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Economic valuation of kelp forests in northern Chile: values of goods and services of the ecosystem

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Abstract Kelp beds, besides being one of the most important benthic resources in northern Chile, provide a variety of environmental goods and services. In order to evaluate economically the wild kelp populations in northern Chile (26° to 32° S) more than simply their commercial value as a source of raw materials for alginate extraction, we used several economic indicators to holistically assess the value of a group of brown seaweeds of economic importance, *Lessonia* spp. and *Macrocystis pyrifera*: (1) market value of biomass as a source of raw material for extraction of alginic acid, (2) market value of associated species of economic importance, (3) value as a source of scientific information, (4) value as a climate buffer (CO_2 capture and release of O_2), (5) value of associated biodiversity (non-commercial species), (6) value as cultural heritage and (7) value as a reservoir of biodiversity. Existence values of kelp beds which estimate the willingness of citizens to pay and work without payment to preserve the ecosystem were calculated using the contingent valuation technique. The results indicate that kelp beds in northern Chile have a total value of US $540 million. Of this total, kelp fishery accounts for 75 % and associated-species fisheries account for 15 %. In this context, the economic value of Chilean kelp beds is mainly associated with the industry of alginate extraction. By contrast, existence value as a source of scientific information or environmental buffer for CO_2 capture or O_2 production represents only 9 % of the total value, representing a very low relative importance to society. The economic valuation of coastal resources and marine ecosystems is a complementary tool for decision making and implementation of public policies related to the conservation and sustainable exploitation of renewable resources and their ecosystems.

Keywords Kelp fishery · Phaeophyta · Administrative policies · Ecosystem goods and services · Conservation · Economic value

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Introduction

In northern Chile, kelp fishery has enormous social, ecological and economic importance. More than 11,000 people depend directly or indirectly on the collection and harvesting of this resource. Ecologically, kelps constitute areas for food, reproduction and refuge for hundreds of invertebrates and fish species. Economically, the landing of up to 300,000 dry t year^{-1} represents close to US $70 million. Until 2002, brown seaweed fishery was mainly sustained by natural mortality, where plants cast ashore are collected by artisanal fishermen. Since then, three species of economic importance, *Lessonia nigrescens* complex (see González et al. 2012), *Lessonia trabeculata* and *Macrocystis pyrifera*, have been intensively harvested in coastal areas between 18° to 32° S as raw material for alginate extraction (Vásquez 2008; Vásquez et al. 2012).

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Estimating the economic value of kelp forests in Chile is a challenge that emerges from their economic, social and ecological importance, especially when there is a national management plan (Vásquez et al. 2012) designed for sustainable exploitation and protection of the ecosystem goods and services that kelps offer (Vásquez 2008).

The economic valuation of natural ecosystems uses the tools of environmental economics (Dixon et al. 1994): a methodological scheme that consists of identifying the relevant ecosystem goods and services and applying appropriate valuation techniques. Thus, the total economic value is the sum of all the benefits that can be attributed to the specific resource or ecosystem that is the object of study (De Groot et al. 2002; UNEP 2007). However, for the kelp ecosystem, it is unlikely that economic valuation will result in a finite value, due to the fact that the value of algal-based products would change over time with new products emerging for novel uses and perhaps any estimate will not be completely objective. Also, new pressures and insights would modify the type and amount of ecosystem services. On the other hand, other roles of kelp beds like contribution to the iodine cycle (O'Dowd et al. 2002), atmospheric and climate impacts (see Graham et al. 2007), nutrient budgets, exudation rates (Colombo-Pallotta et al. 2006) and enhancement of photoprotection in surface and near surface blades (Abdullah and Fredriksen 2004) are not well understood, and the available scientific data are not sufficient to quantify exactly the environmental services of kelp populations (Daily et al. 2009).

