Ocean & Coastal Management 71 (2013) 195–202

Contents lists available at SciVerse ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

The social cost of dredging: The Bahia Blanca Estuary case

Mariana I. Zilio [a,b,*], Silvia London [a,b], Gerardo M.E. Perillo [c,d], M. Cintia Piccolo [c,e]

[a] CONICET – Universidad Nacional del Sur, Instituto de Investigaciones Económicas y Sociales del Sur, 12 de Octubre y San Juan, B8000CTX Bahía Blanca, Argentina
[b] Departamento de Economía, Universidad Nacional del Sur, 12 de Octubre y San Juan, B8000CTX Bahía Blanca, Argentina
[c] CONICET – Instituto Argentino de Oceanografía, CC 804, B8000BFW Bahía Blanca, Argentina
[d] Departamento de Geología, Universidad Nacional del Sur, San Juan 670, B8000ICN Bahía Blanca, Argentina
[e] Departamento de Geografía, Universidad Nacional del Sur, 12 de Octubre y San Juan, B8000CTX Bahía Blanca, Argentina

ARTICLE INFO

Article history:
Available online 3 November 2012

ABSTRACT

The Bahia Blanca Estuary System constitutes an ecosystem unique in the world by its physical, geographic and biological characteristics. In the frame of a major investment project related with natural gas provision, a dredging process has been planned and its execution results imminent. However, the analysis of socioeconomic effects of this dredging process has not been performed up to now. In this context, our objective is to estimate social costs and benefits of the dredging process related with the gas plant project mainly derived from the loss of the nursery services of the estuary and the loss of the jobs associated with fishing activities. Our results indicate that socioeconomic cost of the dredging related with the project is between US$ 5 million and US$ 6.5 million depending on how the displaced labor force can be reallocated.

1. Introduction

The Bahia Blanca Estuary (BBE) (Fig. 1) is located in the southwest of Buenos Aires Province, Argentina, having an area of ca. 3000 km^2. Within its area of influence, the estuary contains a wide range of valued coastal resources, among which fisheries, open spaces, natural reserves and wildlife habitat can be stressed. The estuary could be described as a series of major NW-SE tidal channels which separate extensive coastal wetlands and islands (Perillo and Piccolo, 1999). The mesotidal range on a low relief area gives place to large tidal flats and both *Spartina* and *Sarcocornia* marshes which allow adequate conditions for benthic infauna and the development of particular biological structures worldwide unique (Perillo and Iribarne, 2003).

The coast of the Canal Principal (northernmost tidal channel) houses the largest and deeper harbor system in Argentina from which most of the grain and other industrial exportations are made. These harbors include oil transfer buoys, the trading dock of Rosales Port and the largest navy base (Puerto Belgrano). Moreover, the inner estuary houses the port of Ingeniero White, which has two differenced areas: one devoted to grains and the other to general merchandise.

In 1989–1991, the navigation channel was dredged to a depth of 13.5 m (45 ft) from a previous 10 m, and its development has promoted the settlement of several industries that have conformed one of the most important petrochemical poles of Argentina. Furthermore, certain particularities of the BBE convert it into a unique system. One of these singular characteristics is given by its calm waters and nutrient richness, which create favorable conditions to several migratory fishes and birds that stay in the estuary for its feeding during youth. The inner reach of the Canal Principal is the sector where the trophic chain of the system initiate based on a winter bloom of phytoplankton which is directly related to calm winds, no waves and, consequently, lower concentration of suspended sediments (Guinder et al., 2010). The bloom is favored by the higher light penetration and the significant nutrient pool that is not depleted by the bloom (Guinder et al., 2009).

Two mysids species are present in the BBES: *Arthromysis magellanica* (Cunningham) and *Neomysis americana* (Smith). They are present in the estuary from August to March and constitute the main food for various species living in the estuary, as Whitemouth Crocker *Micropogonias furnieri* (Desmarest), flosunder *Paralichtys orbignyanus* (Jenyns), rays *Synpterygia* spp, *silversides Odonthesthes* spp, and weakfish *Cynoscion striatus* (Cuvier) (López Cazorla, 1987). These species, along with other ones living in the coastal waters

* Corresponding author. CONICET – Universidad Nacional del Sur, Instituto de Investigaciones Económicas y Sociales del Sur, 12 de Octubre y San Juan, B8000CTX Bahía Blanca, Argentina. Tel.: +54 291 4595138; fax: +54 291 4595137.
E-mail address: mzilio@uns.edu.ar (M.I. Zilio).

0964-5691/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ocecoaman.2012.09.008

