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South Australian Beach-Cast Seagrass and Marine Algae Fishery Assessment

23 DECEMBER 2014

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

SOUTH AUSTRALIA

Government of South Australia
Primary Industries and Regions SA

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Executive Summary

This report summarises information relevant to the South Australian Miscellaneous Fishery, specifically to those licence holders permitted to harvest beach-cast seagrass and macro-algal wrack.

The Miscellaneous Fishery is licensed under the *Fisheries Management Act 2007* and consists of two licence holders permitted to harvest beach-cast wrack. The licences are subject to specific licence conditions which required the licence holders to record and provide monthly catch and effort information to the Minister. The information is collated and reported on by the South Australian Research and Development Institute of South Australia (SARDI) Aquatic Sciences. The information contained in relation to harvest volumes has been authorised by the two licence holders to be made publicly available and transparent for this assessment.

Beach-cast accumulations (wracks) of decaying seagrass and marine algae are considered essential components of coastal ecosystems. They serve several important roles in the ecology of local coastal environments. Wracks contribute to the food web dynamics of beach and near-shore marine communities, including valuable fisheries, by supporting microbial processes and invertebrate fauna that are preyed upon by higher-level consumers and supplying nutrients that can be utilised by plant and animal communities (Kirkman and Kendrick, 1997). Many bird species, some of high conservation status, also utilise these habitats. Wracks also provide protections to coastal dunes and other important coastal environments.

The seagrass wrack fishery is limited in spatial scale being restricted to a 7.2 km extent of beach around the town of Kingston where the harvest of seagrass wrack is undertaken primarily to address a beach amenity issue. The build-up of wrack in this region is a result of the development of groynes along the coast which causes trapping of excessive quantities of seagrass wrack. An assessment of the seagrass wrack removal at Kingston (Duong 2008) concluded that there was no environmental impediment to the removal of this wrack.

The macro-algal wrack fishery occurs across a more extensive length of coastline comprising some 102 km from Cape Jaffa in the north to Kingston in the south. Historically the macro-algal wrack fishery, although covering a larger coastal extent than the seagrass fishery, has been a very small operation in comparison to similar fisheries elsewhere (being on average about 1/25th the size of the King Island based southern bull kelp fishery). This smaller size means that there is a concomitantly smaller number of operators with much less time being spent on beaches undertaking harvesting operations.

While there have been no reported interactions with Threatened, Endangered or Protected Species it is acknowledged that the macro-algal wrack fishery occurs along a coastline where there is potential for interactions with a number of shore-bird species. These interactions can be managed through licence conditions to ensure that operators do not impact on nesting birds and those interactions with feeding / foraging birds are controlled. It is noted that two species, the Hooded Plover and the Orange-bellied Parrot are both listed species and there is a particular need to ensure that management of the harvest operations (including transport to and from beaches) is undertaken to ensure that there are no adverse interactions with these species.

It is recommended that licence conditions for the fishery should be revised in the light of recent work including the advice from the Department of the Environment (DotE) and key stakeholders. Such a revision should include the adoption of a spatial management strategy that would ensure that areas of coast with high conservation significance are protected through the use of explicit harvest exclusion zones. The area to be protected through harvest exclusion zones should comprise 50% of the coastal extent of the Licence Y078.

Introduction

Description of the Fishery

Beach –cast accumulations (wracks) of decaying seagrass and marine algae are considered essential components of coastal ecosystems. They serve several; important roles in the ecology of local coastal environments. Wracks contribute to the food web dynamics of beach and near-shore marine communities, including valuable fisheries, by supporting microbial processes and invertebrate fauna that are preyed upon by higher-level consumers and supplying nutrients that can be utilised by plant and animal communities (Kirkman and Kendrick, 1997). Many bird species, some of high conservation status, also utilise these habitats. Wracks also provide protection to coastal dunes and other important coastal environments (Ivey et al, 2013). Technically, wrack may consist of kelp or other detached macro-algae, seagrasses, animal carcases and other organic matter deposited from the sea onto a beach by waves or winds (Fairweather and Henry 2003; Duong 2008). Harvesting includes the removal, clearance, movement, re-location or disturbance of any part of a wrack. It is emphasised that this report covers only beach-cast material and does not refer to flora attached to a substrate or drifting in the water column, which is not available for harvesting.

The commercial harvesting of beach-cast seagrass and marine algae in South Australia is a small, but growing, industry. Interest in harvesting has resulted from a rising market demand for seagrass and algal products both locally and internationally. An authority to collect any marine flora for commercial purposes is required under the *Fisheries Management Act 2007* (the Act). The commercial harvesting of wracks from any beach of the State is under the care, control and management of PIRSA Fisheries and Aquaculture on behalf of the community in accordance with the Act. The Act provides a broad statutory framework to ensure the ecologically sustainable management of South Australia's aquatic resources. The regulations that govern the management of the South Australian Beach-Cast Seagrass and Marine Algae Fishery are the *Fisheries Management (Miscellaneous Fishery) Regulations 2000* and the *Fisheries Management (General) Regulations 2007*.

The South Australian Beach-Cast Seagrass and Marine Algae commercial fishery is managed by a series of input controls, such as exclusion zones and specific methods of harvesting, subject to licence conditions. There are two non-transferrable Miscellaneous Fishery licences which permit the harvest of wrack in SA, and both are for areas that are located in the southeast of the State, each with its own permitted area of operation (Figure 1 and 2). The harvest of wrack for commercial purposes has also been granted to a small number of operators in the past through Ministerial exemptions. Currently there are no active exemptions. In December 2013, PIRSA Fisheries and Aquaculture implemented the *Fisheries Management (Miscellaneous Developmental Fishery) Regulations 2013*. These regulations provide provisions for the issuing of permits for exploratory and developmental fishing activities for species not currently fished commercially and undertaking fishing activities in new areas. The harvest of wrack in areas not currently allocated to the two Miscellaneous Fishery licence holders may meet the criteria of exploratory and developmental fishing permits. PIRSA Fisheries and Aquaculture has not issued any permits for exploratory and developmental wrack harvest as yet.