The ecosystems that most commonly have been evaluated economically are wetlands, coral reefs, mangrove communities and seagrasses (Rönnbäck 1999; De Groot et al. 2002; Ramachandra et al. 2005; UNEP 2007). In these ecosystems, the goods and services are classified as a function of the following: (1) the value of direct use or use directly measurable using market prices; (2) the value of indirect use or use indirectly measurable using market prices and (3) the value of non-use (UNEP 2007). According to this classification, Zuñiga et al. (2009) propose that kelp and other commercial species associated with the kelp forests (e.g. rockfish, sea urchins, molluscs) have a direct extractive and consumptive use value, while education and ecotourism have a direct non-extractive and non-consumptive use value. By contrast, the indirect use values come from ecosystem functions that kelp forests can offer, such as carbon sequestration and nutrient retention, as well as basic and applied research. These values do not have direct market prices; however, equivalent values generated from different valuation methods can be used (Ebarvia and Corazón 1999). The non-use value depends on the value that society assigns to kelp forests for their conservation (quasi-option value), as cultural heritage (bequest value), or for their importance as a reservoir of biodiversity, gene bank or potential source for harvesting (existence value).

In Chile, kelp forests create an ecosystem dominated by an assemblage of various species of the Order Laminariales (*Lessonia berteroana*, *Lessonia spicata*, *L. trabeculata* and *M. pyrifera*), and one species from the Order Fucales (*Durvillaea antarctica*), which inhabit the rocky substrata from the lower intertidal zone to depths of 30 m (Hoffmann and Santelices 1997; Vásquez 1992; González et al. 2012). The ecosystem services that kelp forests offer have been classified into supply services (source for extraction of bioactive compounds and fresh food) and cultural services (e.g. employment, ecotourism, education, research), which can be valued economically (Vásquez et al. 2008; Zuñiga et al. 2009).

The objective of this study is to economically evaluate the kelp forests in the north of Chile using the most representative goods and services of this coastal marine resource, and identify the principal services that kelp forests offer, in relation to their direct and indirect use as well as their non-use (existence value).

Materials and methods

This study was conducted in the north of Chile, between 26° and 32° S, where most of the kelp extraction in the country takes place (Vásquez et al. 2008). The study area includes more than 700 km of rocky exposed coast (Fig. 1), where harvesting and collection of kelp affect the distribution and abundance of four brown seaweed species: *L. nigrescens* complex (*L. berteroana* and *L. spicata*, see Gonzalez et al. 2012), *L. trabeculata* and *M. pyrifera*. Nevertheless, more than 70 % of the total brown algae annual landings correspond to *L. nigrescens* complex (Vásquez et al. 2012).

The economic value of kelp forests was estimated as a function of the total surplus, which is a measure of welfare of society derived from the use of services and goods that this offers (Kolstad 2010). Thus, if the disappearance of the resource represents an economic loss to society equivalent to the productive value of the total surplus, then the economic value of the decrease in shipped volume of the resource decreases in an equivalent proportion to the total surplus.

To estimate the surplus or economic value of the kelp forests, three different methodologies were used (Kolstad 2010). “Assumed preference techniques” use market prices to value the services of the forests. “Revealed preference techniques” measure the willingness of people to pay for the kelp forest services when there is no market, by observing their behaviour in related markets (e.g. hedonic prices, trip cost method). “Stated preference techniques” apply a continent valuation method using surveys which reveal the willingness of people with different social backgrounds to pay for the good or their willingness to work without pay for its conservation. This valuation methodology reflects the maximum desire to pay for the conservation of a good or service that the kelp forest offers, or the minimum desire to accept compensation to reduce the quality or quantity of the good or service.