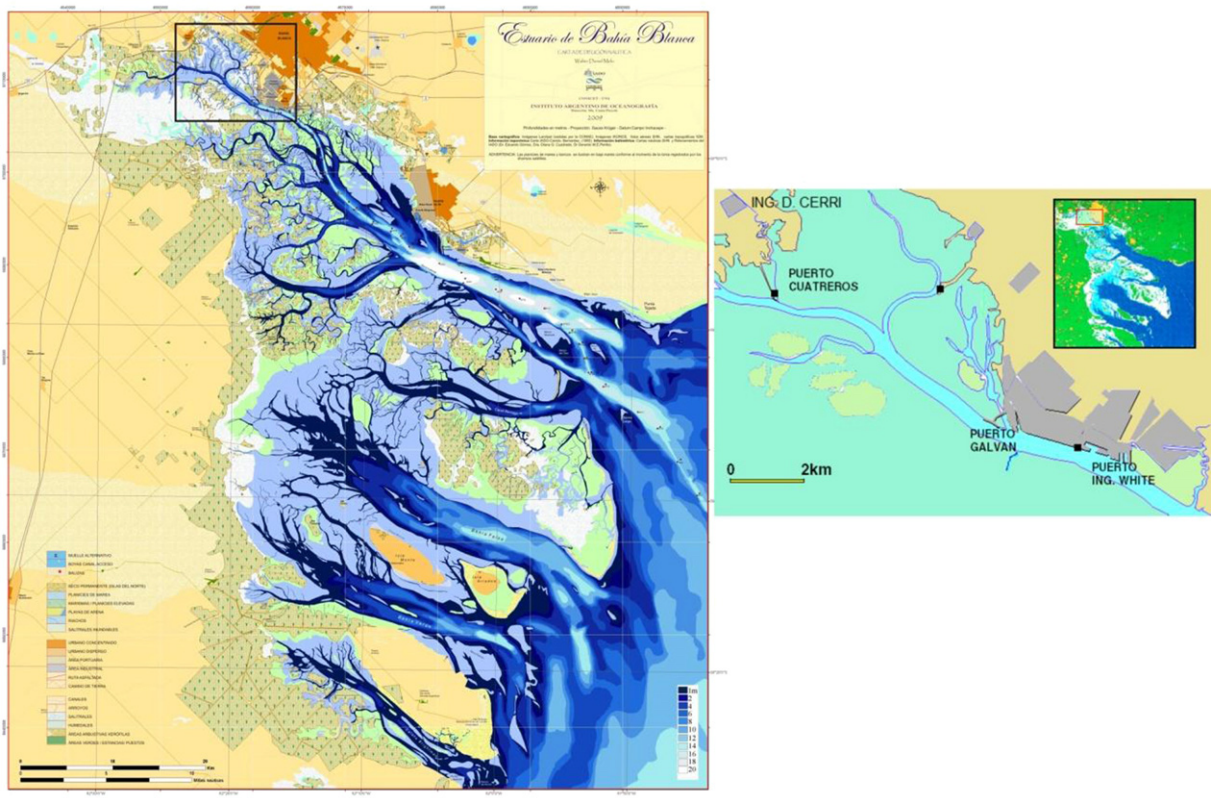

Fig. 1. General map of the Bahia Blanca Estuary with the area to be dredged in the insert.

that form the channels and islands of the BBE, as prawn *Pleoticus muelleri* and shrimp *Artemesia longinaris*, constitute the traditional fishery of the area from several decades ago. Furthermore, this artisanal near-shore fishery constitutes the only labor source of numerous families of neighboring population.

The local community comprises two small towns, General Daniel Cerri and Ingeniero White (Fig. 1), both belonging to the area of influence of Bahia Blanca City, with a population of 8716 and 10486 inhabitants, respectively (2010 and 2001 INDEC Census), in its major part directly and indirectly related with fishery and other productive activities carried out on the base of the estuarine services.

In this frame, the proposal to build a processing gas plant on the shore of the estuary requires an extensive estimation of its potential effect over the local community. Mainly due to the close link between activities of a large portion of the population and the estuarine ecosystem services, there is a need to take into account these concerns when estimating costs and benefits of any investment project involving the area.

The hypothesis we follow is that the effects of the dredging and further construction of the plant as well as the vessel circulation and maintenance of the channel and harbors will sensibly reduce the ecosystem value. Potentially, these modifications of the system will be able to introduce such irreversible changes that will fully alter the ecological conditions of the whole estuary. As a consequence, fisheries activities on the area will be indirectly affected by the dredging process, with a clear impact on the social conditions of local communities.

The structure of the paper is organized as follows. In the next section, we summarize the main aspects of the processing gas plant projected in the area of the BBE. Considering this, we highlight the potential effects that this project could have on local community at social level. After briefly exposing the relevance of ecosystem services valuation, we present the methodology employed in order to perform a cost-benefit analysis. Finally, we conclude about the social effects of the dredging process planned in the frame of the project.

2. The project behind the dredging

As stated above, the proposed valuation process emerges from the need to measure the socioeconomic impact of the dredging process planned for the inner portion of the BBE in the frame of a greater project related with national gas provision. Such project, called LNG Puerto Cuatreros (LNGPC hereafter), mainly motivated for unmet needs of natural gas at national level, will demand an investment of around US$ 200 million and it is estimated to begin operations in March 2013.

The first stage of the plan involves the construction of a pier with two berths, designed to receive the current fleet of Liquefied Natural Gas (LNG) ships on the south side and be home of a fixed re-gasification vessel on the north side. In this point, it is necessary to mention that there is another vessel already operating in a central area of the port zone. As this vessel is very close to local population and the petrochemical plants, the potential damage is very high in case of an eventual accident. The location of this ship has generated a deep discussion between residents and industrial sector, which has declined in intensity as residents have become accustomed to the presence of the ship at the dock. Although the possibility of relocating the first re-gasification vessel in an area outside the estuary (or at least away from the populated area) is being analyzed, the installation of a new re-gasification ship could raise a new concern on residents regarding the security conditions under which they operate.

During the second stage, the project includes moving the re-gasification process to land and store LNG in a ship moored on

the north side of the pier, a process that will provide between 14 and 25 million of cubic meters of gas daily.

In order to complete both stages, LNGPC project involves the dredging of a navigation channel of the inner estuary to a depth of 13.5 m (45 ft). In a later stage, it is planned the construction of a 12 km gas pipeline to a gas processing plant already installed near the area under study. Moreover, the project includes refurbishment works on the current pier Puerto Cuatreros, in order to allow community access for recreational use.

