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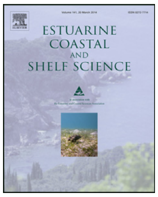

Invited feature-FLA

Quantitative estimate of commercial fish enhancement by seagrass habitat in southern Australia

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A B S T R A C T

Seagrass provides many ecosystem services that are of considerable value to humans, including the provision of nursery habitat for commercial fish stock. Yet few studies have sought to quantify these benefits. As seagrass habitat continues to suffer a high rate of loss globally and with the growing emphasis on compensatory restoration, valuation of the ecosystem services associated with seagrass habitat is increasingly important. We undertook a meta-analysis of juvenile fish abundance at seagrass and control sites to derive a quantitative estimate of the enhancement of juvenile fish by seagrass habitats in southern Australia. Thirteen fish of commercial importance were identified as being recruitment enhanced in seagrass habitat, twelve of which were associated with sufficient life history data to allow for estimation of total biomass enhancement. We applied von Bertalanffy growth models and species-specific mortality rates to the determined values of juvenile enhancement to estimate the contribution of seagrass to commercial fish biomass. The identified species were enhanced in seagrass by 0.98 kg m^{-2} y^{-1}, equivalent to ~$A230,000 ha^{-1} y^{-1}. These values represent the stock enhancement where all fish species are present, as opposed to realized catches. Having accounted for the time lag between fish recruiting to a seagrass site and entering the fishery and for a 3% annual discount rate, we find that seagrass restoration efforts costing $A10,000 ha^{-1} have a potential payback time of less than five years, and that restoration costing $A629,000 ha^{-1} can be justified on the basis of enhanced commercial fish recruitment where these twelve fish species are present.

Editor's note

The Invited Feature Article in this issue highlights issues that are becoming increasingly important in conservation and management of coastal ecosystems. Many key coastal ecosystems are increasingly threatened: seagrass meadows are one such endangered habitat. The services furnished by such habitats need to be more widely appreciated by various sectors of coastal stakeholders. Further, we also could better assess the human-oriented benefits of certain services that the threatened ecosystems. While it is true that it is not always advantageous to convert environmental benefits into currency as not all benefits can be monetized, it does make sense to convey to stakeholders the socio-economic advantages of conservation of coastal environments. The Invited Feature Article in this issue by Blandon and zu Ermgassen includes contributions to all these aspects.

1. Introduction

Seagrass habitats are widely recognized to be important nursery grounds for fish, with juvenile fish routinely being found at higher densities in seagrass beds than in nearby unvegetated substrates (Heck et al., 2003). In addition to providing fish habitat, seagrasses play important roles in nutrient recycling, sediment stabilization, oxygenation of surrounding water, reduction of wave impacts and carbon sequestration (Short et al., 2011). Yet seagrass meadows are under increasing pressure from human development. An estimated third of seagrass meadows have already been lost globally, with losses occurring at a rate of 110 km^2 yr^{-1} since 1980 (Waycott et al., 2009). The decline in seagrass habitat can be attributed to numerous drivers, including destructive fishing practices, coastal engineering, cyclones, and anthropogenicaly driven water quality degradation (Orth et al., 2006). Although these pressures are being addressed in some locations (Greening and Janicki, 2006), the global rate of decline in seagrass is still believed to be accelerating (Waycott et al., 2009). The value of the associated ecosystem services is often a major impetus for the protection and restoration of threatened habitats, yet few attempts have been made to value the benefits derived from seagrass habitats (Barbier et al., 2011).

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Seagrasses in southern Australia are no exception to the global trend; six of the ten major areas of seagrass loss in Australia are located in the southern states (Kirkman, 1997), with near ubiquitous declines in the region (Waycott et al., 2009). These declines are increasingly being countered by stronger regulation and increased restoration efforts (Seddon, 2004; Western Australia Environmental Protection Authority, 2004). Following limited early success in restoration efforts, recent developments have resulted in improved site selection and more appropriate transplanting methodologies for the slow growing seagrass species that are under threat in southern Australia (Seddon, 2004). Restoration efforts are, however, extremely expensive, ranging in cost from \$A10,000 ha^{-1} for *Amphibolis* species, which may take from seed, to >\$A1,308,284 ha^{-1} for species that require transplanting of plugs (Ganassin and Gibbs, 2008; 1 \$A ≈ 0.9 \$US). Given the costs involved in restoring seagrass beds, valuation of the potential benefits arising from seagrass restoration efforts can play an important role in decision-making and in attracting necessary investment.