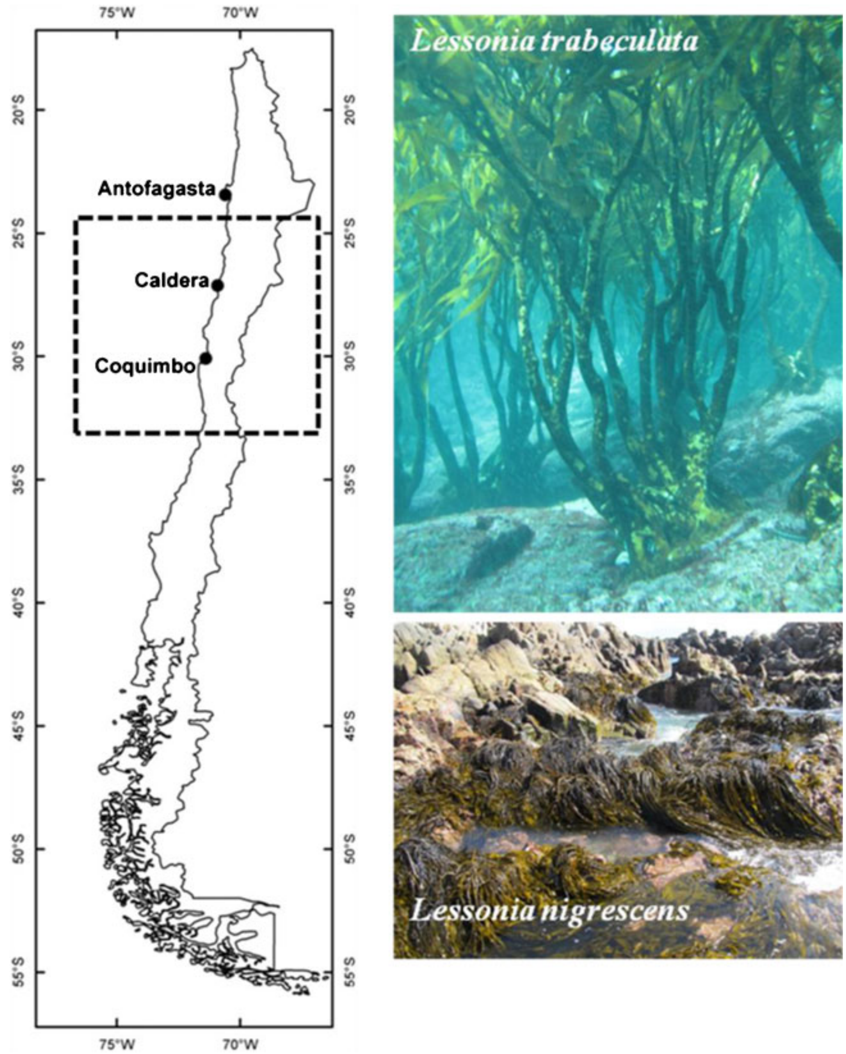

Fig. 1 Study area (*rectangle with dashed lines*) and kelp species of economic importance in northern Chile

The total economic value of the kelp forests was estimated as the sum of the value of each ecosystem service. This analysis requires that the ecosystem services be independent from each other, so that it is possible to identify separate markets (UNEP 2007). This methodology allows for the calculation of total economic value as the sum of the values of previously estimated ecosystem services (Dixon et al. 1994) of kelp in northern Chile.

The current value of the kelp forest was calculated based on future annual values of the benefits of each ecosystem service on a horizon of 10 years (Vásquez et al. 2008). The future annual value of each service was considered to be fixed with a constant annual increase (Vásquez et al. 2008). The current value of non-use value of the ecosystem goods and services is the sum of the valuation of willingness to pay and willingness to work without pay for the conservation of kelp biodiversity (genetic, structural and functional components), potential associated fisheries and cultural heritage.

To estimate direct use, which includes the harvesting of kelp and the associated commercial species, a discount rate was used which considered the capital cost or opportunity cost for businesses (Sharpe 1964). In Chile, the rate of capital cost is close to 15 % yearly (real) for the exploitation of natural resources, including marine seaweeds; that is to say there is a rate free of risk of 5 % and a reward for risk of 10 % (Zuñiga et al. 2009). By contrast, to estimate the value of indirect use and non-use, a social discount rate was used, which is the cost that society incurs when the public sector exploits natural resources to finance social projects (8 % yearly according to MIDEPLAN—Chilean Ministry of Planning and Cooperation; Zuñiga et al. 2009).