Official information about the dredging project providing the precise location of the future gas plant (Fig. 2), confirms the realization of several studies analyzing soil conditions, sedimentation and marine currents, as well as environmental impact studies. These studies have been recently presented publicly but analysis of their findings, especially regarding the baseline environmental conditions, show that their results are totally biased towards acceptance of the project without serious concerns to the environmental impact of the whole project. Furthermore, there are significant errors within the study that basically call for both methodological and interpretation concerns regarding as how the environmental impact assessment was made. The large number of errors indicated have been presented in two reports (IADO, 2012a, b) that are being analyzed by the Organismo Provincial de Desarrollo Sustentable (OPDS) which is the environmental authority of the Buenos Aires Province that has the final approval capability for the dredging. These reports clearly show lack of adequate or minimum information about the actual processes that occur in the estuary, deficiencies in the forecast models and wrong or biased interpretation of previous work among many other issues.

As we stated above, the main motivation of LNGPC project is the severe problem on current natural gas provision in Argentina. This situation has deep implications mainly due to the concentration of energy generation in thermal energy, which in 2010 is accounted for 63% out of total generation at national level.

This provision problem has also environmental consequences. Since the natural gas reserves in Argentina could only guarantee their provision during a horizon of ten years and due to the existence of gas provision problems at present, other fossil fuels are currently being used as input in power generation. These fuels, mainly gas oil and fuel oil, are clearly more polluting than natural gas, generating a greater level of greenhouse gas emissions and, consequently, a higher environmental damage. There is even a national government project to build a power plant fuelled with low quality coal in the southern part of Argentina.

Moreover, the lack of natural gas has directly implied the need to import gas at higher prices. In fact, Bolivian and Venezuelan gas is currently imported and in some cases re-gasified, as in the case of the above mentioned vessel docked at the port of Ingeniero White. In this frame, LNGPC comes to partially solve the provision of natural gas at national level, since in its final version the projected gas plant will inject above 25 million of cubic meters daily to the interconnected national system.

Despite the advantage associated with the increased volume of gas that will provide the new project, it may not be appropriate to the local community. There are two reasons explaining this result. On one side, higher volumes of gas will not imply lower prices. In fact, prices of gas are in Argentina subject to a strong regulation and almost directly related with the freezing of wellhead prices of natural gas. On the other side, the raise in gas price resulting from importation of Bolivian natural gas and Venezuelan and Trinidadian LNG, importations has been recently allowed to be translated to the distribution system. While LNGPC will probably regasify LNG from those countries, the positive effects derived from a higher volume of gas will probably be offset by higher final prices. Moreover, recent changes in the tariff structure aimed to cut subsidies in the Argentinean energy sector will exert additional raises in final gas prices in the short term. For these reasons, a net benefit is not expected at local level, although the contribution of

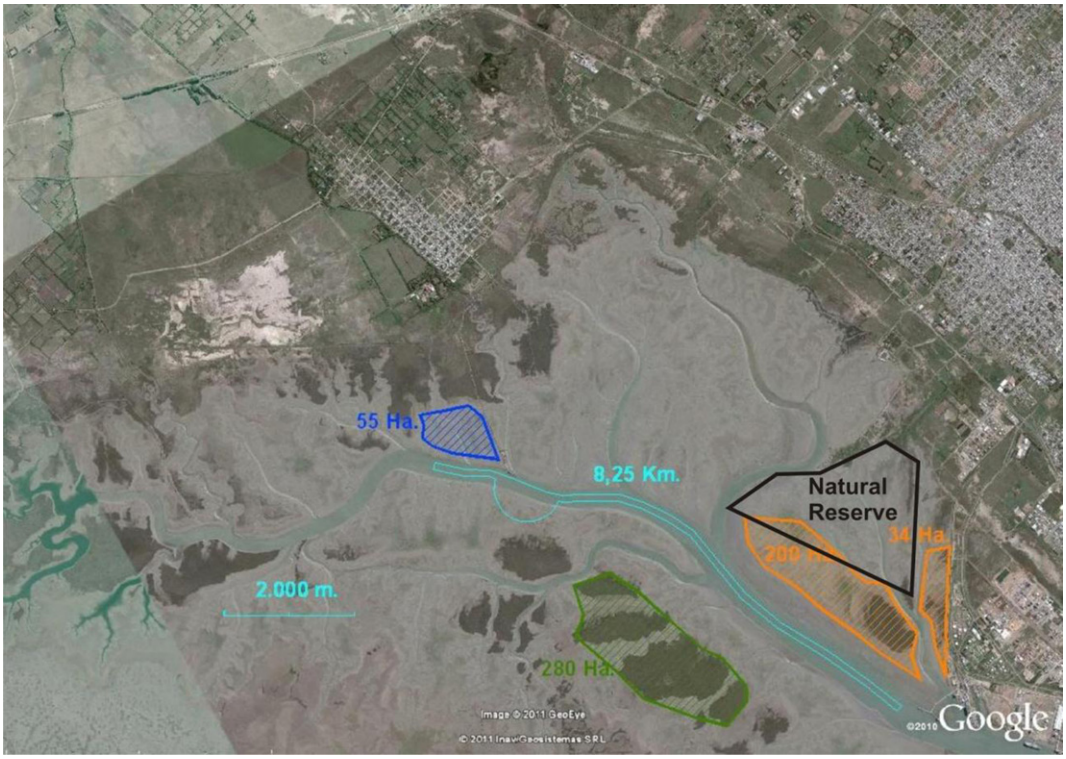

Fig. 2. Dredging project as provided by the port Authority. The natural reserve which also will be affected by the dredging and the location of the dredge disposal sites is also indicated.

the project to solve the problem of natural gas provision will be clearly positive nationwide.