Food Webs and Nutrients

Several studies, most notably in South Australia, Western Australia and South Africa, have highlighted the importance of beach-cast seagrass and macro-algal accumulations as sources of detritus and of particulate and dissolved nutrients which can contribute to beach and inshore marine foodwebs (e.g. Griffiths & Stenton-Dozey 1981; Koop & Griffiths 1982; Lenanton *et al*. 1982; Robertson & Hansen 1982; Griffiths *et al*. 1983; Duong 2008). Wracks of dead seagrass and algal material are physically broken down by wave and sand abrasion and are biologically decomposed by the action of bacteria and small invertebrates. Decomposition by bacteria releases nitrogen and phosphorous - nutrients necessary for the growth of offshore seagrass meadows (Bell 1983). In Western Australia, substantially higher concentrations of dissolved nutrients were measured in waters adjacent to beaches covered in decaying

wrack material compared with wrack-free beaches, where waters were relatively nutrient- deficient (Bell 1983).

A rich community of detritivores, such as amphipods, isopods (sandflies), coleoptera (beetles) and diptera (flies) rapidly colonises and consumes the decaying vegetation, breaking it down into detritus and particulate carbon (e.g. Griffiths & Stenton-Dozey 1981; Marsden 1991; Duong 2008). Griffiths, Stenton-Dozey & Koop (1983) for example recorded 35 species (of which 22 were insects) amongst kelp wrack, which together amounted to more than 97% of the total intertidal faunal biomass. These organisms can reduce the biomass of dead macro-algae to 50% of its initial weight after 2 days and 20% after 14 days, mainly due to consumption by amphipods and dipteran (kelp fly) larvae (Griffiths & Stenton-Dozey 1981; Rieper-Kirchner 1990). Several species of beach flies complete their life cycles within seagrass/algal wrack (Blanche 1992 in Kendrick *et al*. 1995; Duong 2008). The herbivorous detritivores are in turn preyed upon by beach-dwelling macrofauna such as beetles, birds and isopods (Duong 2008). Griffiths *et al*. (1983) suggest that at some sites on the southwest coast of South Africa, approximately 95% of the food supply of beach macrofauna comes from the regular, enormous influxes of kelp. Duong (2008) found that algal wrack in South Australia, particularly brown algae including kelps, appeared to be a potential source of nutrition for beach and nearshore consumers such as amphipods and dipterans.

Detritus from wracks can also be exported offshore to supply food to demersal and abyssal fauna (Suchanek *et al*. 1985 in Thresher *et al*. 1992; Joselyn *et al*. 1983 in Kendrick *et al*. 1995). In addition, work in Tasmania (Thresher *et al*. 1992) strongly suggests that "it might also constitute a widespread and potentially important source of productivity for planktonic ecosystems as well". These authors found evidence that the food chain supporting first-feeding larvae of Tasmanian Blue Grenadier (*Macruronus novaezelandiae*) - the dominant nektonic (midwater) predator of the region - is based on microbial decomposition of seagrass detritus. First, feeding is often maintained to be a critical period for fish larval survival. Moreover, higher rates of larval growth were associated with periods of frequent winter storms, when offshore transport of seagrass detritus from coastal wrack accumulations is at a maximum (Thresher *et al*. 1992). Thus, the export of detrital material from wracks may significantly affect the reproductive success of one of temperate Australia's dominant fish predators (Thresher *et al*. 1992).

The wracks community therefore constitutes a significant food resource consisting of fragments of seaweed and seagrasses, bacteria, meiofauna and beach macrofauna. It may remain in situ, providing food for terrestrial detritivores and consumers (including insects and birds) or it may be washed back into the sea during storm or high tide events, where it provides food for benthic coastal communities and important feeding sites for shallow water fish species. Particulate matter from the breakdown of wracks may also have an effect on offshore secondary production although it is not clear to what extent this adds to the inputs from detrital material that is not cast ashore but rather decomposes within the marine environment.