As mentioned above, not all the ecosystem services have been included in the analysis mainly because there are no or few data available in the southeast Pacific associated with kelp forest communities.

Results and discussion

Economic valuation is a useful tool to demonstrate to society, participants in the productive chain and decision makers the

Table 1 Ecosystem goods and services used for the estimation of economic value of kelp forests in northern Chile

Direct use value	Indirect use value	Non-use value
Kelp harvesting	Scientific research	Biodiversity
Associated fishery (e.g. rockfish)	Applied research	Reservoir of Biodiversity
Education	Climate buffer	Potential associated fisheries
Ecotourism		Cultural heritage

current benefits that kelp forests provide, and to identify and plan integrative management of this important group of benthic coastal resources.

This study shows that kelp forests in northern Chile have a direct use value because of their harvesting capacity and educational and ecotourism activities that they provide (Table 1). They also have an indirect use value as a source of basic and applied scientific information, and as an environmental purifier because of carbon capture and oxygen emissions (Table 1). The kelp forests also have a non-use value because they house a large amount of biological diversity including species of economic interest (potential fisheries), representing cultural and historical heritage associated with the landscape of the coastline (Table 1). With the exception of education and ecotourism, all of the ecosystem services have economic value.

However, values and prices of kelp in Chile and other countries where this resource is socially and economically relevant may change according to new discoveries, emerging industries and also better recognition of the ecological and social role of kelp coastal communities. In this context, it is not easy to make predictions of finite values when several aspects such as, O_2 release, CO_2 capture, iodine cycle (O'Dowd et al. 2002), atmospheric and climate impacts (see Graham et al. 2007), nutrient budgets, exudation rates (Colombo-Pallotta et al. 2006), and enhancement of photoprotection in surface and near surface blades (Abdullah & Fredriksen 2004), are not well understood, and the available scientific data are not sufficient to quantify exactly the environmental services of kelp populations (Daily et al. 2009).

Value of kelp harvesting The exploitation of kelp is based on the collection and harvest of biomass (Vásquez 2008). The historic harvesting of kelp in northern Chile is represented principally by *L. nigrescens* complex (>70 % of total annual harvest) and a smaller proportion by *L. trabeculata* (15 % of total annual harvest) and *Macrocystis integrifolia* (5 % of total annual harvest) (Vásquez et al. 2012). To valuate the harvesting of kelp, the sanction prices that are set by the Subsecretary of Fishing to punish unauthorized exploitation of marine resources were used (Mondaca-Schachermayer et al. 2011). The sanction value is a good approximation of the average yearly price paid per kilogram of kelp, which is corrected for export prices (Zuñiga et al. 2009). The values of sanction for kelp as well as the value of kelp harvests show an increase over time (Fig. 2).

The projected value of the kelp industry was assigned an annual increase rate of 10 % for *Lessonia* and 5 % for *Macrocystis* as a function of the percentage of the volume harvested (Zúñiga et al. 2009). The perpetual economic increase rate of the harvesting industry reaches an equilibrium point between 2 and 5 % yearly, assuming that the total harvest stabilizes over the long term with a minimum increase in the prices paid per kilogram of kelp (Zúñiga et al. 2009).