Regarding employment generation, the expected impact of the LNGPC project as a whole is very small. According to official information, the creation of one hundred new jobs is expected during its building, while only sixty permanent employments will be generated once the plant is working.

In spite of these small effects on local community, we recognize the social relevance of this project at national level. However, the scope of this paper is limited only to the estimation of the social costs and benefits of the dredging process required to the operation of the gas plant in the inner zone of the estuary. Such estimation requires taking into account not only the implications that the dredging process could have for ecological functioning but also their effects on the local labor market. It is important to indicate that, besides the dredging project discussed here, there is a more advanced deepening of the main navigational channel from Ingeniero White seaward to a depth of 15.25 m (50 ft). Both dredging projects are independent and they can be made even if the other is not done. In this context, the objective of this paper is to develop a cost-benefit analysis in order to estimate, in current dollars, the social impact that the dredging process of the inner reach of the BBE in the LNGPC project frame could exert on local community.

2.1. Proposed dredging operation and its effect over the fauna a flora of the estuary

As indicated in Fig. 2, the development of the LNGP will require dredging of over 10 km of the Canal Principal from Puerto Galvan to Puerto Cuatreros. Most of this sector of the channel has an average depth of 4 m to the reference datum for the area and maximum depth of 7 m in high tide. Dredging will be made at a depth of 13.5 m to the reference datum to insure vessel circulation most of the tidal period. The estimated volume of sediment to be dredged and dumped on the adjacent wetlands is 11 million m^3. The sediment in the bottom of the channel are in its majority silty clay quite compacted as they correspond to the old deposits from the Colorado River Delta (Gómez et al., 1996; Melo et al., 2003) and outcrops of the Pliocene Chasicó Formation (Gómez et al., 1996).

The inner sector of the Canal Principal of the estuary is the main sector where two phytoplankton blooms occur along the year; the largest one occur in winter and a relatively smaller one in middle to end of summer (Guinder et al., 2009, 2010). These blooms occur in this area due to a reduction in wind activity which concomitantly reduce wave action on the tidal flats and the consequent significant reduction of the suspended sediment concentration (SSC) (Perillo and Sequeria, 1989; Guinder et al., 2009, 2010). As SSC decreases, light penetration increases favoring the phytoplankton growth with the initiation of the trophic chain. Since this area has a very low residence time (estimated in 28 days, Piccolo and Perillo, 1990; Perillo et al., 2004) any SSC that will be removed during the dredging will have a long residence time within the area and necessarily affect the levels of light penetration and phytoplankton growth.

Furthermore, the two dumping areas located on the northern margin of the channel and near Puerto Galvan are in direct conflict of the Municipal Natural Reserve blocking the natural circulation of system and clearly affecting the evolution of an area which is worldwide unique (Perillo and Iribarne, 2003).

3. Methodology

Scientific literature has widely focused on economic valuation of ecosystems over the last four decades. With this purpose, a wide range of methodologies have been developed, as well as several studies have provided a framework of analysis for the valuation of ecosystem services (Constanza et al., 1997; De Groot et al., 2002; Millennium Ecosystem Assessment, 2003; among others). In this context, ecosystem services consist of flows of materials, energy and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare (Constanza et al., 1997).

According to Barbier (1994), any ecosystem offers a range of goods defined as harvested resources, services that contribute to economic production, and attributes related to the structure and organization of biodiversity that are essential to sustain life. They include nutrient cycling, biological productivity, hydrology, sedimentation and the ability to support life itself, among others. Even if this concept of ecosystem goods and services has been widely popularized, the Millennium Ecosystem Assessment (MEA) (2003) have redefined ecosystem services, grouping them into provisioning services (food and water), regulating services (flood, disease control), cultural services (spiritual and recreational benefits) and supporting services (nutrient cycling). It is noticeable that provisioning, regulating and cultural services are not possible to occur without supporting services. For this reason, the estimation of the latter category has become a controversial point in the frame of ecosystem services valuation since it tends to double counting.

In particular, estuaries offer a wide variety of ecosystem services that generate value and contribute to human welfare (Barbier et al., 1994). In this frame, it is possible to distinguish some particular ecosystem goods, services and attributes of aquatic and water-dependent ecosystems that become more relevant than others. Effectively, Constanza et al. (1997) ascribes to estuaries a high importance status to production of fish and food plants and medicinal plants (as goods), refugia, nursery areas and export for materials, nutrient and sediments (as services), and structure and composition of biological communities (as attributes).

In order to assign value to ecosystem services, environmental economics uses the concept of Total Economic Value (TEV) compounded by direct use, indirect and non-use and option value. Direct use value derives from the consumptive or non-consumptive use – or extraction – of resources; indirect use value is generated by outputs from ecosystems that act as input into production of other sectors or contribute to saving costs; and non-use values includes the value of having the option to use the resources in the future, as well as the value of knowing that the resource exist in the present, measured through the willingness to pay for it.

As stated before, economic valuation of ecosystem services has been object of a deep debate all across environmental and ecological economics literature (De Groot, 1987; Constanza et al., 1997; Heal et al., 2005; Barbier, 2007). However, a wide consensus exists on the relevance to quantify direct values as well as indirect ones, while debate is still open about the convenience to estimate both option and non-use values. The latter case became a very controversial point mainly due to the techniques applied in order to get a value to intangible attributes. In fact, contingent valuation and hedonic prices – generally used to valuate this kind of services – have been, and still are, highly questioned. The main criticism points out that it is not always possible to connect the answers of individuals involved on the valuation process with their real behavior if the proposed situation is effectively verified (Ingraham and Foster, 2008).