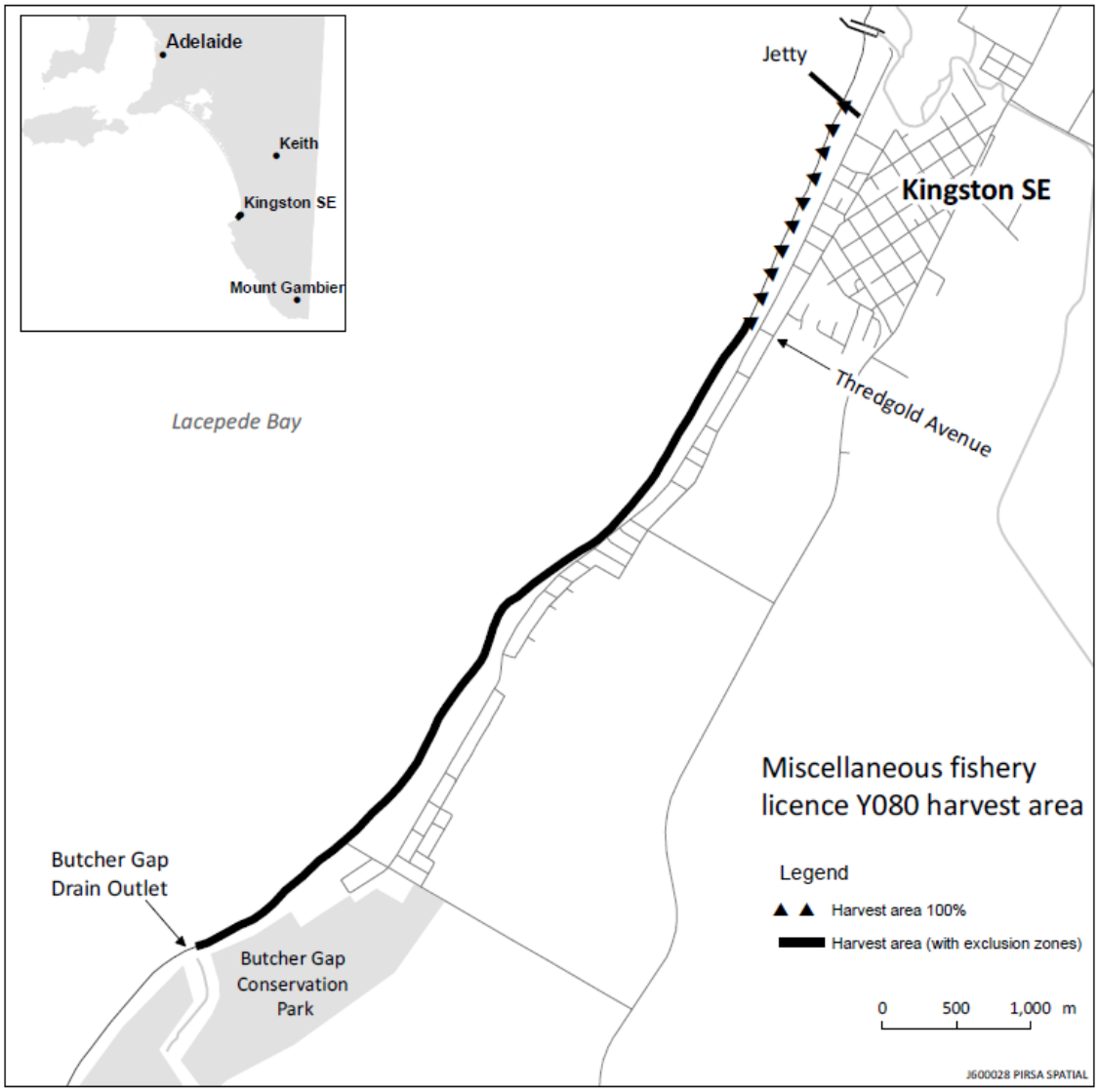

Figure 1: Map detailing permitted areas of wrack harvest for Miscellaneous Fishery licence Y080.

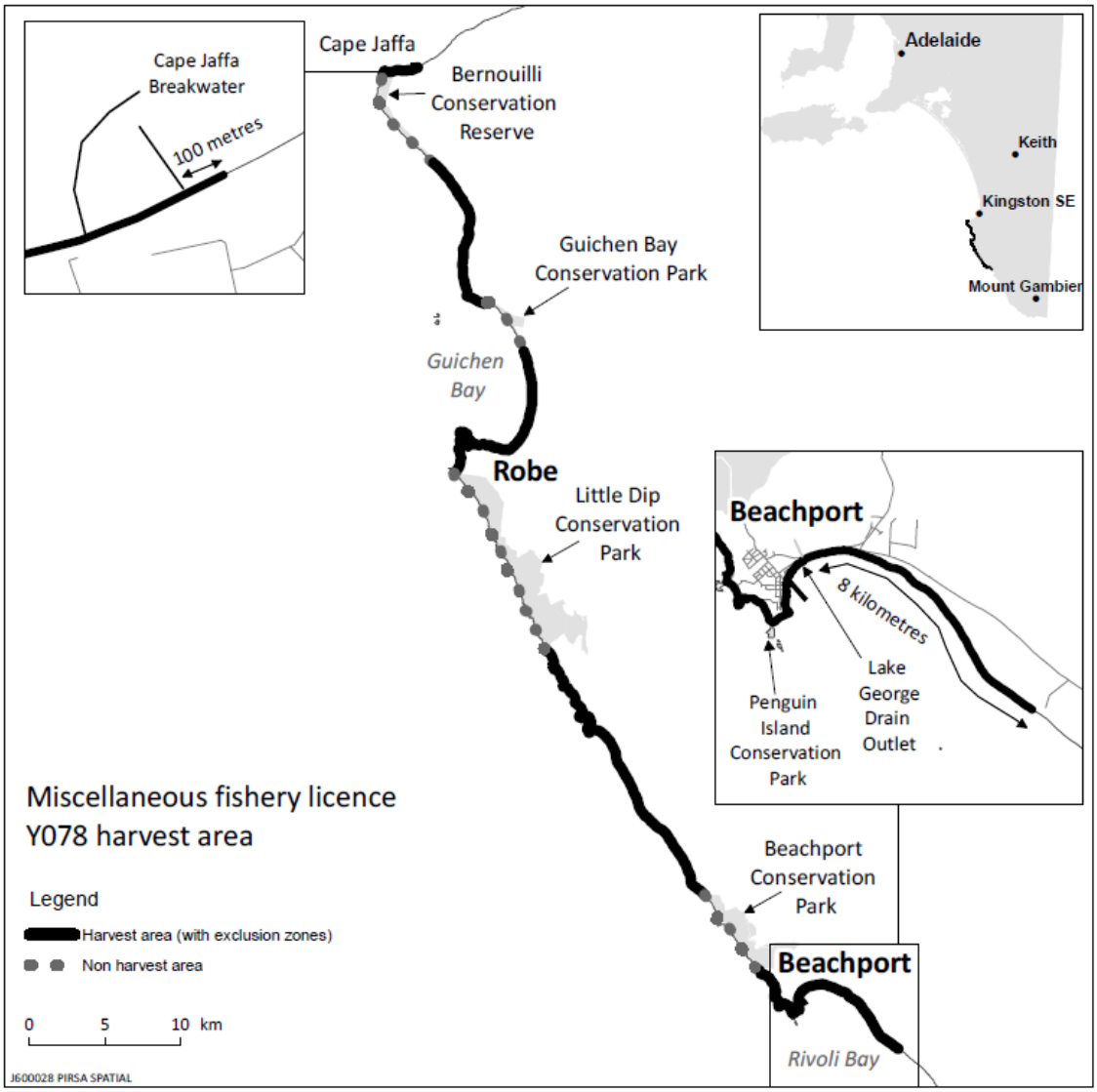

Figure 2 Map detailing permitted and restricted areas of wrack harvest for Miscellaneous Fishery licence Y078.

