmental Agency (IBAMA) and mariculture of any kind is not allowed. Data concerning Federal and State Conservation Units were obtained from

Foundation CIDE (2005) while Municipal conservation units were obtained from the Municipality of Paraty (Macrozonation and the Master Plan of the Municipality).

The nautical maps of the Brazilian Navy number 1633 and 1634 were used to determine the coastal limits that after Marinha do Brasil (2003) restrict any aquatic activities within 200 meters from sandy beaches or 50 meters from rocky shorelines. The activities developed in the marine environment, which may constitute potential conflicts with mariculture have also been plotted: navigation channels, diving areas, leisure boating areas, trawlers' fishing and tourism areas. In addition to areas where mariculture is already being developed.

The identification of the main navigation routes was carried out using the method of "participatory mapping" (Tuan, 1975, 1983), which consisted of collecting information from community members. In the fieldwork, the main routes were set with the aid of the Secretary of Fisheries and Aquaculture of Paraty. Information on that matter was also obtained from the Brazilian Navy Agency at the Port of Paraty. It has to be underlined that the navigation routes obtained and plotted are preferred areas, but there is no rigid limits.

The areas for diving and tourism were identified following consultation with operators and tourist guides of Paraty. The points of nautical tourism, as well as the classification of areas according to the degree of potential for tourism, were obtained from a Zonation Map of the Touristic Potentials, part of the Master Plan for Tourism Development by the Municipality of Paraty. The degree of potential for tourism ranged from 1 to areas with lower potential to 5, for those with greatest potential.

The locations of the areas where fish-trawling is developed were obtained from the Management Plan of the EPA Cairuçu. This Environmental Protection Areas comprises the whole southern coast and all of the Island of the Municipality of Paraty and therefore the document includes the whole coastal region. Furthermore, the areas of installed marine farms, including those of scallop, algae and fish were obtained from the Secretariat of Aquaculture and Fisheries of the Presidency of the Brazilian Republic (SEAP-PR), which has a register of areas required for the activity.

In Paraty, the main source of contamination is domestic sewages, that frequently are directly dumped in the drainage and rivers. Except for a few small shipyard (leisure boats), no possible source of contamination from industrial activity is present in the drainage basin. Agricultural activities are also scarce in the region (Rocha, 2005) because of the steepness of the terrains and therefore very little nutrient inputs from fertilizers can be identified (MRS, 2006). Based on the above statements and order to access the impact and extent of the domestic pollution in shellfish farm areas, a buffer of 500 meters or 1000 meters radii from the mouth of the rivers and streams was established, beyond which, mariculture is adequate or ideal (respectively). These limits were established without any consistent ground, but were corroborated by IED-BIG (2002). For a better establishment of these buffers a hydrodynamic transport numeric model has to be developed, in order to simulate conservative and non-conservative contaminants.

According to Instituto Brasileiro de Geografia e Estatística (2000), 85% of households don't have sewages treatment that may constitute a serious restriction to mariculture. Contamination with coliforms or with nutrients may cause harmful algae blooms (HAB) constituting serious threats to consumers of sea food. After an outbreak of HAB, the recovery of the activity is very difficult and demands a lot of new investments. The importance of the evaluation of the impact of these contaminants was recently demonstrated in the outbreak of what looked like a shellfish disease in the Ilha Grande Bay (Côrtes et al.,

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2009). The disease colored the kidney of scallops and as scientists tried to identify what was responsible for the anomaly, no side environmental data could support any of the hypotheses. Furthermore, the studies initially carried out were not integrated and did not constituted reliable evaluations. Considering the risks in cultivation of mollusks and fishes, including contamination with harmful algae blooms, it is advisable that a technical and scientific team should be ready for action in the case of outbreak of diseases.