While numerous researchers have explored the evidence that seagrass habitats benefit commercially important species and may increase fisheries yields (Coles et al., 1993; Jenkins et al., 1997; McArthur et al., 2003), quantitative assessment of the benefits is challenging and has rarely been attempted (Barbier et al., 2011). In southern Australia, only one previous study has sought to determine the value of commercial fisheries enhancement resulting from seagrass habitats. McArthur and Boland (2006) applied a model based on a predetermined index of seagrass residency (Scott et al., 2000), to catch per unit effort data of seven commercially important species in GARFIS fishing blocks with a known seagrass extent. The seagrass residency index used was based on expert opinion of the relative duration of each fish species' life history stage in seagrass (Scott et al., 2000). This methodology identified numerous species, in particular King George whiting (*Sillaginodes punctata* [Cuvier, 1829]), calamari (*Sepioteuthis australis* Quoy and Gaimard, 1832) and garfish (*Hyporhamphus melanochir* [Valenciennes, 1847]), whose abundance was strongly dependent on seagrass. They also found evidence of a short term decline in fish abundance corresponding to an episode of seagrass loss in one block (McArthur and Boland, 2006). The methodology was, however, limited as to the extent to which it was able to verify that seagrass declines were responsible for the fisheries declines (McArthur and Boland, 2006). The observed declines affected a region larger than the examined fishing block alone, suggesting that other external factors, for example related to hydrodynamic conditions, could have played a role in the observed fisheries declines (McArthur and Boland, 2006). Furthermore, as the seagrass residency index was developed on the basis of expert opinion as opposed to quantitative data, its application in a quantitative model should be viewed with caution. Nevertheless, this model represents the best current estimate of the commercial fisheries value of southern Australian seagrasses.

An alternative methodology, developed by Peterson et al. (2003) for estimating the fisheries value of oyster reef restoration in the south eastern United States, combines quantitative abundance data with established growth and mortality relationships to estimate the fish biomass enhancement for species that are enhanced at the juvenile stage by the presence of the habitat. A similar approach was used by Watson et al. (1993) to estimate the value of enhancement by seagrass to the penaeid shrimp fishery in northern Queensland and also by Powers et al. (2003) to estimate the value of artificial reefs in the US. The method is based on the assumption that, where nursery habitats have been severely reduced in extent, habitat can limit fish recruitment. In the current study, we apply this approach to seagrass habitat in southern Australia to derive an estimate of the value of enhancement for commercially important fish species per hectare of seagrass, as well as an estimate of the payback time of seagrass restoration efforts based on this ecosystem service.

2. Material and methods

2.1. Data collection

A review of the literature was undertaken in January 2012 using the Web of Knowledge Service with search terms "fish", "seagrass" and "Australia" to identify studies that fulfilled the following criteria: 1) conducted in southern Australia (defined as South Australia, New South Wales, Victoria and Western Australia below 24° latitude), 2) included data on individual fish species and their density in both seagrass and an unvegetated control and 3) used sampling techniques that are strongly biased towards the sampling of young of year fish (fine mesh seine nets and pop nets). Studies based on artificial beds created to mimic seagrass were excluded.

The search identified more than 400 articles, of which eleven fulfilled the required criteria (Table 1). Care was taken to ensure that studies included in the meta-analysis were independent of one another; while some locations are represented in multiple studies,

Table 1
Synopsis of the eleven studies from which data were extracted for inclusion in the meta-analysis.

Reference	State	Location	Seagrass species	Sampling method	Mesh size
Humphries et al., 1992	Western Australia	Wilson Inlet	*Ruppia megacarpa* Mason 1967	Seine	Wings: 6 m of 9 mm mesh, 4 m of 6 mm mesh Bunt: 6 mm mesh
Connolly 1994a	South Australia	Barker Inlet – Port River	*Zostera muelleri* Irmisch ex Ascherson 1867a	Seine	Large net: 6 mm Small net: 1.4 mm
Connolly 1994b	South Australia	Barker Inlet – Port River	*Z. muelleri*	Pop net	Not given
Edgar and Shaw 1995	Victoria	Western Port	*Heterozostera tasmanica* (Martens ex Ascherson) den Hartog 1970, *Z. muelleri*	Seine	1 mm
Gray et al., 1996	New South Wales	North East New South Wales	*Zostera capricorni* Ascherson 1867a	Seine	6 mm
Jenkins et al., 1997	Victoria	Port Phillip Bay & Corner Inlet	*H. tasmanica*, *Z. muelleri*	Seine	1 mm
Jenkins and Wheatley 1998	Victoria	Port Phillip Bay	*H. tasmanica*	Seine	1 mm
Hindell et al., 2000	Victoria	Port Phillip Bay	*H. tasmanica*	Seine	1 mm
Griffiths 2001	New South Wales	Shellharbour Lagoon	*Z. capricorni*	Seine	6 mm
Bloomfield and Gillanders 2005	South Australia	Barker Inlet – Port River	*Z. muelleri*	Seine and pop net	Seine: 1 mm Pop net: 1 mm
Smith et al., 2008	Victoria	Port Phillip Bay	*Heterozostera nigricaulis* J. Kuo 2005	Push net	1 mm