Existing areas where harvesting is permitted will be changed in the future to reflect the changes in the management arrangements as a result of the DotE recommendations as part of the assessment.

Description of the current fishery

Target species

Seagrass

Seagrasses are underwater flowering plants that evolved from land plants between 20 and 90 million years ago (Papenbrock 2012). There are about 30 different seagrass species from 12 genera in Australia. Seagrasses grow on sandy to muddy substrates, from the intertidal zone to a depth of approximately 40 metres. They are anchored to the substrate by a network of fibrous underground stems or rhizomes. Their distribution is dependent upon temperature and exposure to wave action but, most importantly, upon light. The depth distribution of seagrasses is therefore influenced by water clarity, as this controls light penetration.

In South Australia, seagrass meadows cover approximately 5000 km^2 of sea floor (Shepherd & Robertson 1989). Combined with meadows in Western Australia and Bass Strait, this constitutes one of the largest temperate seagrass ecosystems in the world (Shepherd & Robertson 1989). Most of these meadows are comprised of *Posidonia spp*. occupying the clear, sheltered waters of Spencer Gulf and Gulf St Vincent. Other major areas of seagrass distribution include the shallow embayments on the western coast of Eyre Peninsula (e.g. Streaky Bay), Lacepede Bay in the southeast of the State and areas of Backstairs Passage, wherever suitable substrate occurs.

The main seagrass species occurring in South Australia are: *Posidonia angustifolia, Posidonia australis, Posidonia coriaceae, Posidonia denhartogii, Posidonia sinuosa, Amphibolis antarctica, Amphibolis griffithii, Heterozostera tasmanica, Halophila australis* and *Zostera muelleri* (Larkum & den Hartog 1989). In low-energy environments such as the two gulfs and Lacepede Bay, the meadow-forming species *P. angustifolia, P. sinuosa,* and *P. australis* are most abundant. *Posidonia* generally requires stable, non-mobile sediments on which to grow and establish dense meadows. *P. coriaceae* and *P. denhartogii* generally only occur as small stands or as fringe communities. The four other species, (*A. antarctica, A. griffithii, H. tasmanica* and *H. australis*) occur either as fringe communities on the edges of blowouts in *Posidonia* meadows, as thin, dispersed populations on mobile sediments or in stands of mixed species composition (Clarke & Kirkman 1989; Shepherd & Robertson 1989).

Seagrass plants generally shed their leaves annually in early autumn; the blades are initially buoyant, then sink and accumulate in drifts on the seabed (Shepherd pers. comm.). Nutrient levels in the surrounding waters have been shown to play a role in leaf shedding as well. During periods of strong wind and wave activity, particularly in the winter months, surge and swell resuspends and mobilises the detached leaf blades. Persistent onshore winds blow this drift-cast material into the surf zone and at high tide it is washed onto the beach in clumps. Greater than 95% of the beach-cast seagrass in South Australia consists of the blades of *Posidonia spp* (Shepherd pers. comm.).

The amount, location and timing of wrack deposition depend on the density and areal extent of offshore seagrass meadows as well as on local tidal, current, wind and storm activity. Wrack remains on the shore for variable lengths of time - in some cases only one tidal cycle - or may become stranded above the high water mark and accumulate over weeks or months forming large semi-permanent deposits. Often, beach-cast material is washed back into the surf zone and re-deposited several times resulting in significant longshore movement of wrack. Consequently, large variations in wrack deposits occur from one location to another and on a monthly, weekly or daily basis (Duong 2008). Persistent accumulations are often associated with man-made structures such as groynes, breakwaters and jetties. At Kingston for example, there is a large, permanent accumulation of seagrass wrack approximately 2-3 metres deep covering the beach between the southern groyne of the Maria Creek outlet and the town jetty; this accumulation is believed to have been caused by the development of the groyne (Duong 2008) and as such the removal of the deposit is seen as an issue for public amenity.

Macro-algae

The marine macro-algal diversity of temperate Australia is one of the richest in the world, with approximately 123 species of Chlorophyta (green algae), 203 species of Phaeophyta (brown algae) and over 800 species of Rhodophyta (red algae) recorded within southern Australian waters (Womersley 1984, 1987, 1994, 1996, 1998); many of these macro-algal species are endemic to the region.

Given this diversity the accumulation and composition of beach wrack can be highly variable (e.g. DEH 2004, Colombini and Chelazzi 2003, Dugan *et al.* 2011, PIRSA 2014) and the proposed harvest may be taxonomically opportunistic such that information on the distribution of any individual or group of species is unlikely to be informative. However, the harvest area includes the stretch of coast that abuts the western extent of what was traditionally called the Maugean Marine Biogeographical Sub-province (Womersley 1990) More recently, marine bioregionalisation has been revised in a manner which largely reflects the cumulative distribution patterns of pelagic and demersal fishes, marine plants and invertebrates (IMCRA version 4; Commonwealth of Australia, 2006). Within the context of IMCRA 4.0 the Maugean Sub-province is largely congruent in its South Australian extent with the Otway Bioregion but also extends across the Victorian coastline, the western and eastern Bass Strait and Tasmanian coastal regions through to the Twofold Shelf region into Southern NSW. The area specifically relating to macro-algal wrack harvests in South Australia (licence Y078) is almost entirely within the Otway Bioregion whilst the seagrass harvests from Kingston are located close to the southern extent of the Coorong Bioregion.