In our case, non-use value of the estuary is mainly related with the construction and maintenance of local identity. Even when we recognize the relevance of this, we consider that an accurate valuation of these non-use values is out of the scope of this paper. For that reason, our work is aimed to estimate only social costs and benefits related with both direct and indirect economic values of

the ecosystem services potentially affected by the dredging process, using the cost-benefit analysis (CBA) proposed by Hanley and Barbier (2009).

Furthermore, we focused on local communities to estimate the social costs and benefits derived from the dredging process related with LNGPC project. This is because, naturally, stakeholders can have very different perceptions on the values of ecosystem services, depending mainly on their dependency upon specific services to provide income or sustain their own living environment (Hein et al., 2006). The more the degree of involvement with activities related to ecosystem services of the estuary, the more the effect that this dredging process will have on local community. In particular, non-commercial fishermen, their families and the whole General D. Cerri community are potentially the most affected by the activities related with the dredging process.

Regarding temporal dimension and, because natural assets continuously provide ecosystem services through time, our cost-benefit analysis is not static. As stated by Barbier (2007), it is necessary to model how the changes in stock or biological population may affect the future flow of benefits. In this sense, to use a dynamic approach in order to take into account inter-temporal stock effects of environmental changes becomes essential, since offering a picture of situation in a given moment of time is not useful. In view of this, this paper comprises a temporal horizon of 10 years. We consider this length as big enough to take into account the time in which the effects of dredging process can persist, as well as is not too short to consider natural regeneration of ecosystem services of the estuary.

The latter point becomes crucial to estimate the cost of dredging process. If BBE were a completely closed system, the dredge would definitely deplete nursery services. This is true in the case of the removal of primary and secondary production as well as benthic biota generating total disappearance of marine life. However, if the estuarine system is open, it has a relative advantage in order to recovering such productions. In this sense, it is probable for BBE to partially recover the conditions that make it the best option for several species that use their waters as nursery and breeding habitat, in a relatively short time period. However, new dredging activities are projected once a year in order to maintain the reached depth. The dumping of the subsequent dredged material will be made on the various islands that will be formed during the primary dredging. It is expected that these islands will be employed in the future by the harbor to expand its premises. For that reason, the long term effects of dredging process on estuarine environmental conditions remains unknown, and the uncertainty degree over its recovery process is too high to be dismissed.

As stated by other similar studies estimating the value of ecosystem services (Ingraham and Foster (2008) for US National Wildlife Refuge System; Kaufmann (2011) for Delaware Estuary, among others), our estimates are not all inclusive. Unavoidably, some benefits to inhabitant of the area, as well as some services provided by the system, are not able to be measured and, then, it is not possible to fully estimate the real value of the estuary. Regarding ecosystem services affecting social conditions, we consider that nursery and refugia are the more relevant services in the BBE case. Consequently, we propose to estimate only supporting services in order to capture the social impact of dredging process on local community. Doing this, we avoid the double counting problem and find an accurate value of the estuarine ecosystem services for this case, assuming that supporting services represent the main value of the system.

In order to develop our analysis, we consider that main social effects of the projected dredging process at social level would be the changes on local identity, the temporary disappearance of the nursery service and the impact on the local labor market. Since the former is not easy to estimate because of its intangibility, as we stated above, we concentrate into the estimation of the latter two factors.

Furthermore, we choose the traditional project analysis approach, based on the estimation of a cash flow during the selected period. The main reason is the singular characteristics inherent to BBE cited above, which make it impossible think any valuation of ecosystem services in the system on the basis of a benefit transfer methodology.[1]

4. Benefits and costs of the dredging process

As we stated above, benefits and costs of the dredging process related with LNGPC derives from the potential changes on local identity, the temporary effects on the nursery service and the impact on the local labor market. Moreover, other effects of dredging process can be cited, although it could be not estimated for practical reasons. Negative impact of the dredging process on recreational fishery in the area is one of them. Unfortunately, its valuation remains out of the scope of this paper, mainly because it involves the use of some methodologies – as contingent valuation methods – which are, as we mentioned above, very complex and widely questioned across the environmental literature.

Other factors, argued by individuals of the local community that try to discourage the whole project, such structural damages into the houses of residents in the area and a higher pollution level into estuary waters, are not proven attributable to the dredging process. For that reason, we dismiss its effects in the frame of our cost-benefit analysis.

4.1. Changes on local identity

One of the berths planned in the frame of LNGPC project is located between the Bahía del Pejerrey and Maldonado channels (Fig. 1), about 2500 m near the urban zone of General D. Cerri. This area currently houses a great portion of artisanal fishery, which develop near-shore fisheries activities and will be clearly affected because of the dredging process.

As described below, the dredging will directly affect phytoplankton, zooplankton and benthic populations causing the disappearance of the resource from the beginning of the trophic chain. This depletion could generate the move of the affected fishermen to other areas adjacent to the dredging zone. However, it has not been proven that this move will be cost free or even feasible, since the real mobility of artisanal fishermen could be clearly conditioned to their ability to fish offshore, the size and characteristics of their boats, the economic costs of moving and the availability of fish in such adjacent areas.

In this frame, it is worth noting that during the dredging process and until the estuary recovers its natural ecosystem conditions, the situation of artisanal fishery is a mystery. What is clear is that their labor source will be temporarily cancelled, as well as the possibility of developing their activity.

The artisanal fishery plays a crucial role in local identity, since it is totally integrated and keeps strong linkages with the whole community. Mainly for that reason, the effect of the dredging directly carries a social impact through the transformation of the activity around which community life evolves. Although a priori this change in local identity is expected to have negative effects due to the breaking-off between local community and its environment, it could also be positive if the transformation were able to improve living conditions.