Finally, the local shellfish farmers were listened in order to determine the areas that their experience indicate as more suitable for the cultivation of mussels, utilizing the participatory mapping method (Tuan, 1975, 1983). Rough outlines were established together with the stakeholders, who identified in nautical charts, in the scale 1:40,000, the most viable areas for cultivation, following what is called "cognitive knowledge".

3.3 Data analysis

The identification of potential areas for mariculture was made according to the results obtained in synthesis maps via the Boolean intersection method (Burrough and McDonnell, 1997). This method of analysis does not require quantitative rating of the production indicators and indicators that showed significant restriction for mariculture. Data on potentially conflicting activities were presented in a separate map (Figure 4), considering the large amount of information being displayed. The areas of conflict are not considered as areas of exclusion of mariculture, but constitute multiple use territories, where acquaintance of use has to be achieved from agreements between local managers and other stakeholders.
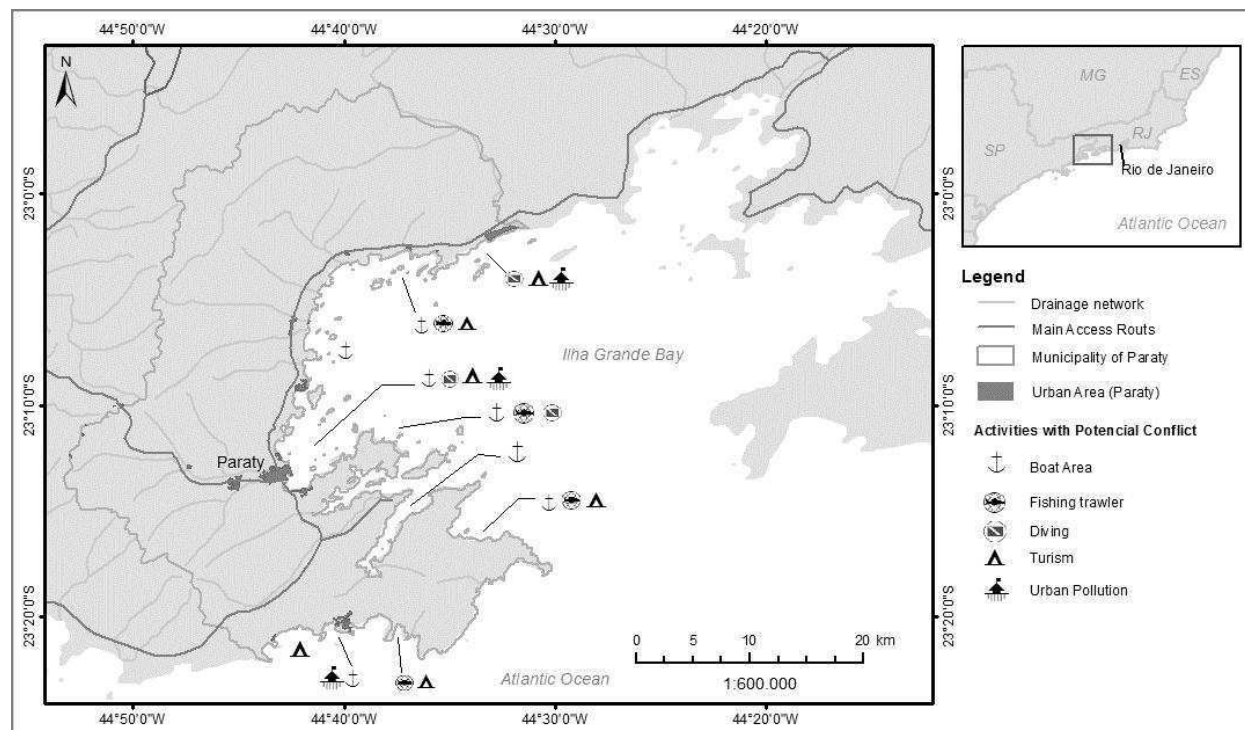

Fig. 4. Potentially conflicting activities in the coastal region of Paraty.