Cape Jaffa (in the southeast of South Australia) represents the westerly limit of the Maugean sub-province and as such this is also the westerly limit in the distribution of a number of key taxa including the large kelp (*Macrocystis pyrifera*) and the southern bull kelp[1] (*Durvillaea potatorum*).Within the Maugean sub-province, higher energy rocky intertidal and sublittoral fringes are typically dominated by bull kelp (*Durvillaea potatorum*) while subtidal reefs include numerous species of foliaceous red, brown and green macro-algae but tend to be visually dominated by species of the giant kelp (*Macrocystis pyrifera*[2]), the kelp (*Ecklonia radiata*) as well as a large variety of fucalean macro-algal species (IMCRA 1997, Edyvane 1999a, b) including many species of *Cystophora* and *Sargassum* as well as the Seirococcacean species (*Phyllospora comosa, Seirococcus axilaris* and *Scytothalia dorycarpa*).

The major commercial harvest is focussed on *Durvillaea potatorum (LaBillardiere) Areschoug* although other brown algal species (e.g. *Ecklonia radiata or Macrocystis pyrifera)* could also be collected.

Macro-algae grow on shallow rocky substrates and are common on the numerous inshore limestone reefs that dot the coastline of South Australia. Some species, particularly the kelps, grow to very large size and form dense subtidal beds. During storms and periods of strong winds, large numbers of these macro-algae are torn off or fragmented by wave action and later washed up on beaches. The supply of cast algae, like seagrass, is highly variable over short time and spatial scales, but is again most predominant in winter when very large accumulations may occur. Various seaweed species are found within algal beach wracks;

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[1] Although commonly called bull-kelp, *Durvillaea* is more appropriately called **southern** bull-kelp to differentiate it from species of *Nereocystis (*which is the northern bull-kelp). In fact, *Durvillaea* is not actually a kelp; kelps are brown algae in the order Laminariales while *Durvillaea* was historically placed in its own order (the Durvillaeales) but more recently has been classified into the family Durvillaeacea within the order Fucales. *Durvillaea* has a direct life cycle, which is one distinguishing feature of the Fucales, but unlike other members of the order it has a diffuse (although apically dominated) meristem.

[2] Previously the western form of giant kelp found in Australia was known as *Macrocystis angustifolia* and it was therefore defined as a different species to *Macrocystis pyrifera* (the form that is broadly distributed around King Island, Victoria and Tasmanian coasts). More recently the genus *Macrocystis* has been revised (Demes et al 2009) and the South Australia form (formerly classified as *Macrocystis angustifolia*) has been merged with *Macrocystis pyrifera*.

their abundance varies depending on location and the source of the material (Duong 2008). The species that are targeted by the fishery are primarily several large brown algae (e.g. *Durvillaea potatorum* and *Ecklonia radiata*) and some of the red algae such as *Gracilaria*.

Harvest process

Commercial History

The commercial fishery began formally in early 1990 when two permits were granted for commercial harvesting of wrack in the southeast of the State. Interest in both algal and seagrass wrack harvesting intensified in 1993, when a number of applications were received by PIRSA Fisheries and Aquaculture for additional permits in the southeast as well as in new areas such as Lady Bay, Port Parham and Port Adelaide (North Haven). These permits were issued

(i) for the purposes of market research and development, to identify potential markets for seagrass and algal products and determine if the industry could be viable; and

(ii) to allow certain seaside councils to improve local beach access and amenity. In 1996 permits for the commercial harvest of wrack were replaced with Ministerial exemptions, as it was deemed that these permits did not adequately apply for the intended purposes.

In late 1996, in response to increased interest in wrack harvest from new and existing exemption holders, PIRSA Fisheries and Aquaculture declared a moratorium on the issue of any new exemptions in the fishery, pending the development of a management plan.

In 2000 a review of management arrangements for the fishery was carried out as part of the process to develop a management plan for harvesting beach-cast seagrass and marine algae. It identified that the most appropriate management arrangement for granting access to beach-cast wrack as a commercial operation was by means of a Miscellaneous Fishery Licence under the *Fisheries Management (Miscellaneous Fishery) Regulations 2000*. In 2003, the Ministerial exemption holders harvesting wrack for commercial purposes were offered a Miscellaneous Fishery Licence in the fishery. This resulted in the issue of three Miscellaneous Fishery Licences for beach-cast wrack harvesting. One of those licences lapsed in 2007 with the death of the licence holder. This licence has not been reinstated as Miscellaneous Fishery Licences are non-transferable. Currently, commercial wrack harvesting is a small-scale 'developmental fishery' with the two licence holders harvesting seagrass and algal material between Kingston and Beachport in the States southeast (**Figure 1** and 2).

Since 1997, commercial wrack harvesters have provided data on their fishing activities through monthly catch and effort returns. All information collected in catch and effort returns is entered and stored with the South Australian Research and Development Institute (SARDI) Aquatic Sciences division. Fishers are required to provide information on species harvested, weight of each species harvested, exact location of the harvesting activity, method used to collect the resource, method used to process the resource, use made of the resource and volume of each product sold each month. Currently, there are no annual stock assessments by SARDI for the Beach-Cast Seagrass and Marine Algae Fishery. A summary of fisheries data and biological parameters was completed by SARDI in 2013 (Ivey *et al.* 2013). This information is confidential under provisions in the Act which restrict the publishing of individual data. PIRSA Fisheries and Aquaculture has contacted the individual licence holders and received authorisation to utilise the statistical data as part of this report.

There is currently no research from South Australia which would allow us to determine the ecologically sustainable wrack harvest levels although it is likely that the dangers of over-exploitation of wrack apply not so much to the wrack itself but to the organisms and communities dependent upon it as a source of nutrients, food, shelter, and refuge. Moreover, any assessment of wrack abundance is problematic because of the highly patchy and mobile nature of the resource (McClary *et al*. 2005). Thus, averaged

amounts of wrack calculated for a length of coastline are probably over-estimates as wrack is patchily distributed across sites and between seasons (Kendrick *et al*. 1995; Duong 2008).