[1] See Barton (2002) and Loomis and Richardson (2008) for further details on benefit transfer methodology.

As we stated before, changes on local identity are difficult to estimate because of its intangibility.[2] Therefore, even when we recognize that these changes play a crucial role in determining social impact of the dredging process, we are not able to include it in the cash flow of our cost-benefit analysis.

4.2. Impact on nursery services

The value of estuarine waters as a nursery and breeding habitat for near-shore fisheries is the most directly affected by the dredging process. Based on the data provided by Guinder et al. (2010), an increase in the suspended sediment in the inner reach of the estuary, produces the disappearance of the winter phytoplankton bloom, which affects the zooplankton and benthic populations. Therefore, the dredging could break the trophic chain in its beginning and directly generates the loss of nursery service for migratory species that use estuary waters for feeding and growing during its youth. This is the key effect of the dredging process. As the dredging removes the bottom of the estuary, in order to deepening the channel, is removing millions of cubic meters of sediment from the seabed. As a result, most of phytoplankton and zooplankton populations will be withdrawn and the remaining will die soon, because of the scarcity of sunlight due to suspended sediment. At this point, the depletion of the nursery service of the estuary will be done.

Furthermore, some intrinsic characteristics of BBE converts this loss of the nursery services in a major problem, since its geographic conditions and ecosystem services richness make it the optimal option to hundred of specimens looking for particular conditions for its growing and feeding. Moreover, artisanal fisheries crucially (if not exclusively) depend on the catch of migratory species, so the break of feeding chain directly implies the death of the activity. This will continue over time until the estuary is unable to recover their supporting life service, situation that will crucially depend on their ability to regenerate habitat conditions as well as on the frequency of maintenance dredging.

On the other side, the moment of the year in which dredging process takes place is totally relevant in order to ensure system survival or regeneration. Examining the evolution of phytoplankton and zooplankton population in BBE across the year, it is noticeable that June and July exhibit the higher peaks of phytoplankton, closely followed by copepods population blooms (Guinder et al., 2009, 2010). According to this information, it becomes clear that allowing dredging operations during these months will generate a higher damage; an issue that is not considered at all in the environmental impact assessment made by the company planning to develop the LNGPC. In fact, the assessment completely disregards this issue as relevant.

In our cost-benefit analysis, we measure the loss of nursery service through the added value of the fishery sector at producer prices for Bahía Blanca County (Dirección Provincial de Estadísticas, Provincia de Buenos Aires, 2004). Using this indicator, we consider not only the fishing industry itself, but also all the economic activities related in the area of influence.

4.3. Effects on labor market and reallocation of labor force

Regarding the impact on labor market, the analysis is twofold. On the one side, we must point out that one hundred on new jobs are expected to be generated during the building of LNGCP. However, the dredging process itself would have no effect on employment generation, since machinery needed for dredging will be outsourced and the jobs related with the dredge will be occupied by non-local workers because of the higher qualification required. Moreover, the estimated third-party services related to the dredging process are also quite low, so its inclusion into the cash flow has been dismissed.

From this standpoint, dredging process will not affect labor market. Nevertheless, on the other side, local labor market will be indirectly affected through the impact that dredging process will exert on the nursery service.

Artisanal fishery continuously interacts with other productive activities at the BBE, which implies a high degree of relation between a loss of the ecosystem service and a disappearance of the labor source of several families all around the influence area.

In this sense, it is noticeable that a depletion of the nursery service of the estuary will directly generate a loss of labor source for around 300 fishermen linked to 114 registered boats (last available official information, Dirección de Desarrollo Pesquero, Provincia de Buenos Aires, 2004).

This situation means these families might lose their livelihoods temporarily and, therefore, must move for a new job in order to replace the lost activity. In this context, two issues deserve to be highlighted. Firstly, fishery has been the activity of these workers all along their lives. In other words, they have little or no capabilities to change activities. Secondly, derived from the previous one, the reallocation of the fishermen in the labor market is very difficult. And the situation is still more crucial when the unemployed worker is old aged. For these reasons, a temporary disappearance of labor source is not a minor problem.

In order to solve this imminent situation, local authorities have offered a monetary subsidy for each boat leaving the activity and rending their fishing license. They have encouraged the retirement of some old aged fishermen. In our cash flow, we include this cost through the consideration of both the amount granted to fishermen who have already arranged their retirement in the frame of this subsidy scheme and the cost of living for the fishermen who decided to stay active at the beginning of the considered period (INDEC, 2011). Nevertheless, in order to analyze different scenarios, we estimate the social NPV of the dredging process for three different cases: an optimist one, in which fishermen find another activity immediately; an intermediate one in which fishermen remain unemployed during both the construction and the first year of operations; and a pessimist one in which fishermen remain unemployed during two more years than the previous scenario.[3]

5. Results and discussion

Beyond economic and environmental effects, our results try to shed light on the social costs and benefits of the dredging process planned in the frame of the LNGPC project.

According to the previous section, our cash flow takes into account the impact on the nursery services of the estuary, the loss of jobs associated with fishery activities and the costs associated with the governmental program to solve the imminent disappearance of the labor source. As well as all these effects are negative at social level, we will use social cost instead of Net Present Value (NPV) to refer to the result of our cash flow. This implies that such NPV is negative in all cases and represent a loss at social level.

As stated before, the proposed analysis comprises a time horizon of ten years. The discount of future flows has been performed using the active interest rate of 18.85% stated by Banco de la Nación Argentina. Complimentary, we propose a sensitivity

[2] An option to estimate this kind of values is to address the issue from the perspective of the Green Economy. Further details can be seen on Andreou et al. (2007).