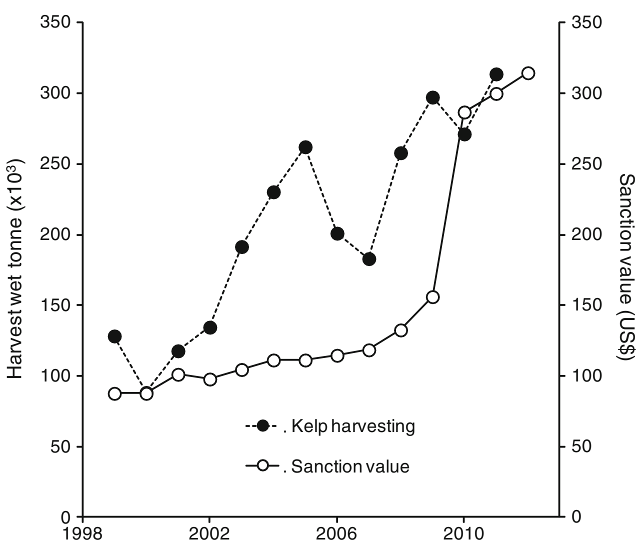

Fig. 2 Indicators used to estimate values of direct use. The figure shows yearly landing of kelp species (*black circles*) and sanction values for illegal use (*white circles*)

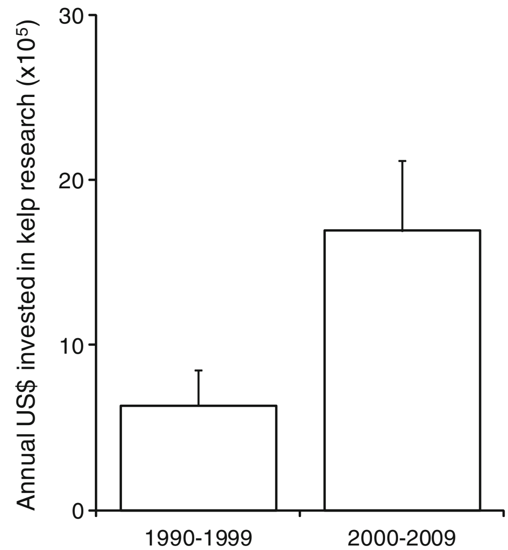

Fig. 3 Decadal trend of funds (US $) for kelp research, an indirect use value of natural kelp forests in northern Chile

Considering an average annual harvest with a discount rate of 15 % yearly and a projection of 1 years, the current value of the stock of kelp in the north of Chile is US $193,494,000. With perpetual growth, the present value of the industry is US $216,033,000. Adding both values results in a projected current economic value of US $409,527,000 for the kelp industry. Thus, from a social perspective, the destruction of the kelp forests due to overexploitation means an economic loss of US $409,527,000, representing the commercial value of the kelp industry in the north of Chile.

Value of the fishing industries associated with kelp forests Numerous fish, mollusc, crustacean and other invertebrate species comprise fisheries associated with the kelp forests in northern Chile (Vásquez et al. 2008), including *Concholepas concholepas* ("Loco" or Chilean abalone), *Fisurella* spp. (keyhole limpets), *Loxechinus albus*, *Pyura chilensis*, and various rock fishes, all of which have economic importance for the coastal population (Godoy et al. 2010; Vásquez and Donoso 2013).

The sanction value prices of the species associated with kelp forests are fixed over time just as with their harvest quantities (Zuñiga et al. 2009). Thus, the current and continuous projection of these fisheries has an annual value of US $8,329,797. Assuming the annual average harvest, an annual discount rate of 15 % and an economic projection of 10 years, the present value (on annual based) of fisheries associated with kelp is US $82,257,712.

Value as a source of scientific information The kelp forests in northern Chile have been the subject of scientific investigation over 30 years (see Santelices 1989; Vásquez and Vega 2004; Mondaca-Schachermayer et al. 2011; Vásquez et al. 2012). The annual investment in basic and applied research has doubled in the last decade (Fig. 3), reaching an average annual investment of US $66,174. Assuming that the increase in annual expenditures is linear and continuous, with a real growth close to 10 % and an interest rate of 15 % over 10 years, then the value of kelp as a source of scientific and applied research is US $25,957,253.