In the absence of scientific data and because of concerns regarding the possible impact on coastal environments from the removal of wrack accumulations, PIRSA Fisheries and Aquaculture has adopted a 'precautionary approach' to the harvesting of wrack. Harvest levels have fluctuated over the life of the fishery with variation in wrack availability dependant on storms and market requirements. Notwithstanding, maximal macro-algal harvest rates have not exceeded 305 tonnes in any year with average harvest rates of <79 tonnes per annum. These rates are at least an order of magnitude less than those for the King Island fishery (where average harvests in the last 10 years have been around 2500 tonne per annum with maximal harvest of 4700 tonne per annum). In fact the very small quantum of the harvest from SA beaches (averaging 1/25th of the harvest rate on King Island) and the correspondingly very low level of harvesting activity on the beaches suggests that the South Australia industry is, by any comparable measure, only a cottage industry. While the ongoing development of the industry is seen as being advantageous to the economic development of the region, it is fair to say that at this point in time the macro-algal harvest contributes almost no additional impact on beaches over and above the existing recreational and community use (current uses include recreational 4WD, trail bikes, fishing and camping as well as general beach goers including swimmers and surfers).

In the context of the seagrass harvest a study in 2008 by Duong, investigating the effects of wrack removal on macrofaunal communities, proposed that the level of commercial wrack removal at Kingston is acceptable based on the following:

- The cover of wrack at Kingston is probably un-naturally high due to the breakwater at the northern end of the beach acting as a wrack trap;
- Macrofaunal abundance and diversity in the wrack banks is low;
- The wrack is mostly old, refractory seagrass which does not input nutrients into the beach ecosystem via either decomposition or incorporation into trophic webs;
- Management arrangements require that within harvest areas a proportion of wrack remain on the beach; and
- Wrack harvest occurs infrequently.

The study did not directly examine the effects of commercial wrack removal at Beachport, however it did highlight that harvesting there occurred infrequently and in small quantities.

Commercial Harvesting

Licence conditions specify methods of access and harvesting and any relevant restrictions on harvesting activities considered necessary by PIRSA Fisheries and Aquaculture have been developed in consultation with other agencies such as the Department of Environment, Water and Natural Resources (DEWNR), Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE), and the Department of Planning, Transport and Infrastructure (DPTI).

Commercial wrack harvesting currently takes place on beaches around the shoreline of Lacepede and Rivoli Bays, mainly along the Kingston and Beachport foreshores (Figure 1). Each licence holder is provided with access to a specified area of foreshore through a licence condition. However, within any area, harvesting has historically taken place in a concentrated area where the largest wrack accumulations occur. Harvesting has been sporadic, generally being carried out opportunistically whenever significant quantities of wrack are deposited on the foreshore. As a result, the majority of harvesting has been undertaken during winter and spring when peak accumulations occur after storms or periods of strong wind (Kirkman & Kendrick 1997; Duong 2008).

Seagrass wracks are normally harvested using machinery such as bulldozers, front-end loaders and excavators while macro-algal wracks are harvested using specially modified forwarders, which load the material onto trucks or trailers for removal, offering an efficient alternative to hand harvesting. Local

councils may restrict vehicle access to the beach and thereby restrict what type of equipment is used to harvest wrack. This includes hours of operation and restricting beach access to existing formalised ramps or tracks. Normal road rules apply on the beach and vehicles must be registered. In addition, whilst undertaking the harvesting activity the removal of any sand must be avoided. Any sand taken incidentally during the harvesting activity must be returned to the foreshore.

Fresh specimens of macro-algae are collected prior to the onset of any degradation or burial by wind-blown sand, from beaches adjacent to offshore limestone reefs. The harvesting of macro-algae is species-specific; that is, the target species is selected specifically for its unique chemical properties. Target species are collected by forwarders, which use a specifically modified 'grapple' allowing it to pick up individual (large) kelp plants whilst minimising sand disturbance, and loaded into trucks or trailers for removal. Non-target macro-algal species are left undisturbed in the wrack. Macro-algae may also be collected as a by-product of seagrass harvesting.

It is unclear at this time as to whether any particular species plays a more important ecological role in beach-cast seagrass and macro-algal wrack (Orr 2013). As a result, licence conditions stipulate that the licence holder may harvest beach-cast seagrass and macro-algal wrack but 'exclusion zones' must be interspersed within harvest sites in this area to the effect that no more than 75% of the estimated biomass of beach-cast seagrass and macro-algal wrack is removed. An ‘exclusion zone’ means a subsection of an area in which no harvesting activity is conducted, and which runs continuously from the low water mark to the fore-dune or scrub within the area. There is no estimate of the percentage of macro-algae that is usually harvested from a wrack but due to the very large size of such wrack accumulations and the high turn-over rate, it is expected that this percentage would be quite low.

This is clearly an area where future harvest management and monitoring can be improved. It is recommended that beach harvesting should be undertaken in such a way as to limit the total harvest to no more than 50% of the available biomass along the coastal extent of the licence. This can be achieved through an explicit spatial management strategy that limits harvesting activities to 50% of the beach through the use of harvest exclusion zones that would extend along beaches covering the entire width from the waters’ edge to the back of beach. Such a strategy has the advantage that it is also easier to ensure compliance because specific areas of the coast can be designated as available for harvest while others are defined as being in harvest exclusion areas. Monitoring can also be done photographically using fixed photopoints showing the area of beach harvested before and after each harvest operation. The use of a camera with built in GPS would also allow scrutiny on the level of compliance around harvest exclusion areas on beaches.

Commercial Utilisation

Wrack harvesting has the potential to produce exportable, value-added primary products and thus improve local regional economies. Some of these products may eventually replace existing imported goods. Seagrass and marine algae are harvested for a variety of uses throughout Australia and overseas. Seagrass wrack is commonly stored in paddocks and allowed to decompose for several years before it is suitable for use as a soil improver or as garden mulch (Kirkman & Kendrick 1997). Macro-Algae are processed immediately either via composting or by drying on outdoor racks and crushing. The principal use for algal derivates is as a food product for abalone aquaculture feed, although they are also used in the production of alginate and agar, mineral supplements, cattle feed, garden fertilisers and pesticides (Colombini & Chelazzi 2003). There is moderate demand for wrack material to supply the domestic market and harvesters have developed products for overseas export.