[3] Details on cost estimation for each scenario are provided in the Annex.

Table 1
Social NPV of the dredging process.

Scenario	**18.85%**	**10%**	**12%**	**15%**
Optimist	**−4.993.708,39**	−6.841.033,37	−6.330.615,01	−5.676.833,47
Intermediate	**−5.581.737,54**	−7.476.372,13	−6.954.608,44	−6.284.548,81
Pessimist	**−6.492.797,65**	−8.579.026,19	−8.009.189,16	−7.272.517,03

Bold indicates the results of cash flow for the selected discount rate in each scenario.

analysis in order to examine how results change depending on the selected discount rate.

Regarding these estimations, two points needs to be highlighted: on the one hand, all estimations are based on official information which in some cases is not updated. For all selected variables, we used the last available official information homogenized in order to be expressed in current dollars and give a meaningful estimation of the social effects.[4]

On the other hand, a certain number of costs have not been included because of the complexity inherent to their estimation. This is the case of a cease of recreational activities all across the BBE coast during the dredging process and yearly maintenance activities; a loss of the coastal landscape; water pollution derived from sediment removing; the effects on groundwater and the changes in local identity in the area of influence above mentioned. In this context, our results could underestimate the real social cost of the dredging process.

Attending to the proposed scenarios, our estimations indicates that in the optimist case, the social cost of dredging process in current dollars is around $ 5 million; in the intermediate scenario the social costs raise to $ 5.6 million; and in the pessimist one in which fishermen stay unemployed during three years is $ 6.5 million. These results seems to indicate that it will be very difficult that social benefits derived from the dredging process, which estimation was not included in our cash flow, could be able to be high enough to outweigh their negative effects.

The sensitivity analysis does not improve the social NPV of the dredging process, since the rates usually applied to discount the future flows are lower than the interest rate selected in this paper. Following Barbier (2007), we estimate the present net value with a discount rate of 10%, 12% and 15%. For the first case, the results indicates a social cost of $ 6.8 million; $ 7.5 million and $ 8.6 million for the scenarios 1 to 3 respectively; for a discount rate of 12% the estimated costs are $ 6.3 million; 6.9 million and $ 8 million; and for a discount rate of 15% the costs are $ 5.7; $ 6.3 and $ 7.3 million. Detailed results are presented on Table 1.

6. Concluding remarks

In the frame of a major project related with natural gas provision in the Bahia Blanca Estuary, the deepening of a navigation channel of the inner estuary to a depth of 13.5 m is proposed. While economic and environmental effects of this dredging process have been partially examined, the analysis of its social impact has been not performed up to now.

In this context, we propose a cost-benefit analysis in which the loss of the nursery service of the estuary, the cost of subsidies grant to fishermen and the impact on the local labor market are considered.

Using the current active rate of interest of Banco de La Nación Argentina for discounting the future flows, we found that social cost of dredging process related with the project is between $ 5 million and $ 6.5 million depending on how the displaced labor force can reallocate. These results get worst if the usual discount rates are applied. In fact, the use of the alternative rates 10%, 12% and 15% raises the costs to $ 7.5, $ 6.9 and $ 6.3 million dollars for the intermediate scenario respectively.

It is worth noting that the inclusion of other social effects derived from this dredging process remains out of the scope of this paper, not only because of the complexity of its estimation, but also because of the lack of information. This is the case of the cease of recreational activities all across the BBE coasts during the dredging process and yearly maintenance activities; the loss of the coastal landscape; the water pollution derived from sediment removing and the effects on groundwater; and the above mentioned loss of local identity in the area of influence. In this manner, our results clearly underestimate the real social cost of the dredging process.

Acknowledgments

The Seventh Framework Program of the European Union is gratefully acknowledged for supporting the research work in Argentina through the COmmunity-based Management of EnvironmenTal challenges in Latin America (COMET-LA) project, which constitutes the base of this paper. The views and opinions expressed in this article do not necessarily reflect those of the funding agency for this research.

Annex

Cost-benefit analysis

Details on cash flow estimation.

Proposed scenarios

1. Optimist scenario: Nursery Service and subsidies, supporting all labor force reallocate immediately
2. Intermediate scenario: Nursery Service, subsidies and fishermen unemployed during one year (measured through official cost of living)
3. Pessimist scenario: Nursery Service, subsidies and fishermen unemployed during three years (measured through official cost of living)

Nursery Service: Fishery Sector data for Bahía Blanca county. Added Value, in current 2011 dollars. Source: Dirección Provincial de Estadísticas, Provincia de Buenos Aires, 2004. All periods of cash flow for all scenarios. Total amount: 1.009.457,11 current dollars per year.

Subsidies: Amount estimated following official information on arrangements with twenty active fishermen, ten boats and three ship owners for a total of 2.8 million of 2011 Argentinean pesos. Source: Municipalidad de Bahía Blanca, 2011. First period of cash flow for all scenarios. Total amount: 702.192,076 current dollars.

Cost of living: Official Cost of Living. Source: Instituto Nacional de Estadísticas y Censos (INDEC), 2011. Unemployed fishermen were calculated taking into account the average occupation of each kind of ship out of order, according to information regarding the number of active ships before the dredging process. None period of cash flow in the optimist scenario; period 2 in the intermediate scenario; periods 2 to 4 in the pessimist scenario. Total amount: 698.872,639 current dollars per year in cited periods.