It is interesting to note that the areas established in the participatory process overlap those established with the indicators of production and constriction. The analysis of Figure 5 indicate that the northern portion of Paraty is not quite suitable for the cultivation of the

scallop, because during summer water can present very high temperatures. This higher temperatures are attributed to the reduced hydrodynamics and shallowness. In this northern portion, the more significant inputs of fresh or contaminated waters, higher levels of suspended matter and other factors are also responsible for the reduced suitability for scallop cultivation.

From Figure 5, the best (ideal) areas for mariculture of scallops are located near the Ilha do Algodão and Enseada do Pouso (Pouso Cove) in the semi-sheltered and barely occupied southern region. Furthermore, the settlement of traditional Caiçara populations favors the installation of shellfish farms that may constitute a sustainable source of incomes for these poor communities. Farther South, the Enseada Martins de Sá (Martin de Sá Cove) is also considered as ideal for the cultivation of scallops, however special structures should be installed in order to stand the destructive potential of the currents and waves expected during storms in the area.
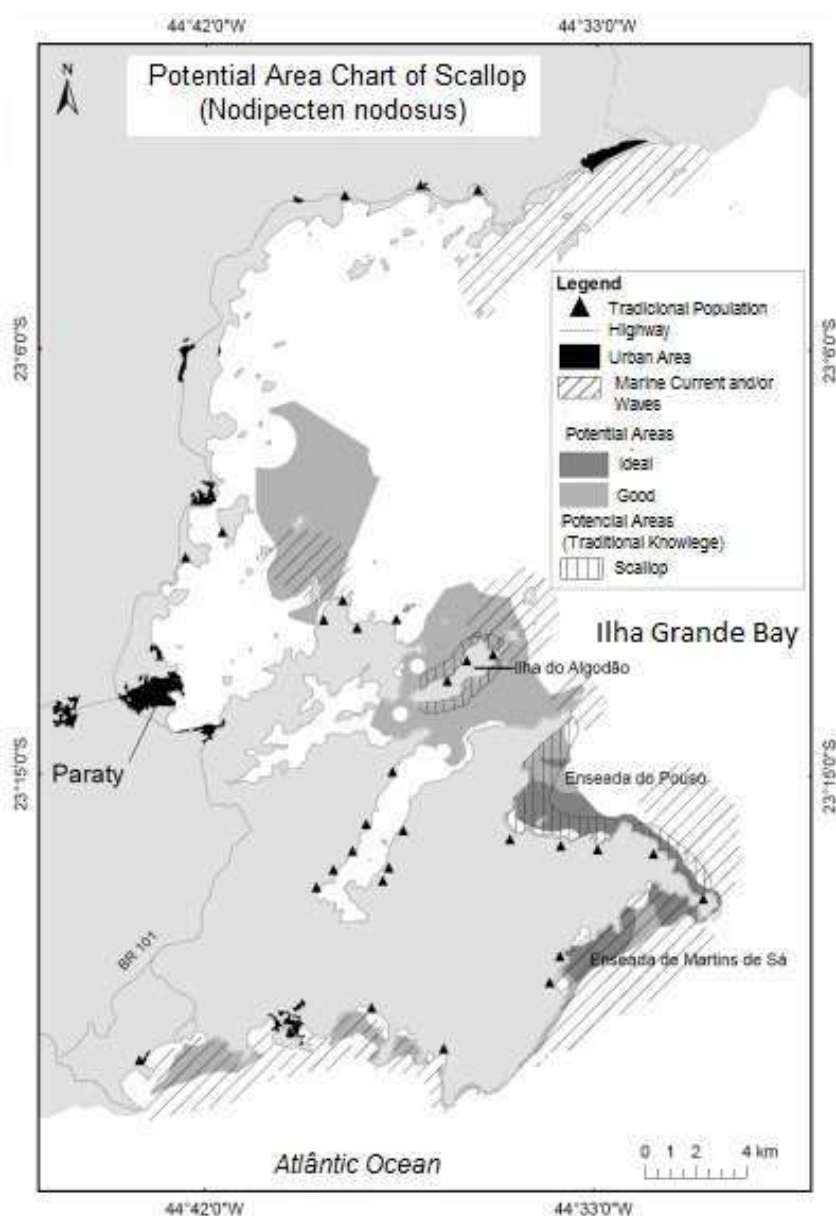
Fig. 5. Summary map, showing the suitable areas for cultivation of scallops (*Nodipecten nodosus*).