Value as a climate buffer The carbon capture and oxygen emission that kelp has the capacity to do is a regulatory service that is very important from an economic perspective. Nevertheless, carbon bound by algae is not permanently bound but released in various forms including dissolved organic matter, the pathways of which are poorly characterized, much less quantified. In this context, the contribution of kelp as a carbon fixer is only valid in the short term and should be viewed as a key component of the carbon cycle but not a permanent sink.

The value of this ecosystem service was estimated using the surface covered by the kelp forests, the capacity of the species to capture carbon and the economic value of tradable carbon credits (Table 2). Considering that kelp fix carbon and liberate oxygen in the same proportion (Lobban and Harrison 1994), and that the surface area is maintained over time, the value of kelp as a producer of oxygen is equal to its value as a producer of carbon. The area covered by *Lessonia* forests is relatively continuous along the coast of northern Chile, while *Macrocystis* has a fragmented distribution (Vásquez 2008; Table 2). Also, the annual estimated carbon fixation rates of *L. nigrescens* and *L. trabeculata* are significantly less than the rate estimated for *M. pyrifera* (Smith et al. 1983; Tala and Edding 2007; Table 2). This difference has an impact on the annual carbon credit per species: the purification value of *Macrocystis* is significantly more than that of other Laminariales species in the Pacific southeast (Table 2). According to the Kyoto Protocol, a carbon credit is equal to a ton of carbon that is stopped from being emitted into the atmosphere. Given that the price of a carbon credit traded on the Chicago Climate Exchange (USA) is US $4.60, the current estimated price of the service of environmental regulation is US $2,041,970 yearly. The projected future value is predicted to have an annual increase of 5 %. Applying a discount rate of 15 %, the value of kelp forests as an environmental purifier is US $21,440,680.

The area covered by its canopy, its regenerative capacity and the productivity of *Macrocystis* forests are relevant attributes that support the proposition of this species as an environmental buffer. However, in northern Chile, the forests are small, principally intertidal and have a fragmented distribution (Graham et al. 2007). Thus, farming in coastal areas and the restoration of natural kelp populations should be explored, not only as a food source for aquaculture invertebrates, alginate extraction or biofuel production but also as an environmental purifier. Although kelp beds play a key role in local carbon cycling, the values attached to the economic contribution of kelps in climate change mitigation are approximate and should be treated with caution. Some recent efforts with private and state funding have been conducted to assess the feasibility of producing biofuel from mass cultivation of *M.*

Table 2 Indirect indicators of use value (yearly based) associated with the valuation of carbon credits (mean value of carbon credits = US $4.60)

Parameters	*Lessonia nigrescens*	*Lessonia trabeculata*	*Macrocystis* spp.
Total mean distribution (ha)[a]	1,060	13,504	1,500
Fixation of CO_2 m^{-2} (t year)$^{-1}$	0.0015	0.0005	0.0072
Annual price of carbon credits (US$)	70,724	307,484	498,663
Annual price of O_2 release and CO_2 captured (US$)	164,695	716,038	1,161,237

[a] Obtained from Vásquez (2008)

[b] Estimated from Smith et al. (1983) and Tala and Edding (2007)

Table 3 Indicators used to estimate existence values of kelp beds. The table shows four indicators obtained from contingent valuation methods ($n = 181$ surveys)

Indicators	Species with fisheries potential	Cultural heritage	Gene Bank	Biological diversity	Total
Surveyee with positive perception	84.5	75.1	83.4	85.1	82.0[a]
Surveyee willing to pay (WTP)	76.5	86.8	83.4	79.2	81.5[a]
WTP monthly mean (US$ month^{-1})	2.22	1.99	2.31	2.08	2.15[a]
WTP yearly mean (US$ year^{-1})	4,042	3,390	4,152	3,873	15,457[b]

[a] Mean of all dimensions

[b] Sum of all dimensions

pyrifera in southern Chile. Although the fjord area south of 42° S is suitable for cultivation of this species, nutrient, light and photoperiod constraints have not produced sufficient algal biomass for biofuel production (Kashiyama 2013).