References

Andreou, A.N., Green, A., Stankosky, M., 2007. A framework of intangible valuation areas and antecedents. Journal of Intellectual Capital 8 (1), 52–75.

[4] Further details on how each component of the cash flow was estimated are presented in the Annex.

Barbier, E.B., January 2007. Valuing ecosystem services as productive inputs. Economic Policy, 177–229.
Barbier, E.B., Burgess, J.C., Folke, C., 1994. Paradise Lost. In: The Ecological Economics of Biodiversity. Earthscan Publication Ltd., London.
Barton, D., 2002. The transferability of benefit transfer: contingent valuation of water quality improvements in Costa Rica. Ecological Economics 42 (1–2), 147–164.
Constanza, R., d'Arge, R., de Groot, R.S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.J., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.
De Groot, R.S., 1987. Environmental functions as a unifying concept for ecology and economics. Environmentalist 7, 105–109.
De Groot, R.S., Wilson, M.A., Bouman, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem services, goods and services. Ecological Economics 41, 393–408.
Gómez, E.A., Ginsberg, S.S., Perillo, G.M.E., 1996. Geomorfología y sedimentología de la zona interior del Canal Principal del Estuario de Bahía Blanca. Revista de la Asociación Argentina de Sedimentología 3, 55–61.
Guinder, V.A., Popovich, C.A., Perillo, G.M.E., 2009. Short-term variability in the phytoplankton and the particulate suspended matter concentration in a high-tidal regime, Bahia Blanca Estuary, Argentina. Brazilian Journal of Oceanography 57, 249–258.
Guinder, V.A., Popovich, C.A., Molinero, J.C., Perillo, G.M.E., 2010. Long-term changes in phytoplankton phenology and community structure in the Bahía Blanca Estuary, Argentina. Marine Biology 157, 2703–2716.
Hanley, N., Barbier, E.B., 2009. Pricing Nature: Cost-benefit Analysis and Environmental Policy-making. Edward Elgar, London.
Heal, G.M., Barbier, E.B., Boyle, K.J., Covich, A.P., Gloss, S.P., Hershner, C.H., Hoehn, J.P., Pringle, C.M., Polasky, S., Segerson, K., Shrader-Frechette, K., 2005. Valuing Ecosystem Services: Toward Better Environmental Decision Making. The National Academies Press, Washington DC.
Hein, L., van Koppen, K., de Groot, R., van Ierland, E.C., 2006. Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics 57, 209–228.
Ingraham, M.W., Foster, S.G., 2008. The value of ecosystem services provided by the U.S. National Wildlife Refuge system in the contiguous U.S. Ecological Economics 67, 608–618.
Instituto Argentino de Oceanografía (IADO), 2012a. Análisis crítico del área seleccionada para instalacion de la planta de regasificación de GNL, en Puerto Cuatreros, provincia de Buenos Aires. IADO, Technical Report, Bahía Blanca, pp. 15.
Instituto Argentino de Oceanografía (IADO), 2012b. Informe ampliatorio del denominado: análisis crítico del area seleccionada para instalacion de la planta de regasificación de GNL, en Puerto Cuatreros, provincia de Buenos Aires. IADO, Technical Report, Bahía Blanca, pp. 55.
Kaufmann, G., 2011. Economic Value of the Delaware Estuary Watershed. Comprehensive Report. Institute for Public Administration School of Public Policy & Administration College of Arts and Sciences. University of Delaware, June 2011.
López Cazorla, A.C., 1987. Contribución al conocimiento de la ictiofauna marina del área de Bahía Blanca. Tesis Doctoral. Facultad de Ciencias Naturales y Museo. Universidad Nacional de la Plata, Argentina.
Loomis, J., Richardson, L., 2008. Technical Documentation of Benefit Transfer and Visitor Use Estimating Models of Wildlife Recreation, Species and Habitats. Dept. of Agricultural and Resource Economics, Colorado State University, Fort Collins.
Melo, W., Schillizzi, R., Perillo, G., Piccolo, C., 2003. Influencia del área continental pampeana en la evolución morfológica del estuario de Bahía Blanca. AAS Revista 10 (1), 37–50.
Millennium Ecosystem Assessment, 2003. Ecosystems and Human Well-being: A Framework for Assessment. Report of the Conceptual Framework Working Group of the Millennium Ecosystem Assessment. Island Press, Washington.
Perillo, G.M.E., Iribarne, O.O., 2003. Processes of tidal channel development in salt and freshwater marshes. Earth Surface Processes and Landforms 28 (13), 1473–1482.
Perillo, G.M.E., Piccolo, M.C., 1999. Geomorphological and physical characteristics of the Bahia Blanca Estuary, Argentina. In: Perillo, G.M.E., Piccolo, M.C., Pino Quvira, M. (Eds.), Estuaries of South America: Their Geomorphology and Physical Processes. Springer Verlag, Berlin, pp. 195–216.
Perillo, G.M.E., Piccolo, M.C., Palma, E., Pierini, J.O., Pérez, D.E., 2004. Oceanografía Física. In: Piccolo, M.C., Hoffmeyer, M. (Eds.), El Ecosistema del Estuario de Bahía Blanca. Instituto Argentino de Oceanografía, Bahía Blanca, pp. 61–67.
Perillo, G.M.E., Sequeira, M.E., 1989. Geomorphologic and sediment transport characteristics of the middle reach of the Bahía Blanca Estuary, Argentina. Journal of Geophysical Research-oceans 94 (C10), 14351–14362.
Piccolo, M.C., Perillo, G.M.E., 1990. Physical characteristics of the Bahía Blanca estuary (Argentina). Estuarine. Coastal and Shelf Sciences 31, 303–317.