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In the surroundings of the city of Paraty, mariculture is not advisable due to heavy boat traffic and the influence of contaminants generated mainly from domestic sewage and fuel oil from leisure boats. In the northern portion of the study area, the presence of Conservation Units prevents the installation of mariculture parks in the surroundings of the islands. However, the proper management of the water quality in this portion of the study area, would allow the installation of the activity in the unrestricted areas. The knowledge of the load capacity of each environment has to be developed, permitting to establish a safer dimension of the activity. Conflicts also must be managed with a strong participatory process, establishing strategies for the multiple use of the territory.

4. Conclusions

In conclusion, wherever mariculture is still scarce, the ordainment procedures tend to be quite simple and there is no formal farm management, while in areas where the activity is already developed, procedures tend to be much more complex, and conflicts are emerging, demanding for evolved systems. Nonetheless, it is clear that with time and the development of mariculture, the planning of the marine territory occupation is an advisable attitude that will avoid problems like those seen in the Northeast Brazil where whole crops of the Malaysian shrimp were lost.

In Paraty a number of items that may be evaluated in order to avoid conflicts of use, overexploitation of the natural resources (compromising sustainability of the activity) and most suitable areas for the activity were determined. These items were plotted in a GIS map, constituting a useful tool for the location of mariculture parks, where the installation of farms is preferred. The organization of the activities in mariculture parks where conditions are more favorable may constitute a solution for the expected growth of the activity avoiding issues with other activities and with the environment.

The findings of this study show that among the indexes of production that determine suitable areas for mariculture in Paraty, stand out: The distance of marine farms in relation to traditional populations; depth, and temperature variation along the year, inputs of freshwater and contaminants. In the area exposed to storms, cultivation is advisable but more expensive investments in equipment have to be applied in order not to have the production lost during stormy weather. An economic study has to be carried out in order to evaluate whether this investments are profitable or not for the local communities.

It has to be warned that the application of the GIS method in other areas may be subject to adaptations that consider local characteristics; nonetheless, it can be a significant contribution for a better management and long term sustainability of mariculture.

5. Acknowledgments

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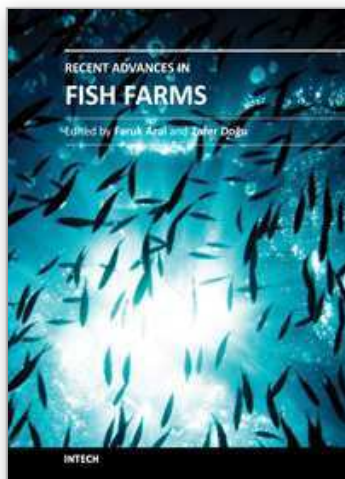
Recent Advances in Fish Farms

Edited by Dr. Faruk Aral

The world keeps changing. There are always risks associated with change. To make careful risk assessment it is always needed to re-evaluate the information according to new findings in research. Scientific knowledge is essential in determining the strategy for fish farming. This information should be updated and brought into line with the required conditions of the farm. Therefore, books are one of the indispensable tools for following the results in research and sources to draw information from. The chapters in this book include photos and figures based on scientific literature. Each section is labeled with references for readers to understand, figures, tables and text. Another advantage of the book is the "systematic writing" style of each chapter. There are several existing scientific volumes that focus specially on fish farms. The book consists of twelve distinct chapters. A wide variety of scientists, researchers and other will benefit from this book.

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