Recently, there has been a good deal of interest in the potential of marine vegetation as a sink for anthropogenic C emissions. As Nellemann et al. (2009) pointed out, marine primary producers contribute at least 50 % of the world's carbon fixation and may account for as much as 71 % of all carbon storage in oceanic sediments. In this context, CO_2 acquisition by marine macroalgae represents a considerable sink for anthropogenic CO_2 emission, and harvesting and appropriate use of macroalgae play a significant role in C sequestration and amelioration of greenhouse gas emissions (Chung et al. 2011).

During the future development of algal-based CO_2 sequestration programs, it will be important to take into account the potential impact of climate change on growth and production of the algae to be used. Climate change will have an effect on not only macroalgal production, distribution and biodiversity but also on their physiology and photosynthetic performance, changing their capacity to sequester CO_2. Climate change also affects the ecosystem as a whole including associated fisheries.

Temperature shifts may also affect the availability of macroalgae to perform in particular geographic areas (see Breeman 1990). Thus, climate change as well as interannual variability of El Niño events will be relevant in the production and performance of wild algal populations, consequently effecting regional variability of CO_2 sequestration and O_2 emission in the southeast Pacific coast.

Value as a source of ecotourism and education Ecotourism in kelp forests is an environmentally responsible form of tourism that includes activities such as sport fishing and recreational diving in a column of water spatially structured by large-sized kelp like those from Laminariales. Recreational diving, along with underwater-guided "trails", can also serve as educational activities that bring people closer to biodiversity and the unique submarine landscape that kelp create. One study identified several touristic areas of interest along the northern coast of Chile (Vásquez et al. 2008). However, none of these areas provided an ecotourism program relating to kelp forests. Tourists dedicate their time to activities that do not involve recreational diving; thus, the valuation of this ecosystem function is $0. In other areas of the planet such as the coast of California, USA, recreational diving in *Macrocystis* forests and sport fishing in the surrounding areas are highly profitable (Menzel et al. 2013).

The lack of public interest in recreational activities and ecotourism associated with kelp indicates that promotion is needed in the areas of ecotourism, environmental education and recreational diving focused on underwater trails, biodiversity and natural history of coastal marine communities.

Non-use value The non-use value was calculated based on the contingent valuation of three ecosystem services. The valuation method measures the contribution of kelp to the welfare of people who have a direct or indirect relationship with kelp, by measuring their willingness to pay (WTP) or willingness to work without pay (WTW) to maintain its existence (Kolstad 2010). Non-use value implies several ecosystem services: the first is that the species associated with kelp and/or those that form part of the trophic chain are economically important (Vásquez et al. 2008). The second ecosystem service is that there is a cultural heritage associated with the species that involves archeological, historical, ethnographical and artistic value (Zúñiga et al. 2009). The third is the maintenance of the biodiversity associated with kelp (Graham et al. 2007), where biodiversity covers genetic, structural and functional components, which are derived from different organizational levels: from individual organisms to species, populations, communities and ecosystems (Harrington et al. 2010).

The contingent valuation surveys were applied to the resident adult population in the cities of La Serena and Coquimbo (Lat. 30° S). The results were projected to the north of Chile,

Table 4 Economic valuation of kelp beds in northern Chile

Value	Dimension	Price (US$)	Percent
Direct use	Kelp harvesting	409,527,000	75.6
Direct use	Associated fisheries	82,257,712	15.2
Direct use	Education and ecotourism	0	0.0
Indirect use	Scientific and applied research	25,957,253	4.8
Indirect use	Climate buffer	21,440,680	4.0
No use	Biodiversity, gene bank, potential associated fisheries and cultural heritage	2,729,412	0.5
Total		541,191,057	

under the assumption that the inhabitants have previous knowledge of kelp forests or are economically and/or socially linked to the productive chain and their willingness to pay or work (WTP and WTW) is not zero.