Amenity clearance sector

The decomposition process of wrack often produces hydrogen sulphide gas, which has a highly unpleasant odour, and attracts plagues of beach flies (Kirkman & Kendrick 1997). Additionally, excessive accumulation of wrack may create hazards or limit access to specific areas such as boat ramps or marinas. Metropolitan and District Councils are therefore interested in removing wrack from beaches which are

recognised as important local tourism assets, as well as at specific sites where wracks are regarded as a problem. This has the potential of cleaning up and beautifying popular tourist beaches and thereby benefiting both local residents and visitors. Wracks that are removed for public amenity purposes are small amounts and are only harvested periodically.

Ministerial exemptions have been issued in the past by PIRSA Fisheries and Aquaculture to local councils, including Ceduna District Council, Corporation of the City of Whyalla, and Kingston Regional Council, to clear wrack accumulations. Currently, DEWNR is involved in the management of wrack removal for amenity purposes. In November 2013, PIRSA Fisheries and Aquaculture notified local coastal councils that any enquiries regarding the movement of wrack for an amenity purpose should be directed to DEWNR.

Recreational sector

Members of the public often seek to obtain small amounts of beach-cast wrack, for use as 'mulch' or fertiliser on domestic gardens. Decisions relating to recreational (non-commercial) harvest of wrack are the responsibility of the relevant Local Government Authority, where enabled through regulation. In some cases, local by-laws exist which prohibit this without Council permission. In the past, these requests have generally been granted, provided the material is harvested by hand, only small quantities are collected, and is strictly a non-commercial activity. In a few cases, where the Council believes it is detrimental to the shoreline, this activity is either discouraged or actively prohibited. The recreational harvest of wrack from within commercial harvest areas is allowed but must be approved by the local Council due to beach access restrictions. PIRSA Fisheries and Aquaculture has recommended to coastal councils that they should contact DEWNR for recreational wrack harvest management advice. There is currently no estimate of product taken recreationally but this is considered to be a very small amount.

Aboriginal Traditional Harvesting

Currently none of the Miscellaneous Fishery Licence holders that are entitled to take wrack are Aboriginal traditional fishers. There are also no known documented historical accounts of Aboriginal traditional use of wrack. The State, Native Title parties and the commercial fishing industry are currently involved in negotiations of Indigenous Land Use Agreements (ILUAs) with a view to resolving native title claims. The future involvement in existing commercial fisheries by Aboriginal traditional fishers or communities may be considered in this process.

Illegal Catch

The illegal harvest of beach-cast seagrass and marine algae wrack is considered to be a negligible risk. South Australia has fisheries compliance resources to address any illegal activities. To date there have been no prosecutions for offences in the fishery.

Harvest volumes from council and commercial operators

The two current Miscellaneous Fishery licence holders permitted to take seagrass and macro-algal wrack have a number of existing licence conditions, including restrictions on areas of harvest. There are no limitations on the total volume the licence holders can harvest as part of their licence, although there are natural limitations for the commercial operator in relation to accessing the ‘right’ species and quality of wrack for their operations.

Implications for non-target species

Many shorebirds and seabirds are associated with wrack accumulations. These birds make use of the beach-cast vegetation for a variety of purposes including nesting, shelter during strong winds or storms and camouflage while resting (Campbell & Anderson 2007). A large number of shorebirds also prey upon wrack-inhabiting organisms such as crustaceans, insects and polychaetes (Kendrick *et al*. 1995), including the hooded plover (*Thinornis rubricollis*), listed as vulnerable under South Australia's *National Parks and Wildlife Act 1972*. In Western Australia, decomposing wrack provides an important winter food source for silver gulls, which feed on kelp fly larvae and amphipods and may time their breeding cycle to coincide with the local availability of wrack (Kendrick *et al*. 1995). On King Island, ruddy turnstones and double-banded plovers are amongst the birds that forage in the bull kelp for small invertebrates. These species have all been recorded feeding in beach-cast vegetation in South Australia.

Wrack accumulations also provide habitat and nursery areas for many birds species, providing protection and camouflage for nest-sites, eggs, chicks and adults alike (McCulloch 1996; Campbell & Anderson 2007).

In South Australia, a total of 40 species of birds have been recorded utilising beach-cast wrack in some way (McCulloch 1996). This includes long-distance migratory birds, waiting out the tide or bad weather in the lee of wrack accumulations, as well as many resident species. For these reasons wracks constitute a valuable component of bird habitat (McCulloch 1996).

The orange-bellied parrot migrates from breeding grounds in Tasmania to coastal areas in Victoria and south east South Australia for each summer period. It usually frequents the dune and beach system feeding on the vegetation along the coast. This species is classified as Critically Endangered under the *EPBC Act*, Threatened under the Victorian *Flora and Fauna Guarantee Act 1988*, Endangered under the Tasmanian *Threatened Species Protection Act 1995*, Endangered under the South Australian *National Parks and Wildlife Act 1972*, and Critically Endangered under the New South Wales *Threatened Species Conservation Act 1995*. A Recovery Plan jointly managed by the Commonwealth, Victoria, South Australia, New South Wales and Tasmania has been developed (Orange-bellied Parrot Recovery Team 2006).

Licence conditions on the miscellaneous licences prohibit the harvesting operations from collecting material within four metres of the dune area in the permitted areas of the coast. This mitigation strategy aims to reduce interactions with non-target species utilising the dune system and avoids the accidental collection of 'other 'flora species.

