



Economic assessment of ecosystem services: Monetary value of seagrass meadows for coastal fisheries



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ABSTRACT

Estimation of the economic value of ecosystem services is particularly incipient in the marine realm, where numerous services still need to be evaluated. Seagrasses deliver essential services to humans. In this paper, we determined the economic value of *Cymodocea nodosa* seagrass meadows for local fisheries at the oceanic island of Gran Canaria (eastern Atlantic). Large-sized fishes, which constitute the fishable fraction, were seasonally sampled through 2011 by means of visual censuses at 12 seagrass-dominated sites. The total fish biomass was 907.6 kg (894.55 kg of commercially-targeted fishes). By using standard market prices, we estimated that the monetary value of this biomass averaged 866 € ha⁻¹; at the island-scale, this value adds up to 606 239 €, when considering the area covered by *C. nodosa*. Small-sized fishes (mostly juveniles that replenish fisheries) were also seasonally sampled, through a seine net, at the same 12 seagrass-dominated sites. Eight nearshore fish species with commercial interest used seagrass meadows as 'nursery grounds'. Estimates of secondary production revealed that this fish production monetarily averaged 95.75 € ha⁻¹ y⁻¹ when considering standard market prices; this value adds up to 67 030.30 € y⁻¹ at the island-scale, when considering the area covered by *C. nodosa*. This study provides complementary assessments of the key economic contribution of seagrass meadows for coastal fisheries as both 'fishing' and 'nursery' grounds. This is a way to promote the social perception of the key role that seagrasses play on the coast and, therefore, the necessity of incorporating seagrasses into conservation legislative frameworks.

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1. Introduction

Habitats dominated by seagrasses provide essential functions and services to ocean ecosystems and human well-being (Duarte et al., 2008; Boström et al., 2011). The value of the world's seagrass meadows has been estimated at US\$ 19 002 ha⁻¹ y⁻¹ based on some ecosystem functions (Constanza et al., 1997); recently, the value of the endemic Mediterranean species *Posidonia oceanica* has been established, based on different services, at 172 € m⁻² y⁻¹ (Vassallo et al., 2014). Not surprising, seagrasses are included in several conservation legislative frameworks, e.g. the European '92/43/CEE Habitats Directive', particularly because seagrass meadows are showing acute regression trends, primarily in areas of intense human development (Waycott et al., 2009).

Among other functions, seagrass meadows provide food and habitat for a wide range of invertebrates and vertebrates, as a result of their large primary production and canopy-structure (Connolly

and Hindell, 2006; Boström et al., 2006; Thomsen et al., 2010). In particular, seagrass meadows have been routinely viewed as crucial 'nursery' grounds for juveniles of many fish species, including commercially-exploited species (Pollard, 1984; Gillanders, 2006; Bertelli and Unsworth, 2013); this results from the large structural complexity (Gullström et al., 2008) and abundance of trophic resources (Bell and Pollard, 1989) provided by seagrasses. Seagrass-associated fishes include adult and sub-adult populations of resident (Hyndes et al., 2003; Berkström et al., 2013) and transient species (Verweij et al., 2006; Vaslet et al., 2013) that directly forage within seagrass canopies (i.e. as 'feeding' grounds), as well as large quantities of fish recruits (i.e. as 'nursery' grounds, Nagelkerken et al., 2000; Beck et al., 2001; Blandon & zu Ermgassen et al., 2014) that may reside, as adults, in seagrass meadows, or experience ontogenetic migrations to other nearshore habitats, e.g. adjacent reefs (Cocheret de la Morinière et al., 2002; Aguilar-Perera and Appeldoorn, 2008; Berkström et al. 2013).

A method for streamlining ecological information into management frameworks considers provision of 'goods and services' by ecosystems, i.e. the so-called 'ecosystem services' jargon (Granek et al., 2011; Townsend et al., 2011). This strategy, despite some

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apparent pros and cons (Koch et al., 2009), is actually perceived as a respected tool for ecosystems management (Barbier et al., 2011). Provision of ecosystem services depend on ecosystem functions; where the former benefits a group of humans and can be economically quantified, the latter represent an ecological process that underpins an ecosystem service (Barbier et al., 2011). Attributing any natural capital a monetary value is risky and difficult and can be approached via different methods; for example, the economic valuation of recreational services around artificial reefs may be estimated through the Travel Cost Method (TCM) and the Contingent Valuation Method (CVM) (Cheng et al., 2013). Recent efforts point out towards this direction as a way of connecting nature and human welfare, so society and organizations involved in the management of marine ecosystems can understand the necessity of appropriately managing nature (Lange and Jiddawi, 2009; Granek et al., 2011). Pragmatically, managers and stakeholders may take decisions on an appropriate cost-benefit principle. Such a simple economic metric is convenient to justify sustainability policies over long-term scales.

Estimation of the economic value of ecosystems is particularly incipient in the marine realm, where numerous ecological services still need to be evaluated (Lange and Jiddawi, 2009). Empirical evaluations of the economic value of seagrass meadows are yet to be performed for a wide array of species and locations (Bertelli and Unsworth, 2013). Some studies have estimated the economic value of seagrass meadows as 'fisheries' grounds following different strategies. In Indonesia, for example, the mean value of seagrass meadows has been established at ca. 113 US\$ ha⁻¹ y⁻¹ (Unsworth et al., 2010); in South Australia, seagrass meadows support fisheries with a value of 100 US\$ million y⁻¹ (the area covered by seagrasses is 85 10⁸ m⁻², McArthur and Boland, 2006); the value of temperate seagrass meadows across Australia has been estimated at A\$ 230 000 ha⁻¹ y⁻¹ (Blandon et al., 2014).