The indicators used to approximate the non-use value showed little variation between selected ecosystem services (Table 3). Eighty percent of those surveyed ($N=181$) were willing to pay for the conservation of coastal ecosystems (Table 3). Willingness to pay and the number of hours willing to work had an average value of US \$2.15 or US \$30.35 per year. Extrapolating this sample to northern Chile, using conversion factors proposed by Vásquez et al. (2008), the non-use value becomes US \$327,941 per year. If a discount rate of 8 % annual is applied under the assumption that there is a small increase over the long term such that society appreciates kelp more and is willing to pay more *per capita*, and assuming annual growth of 5 % for 10 years, the non-use value of kelp forests in the north of Chile is US \$2,729,412.

In synthesis, the economic valuation of kelp beds in northern Chile is close to US \$540 million (Table 4). Kelp harvesting represents 75 % of the total economic value, and associated species fisheries represents 15 % (Table 4). Thus, the economic value of kelps is mainly associated with the collection and harvesting of *Lessonia* species, and as raw material for the alginate extraction industry. The harvesting of kelps of economic importance has been increasing exponentially during the last 10 years. The indirect use value of kelp beds was calculated using stakeholder surveys, demonstrating that there is no interest in them for tourist attractions, recreational diving, and education or ecotourism activities.

Other indirect use values of kelp beds were their importance for research and scientific knowledge, and their capacity for CO_2 capture and O_2 production. However, despite the importance of these ecological processes, their percentage of the total economic value of kelps is only 9 % (Table 4). By contrast, economic resources for scientific research of kelps in Chile have been growing significantly. *Macrocystis*, which covers more surface area with its large canopy, has higher potential for CO_2 capture (60 % of total indirect use value). Nevertheless, kelp beds are quite small and restricted to shallow intertidal areas.

The coastal morphology, the facilities for marine farming and high growth rate of *Macrocystis* would increase the value of indirect use of kelps as a CO_2 capturer and O_2 producer. The existence values of kelp communities show low importance for Chilean society (Table 4); however, 80 % of interviewers have a positive perception and are willing to pay for their existence.

Kelps are the largest benthic organisms that occupy the euphotic zone. Due to their complex morphology, kelp sporophytes can alter abiotic and biotic conditions by dampening water motion, altering sedimentation, shading the sea floor, scrubbing nutrients from the water column, stabilizing substrates, providing physical habitat for hundreds of organisms both above and below the benthic boundary layer, and by distributing trophic resources (from drift kelp to particulate and dissolved organic carbon) within the forests and to surrounding habitats (see review of Graham et al. 2007). All these kelp attributes have not been well quantified and must be considered in order to value those important goods and services of these foundation species (*sensu* Dayton 1985) of coastal marine environments.

In conclusion, the economic valuation of coastal resources and ecosystems is a complementary tool for decision making and the implementation of public policies. The economic value of kelp in the north of Chile mainly depends on its direct use as raw material for alginate extraction and its function as a facilitator of other kelp-associated fisheries. The lack of public interest in natural kelp beds shows there is an opportunity to promote eco-activities, tourism, natural history education and recreational diving. Nevertheless the economic valuation of kelp ecosystem is highly dynamic and does not have a finite value, due to the fact that the value of algae-based products will change over time, with new products emerging for novel uses. Also, new economic pressures and insights would modify the type and amount of ecosystem services.

The use of natural kelp beds for CO_2 capture must be explored and could benefit efforts associated with marine protected areas, marine reserves and parks, long-term monitoring of coastal areas, restoration and management of kelp-dominated areas, and marine farms. On the other hand, other roles of kelp beds like contributions to the iodine cycle, atmospheric and climate impacts, nutrient budgets, exudation rates and enhancement of photoprotection in surface and near surface blades are not well understood, and the available scientific data are not sufficient to quantify exactly the environmental services of kelp coastal communities.

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