The seagrass *Cymodocea nodosa* ranges from the Mediterranean Sea into the contiguous eastern Atlantic, including the Macaronesian oceanic archipelagos of Madeira and the Canary Islands. Meadows constituted by *C. nodosa* are found on shallow soft substrates throughout the Canaries (Barberá et al., 2005), where a diverse range of organisms find shelter and food, e.g. invertebrates (Tuya et al., 2001; Gardner et al., 2013), as well as fish assemblages (Espino et al., 2011a, 2011b). In this study, we aimed to determine the economic value of *C. nodosa* seagrass meadows for local fisheries at the oceanic island of Gran Canaria. Two approaches were adopted. Firstly, we estimated the biomass (per area and year) of large-sized (mainly adult and sub-adult) fish populations inhabiting seagrass meadows, particularly that accounted by commercially-targeted species. Secondly, we estimated the annual production of juvenile fishes of commercial species. In both cases, we aimed to finally provide a monetary value by transforming biomasses and production rates into their corresponding financial value per area (ha) and year. It is worth noting, therefore, that our strategy provide complementary assessments of the value of seagrass meadows for local nearshore fisheries by separating the fishable fraction (large-sized fishes) from the production of recruits (small-sized fishes) that fuel nearshore fisheries.

2. Materials and methods

2.1. Study area

Three monospecific seagrass meadows (ca. 5–10 ha, 70–80% of seagrass coverage, 6–15 m depth; www.sebadales.org) constituted by the seagrass *Cymodocea nodosa* were selected at Gran Canaria Island (Fig. 1). Two meadows were located in the southeast side of the island, ca. 2 km apart, while the other meadow was located in the southwest part of the island. Each meadow was seasonally visited at four times through an entire annual cycle: February 2011,

May 2011, August 2011 and November 2011. At each sampling date, 4 sites were randomly selected within each of meadow to assess the abundance and size structure of associated ichthyofauna.

2.2. Adult fishes: field evaluation

Large-sized (mostly adults and sub-adults) fishes were sampled by means of visual censuses through 25 m long × 4 m wide strip transects (100 m²). Counts were carried out randomly during daytime hours (typically between 10:00–12:00). The abundance and size of all fish species within 2 m at each side of each transect were recorded on waterproof paper by an SCUBA diver, following standard procedures for the study region (Tuya et al., 2004, 2006a). Counts ($n = 6$) were performed at each of the four sites per seagrass meadow and sampling occasion (within 2 days); this yielded a total of $N = 288$ visual counts (28 800 m² of inspected seabed for the overall study).

2.3. Juvenile fishes: field evaluation

Small-sized (mostly juveniles) fishes were sampled through a 6 m long, 4 m wide, 0.5 m high seine net with a mesh size of 1 mm. The net was towed over the seabed by two SCUBA divers following a 25 m transect. This technique captures small fishes that have reduced swimming capacities; this procedure has proven to be effective in capturing juvenile fishes in the study area (Espino et al., 2011a). Trawls ($n = 3$) were carried out during daylight hours at each of the four sites per seagrass meadow and sampling occasion. Captured fishes were kept in formalin for subsequent analyses in the lab.

2.4. Adult fishes: mathematical procedures and monetary assessment

By using standard length–weight relationships, we converted abundance and size structure data into biomasses. In most cases, we

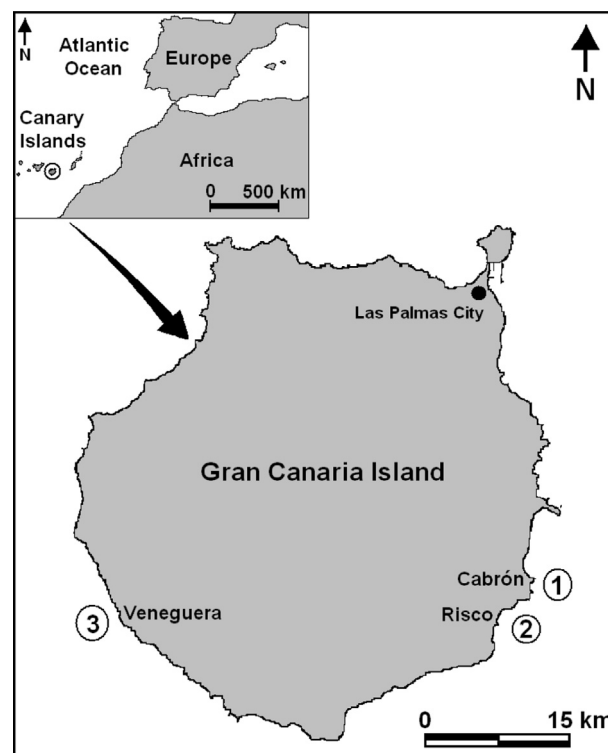


Fig. 1. Study area at Gran Canaria Island, including location of the 3 seagrass meadows where fish collection data took place.

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