It is worth noting that beaches in the South East of the state are utilised heavily by recreational users for things like fishing, camping and four wheel driving (4WD), who would interact more often with native species than the operations of the miscellaneous licence holders. The use of 4WD vehicles is therefore considered to have significant potential impacts on species in the area where harvesting of wrack is permitted. Road Rules apply along South Australian beaches where vehicles are allowed to enter and DEWNR have erected signs in these regions informing drivers to ensure they keep to the tracks so that additional damage to the ecosystem is avoided (Personal Communication).

Threatened, Endangered and Protected Species

SARDI Aquatic Sciences collect information on interactions with threatened, Endangered and Protected Species (TEPS) from all South Australian commercial fisheries annually.

There have been no recorded interactions with TEPS in the Miscellaneous Fishery permitted to undertake seagrass and macro-algal wrack harvests. Annual reports on interactions are produced by SARDI Aquatic Sciences and are available on the SARDI website.

While there have been no reported interactions with TEPS it is acknowledged that the macro-algal wrack fishery does take place along a coastline where there is potential for interactions with a number of shore-bird species. These interactions can be managed through licence conditions, particularly in terms of

restricting access such that harvesting does not occur within 4 m of the foot of a dune and controlling vehicle speeds on the beach.

The Hooded Plover and the Orange-bellied Parrot are of particular concern and it is recommended that management arrangements should be reviewed and if necessary revised to ensure that the harvest operations (including transport to and from beaches) are undertaken in a manner that guards against adverse interactions with these species.

Recommendations for the SA fishery to ensure best practice in comparison to wrack fisheries elsewhere

Best practice Management

Internationally, best practice wrack fisheries would limit the removal of wrack to <50% of total available wrack biomass. Exceeding this threshold been shown to increase the likelihood of broad based impacts on associated systems (Orr, 2013).

A key strategy that can be employed within the fishery is to put aside areas on each and every beach where wrack removal is prohibited at all times. These areas will add to areas that are already put aside (e.g. areas within Marine Park Habitat Protection zones, areas that are inaccessible due to lack of access roads and tracks, areas that comprise promitory or headlands and areas where coastal creeks cut across beaches) and will thereby ensure that total wrack removal is restricted in terms of both biomass and the areal extent of disturbance from wrack harvests is similarly limited. The use of "ungroomed areas" ensures that selected areas of the beach remain **permanently undisturbed** (other than for controlled transit by vehicles moving along the beach).

Ban on live harvest

Harvesting of attached plants is not permitted. This is based on the provisions originally developed for the harvest of *Durvillaea potatorum* on King Island, where it has been recognised that the direct life history strategy of *Durvillaea* (and other fucalean algae which includes a number of commercially interesting species such as *Seirococcus*, *Scytothalia*, *Cystophora* and *Sargassum*) is not suitable for a live harvest. In species with a direct life history the reproductive potential of the plant is stored in the standing biomass and any cutting of attached plants would have a major impact on the persistence of the harvested populations. Similarly, the diffuse but largely apical meristem in *Durvillaea* means that the major growing portion of the plant is the proximal region of the thallus and cutting would remove this material and thereby restrict growth of any remaining plant material.

Harvest processes comparison to other Australian fisheries

KING ISLAND

King Island is the only other comparable commercial wrack fishery in Australia. The fishery currently has export approval and follows a number of management arrangements aimed at reducing ecosystem impacts, including bird interactions.

As outlined in the Department of the Environment and Heritage (DEH) Assessment of the Harvest of Cast Bull Kelp dated 2011, currently native seaweeds in Tasmania are not directly harvested due to their ecological importance to marine ecosystems and fisheries resources. Harvesting of seaweed in Tasmania is presently confined to 3 activities:

1. the collection of beach cast bull kelp (*Durvilleae potatorum*) on King Island and the northern west coast;

2. harvesting of the introduced Japanese Sea Kelp (*Undaria pinnatifida*) on the east coast; and

3. the localised collection of beach cast seaweeds and seagrasses. DPIWE recognizes that bull kelp harvesting is a major industry in Tasmania supplying about 5% of the world production of alginates and generating about $2 million dollars of income for King Island. In contrast, small-scale licensed operations collect cast weed from several locations around Tasmania where large volumes of seaweed and seagrasses are washed ashore. The bulk of this cast weed is bagged and sold in garden shops as garden mulch.

Publicly available information relevant to the fishery	• *Tasmanian Living Marine Resources Management Act 1995* • The Department of Environment and Heritage Assessment Report of the Tasmanian Kelp Fishery, 2005. • Department of the Environment, Water, Heritage and the Arts, Assessment Report of the King Island Cast Bull Kelp Fishery 2008. • Submission from Kelp Industries Pty Ltd, 2011
Area	King Island, Tasmania. The fishery is permitted to harvest cast bull kelp, from the following areas: 1. the west coast of King Island between Cape Wickham and approximately five kilometres due south of Ettrick Beach; 2. the south coast of King Island from Surprise Bay to the east of Stokes Point; and 3. the south-east coast of King Island from three areas around Red Hut Point, Grassy Harbour and City of Melbourne Bay.
Fishery status	There is no fishery status assessment for kelp, however the current scale of the fishery is small and kelp is considered unlikely to be overharvested.
Target species	Cast bull kelp*, Durvillaea potatorum.* Cast kelp refers to kelp plants that have been detached from the substrate and carried shoreward by water movement. As the plants cannot reattach, once they are cast onto the shore, they die. In most cases more than 50 per cent of kelp biomass is left at each harvesting site as other species and smaller kelp pieces are not picked up.
Byproduct species	As this operation collects cast bull kelp which has already washed ashore, there are no byproduct species harvested.
Gear	Hand collection, which is sometimes assisted by winches and in some instances a mechanical harvester with a mechanical grab may be used.
Season	Harvest occurs year round but is dependent on prevailing weather conditions. Harvesting and transporting of kelp is prohibited from September to March (inclusive) on sandy beach areas except the north end of British Admiral Beach and any other sandy beach which would not be detrimental to nesting *Thinornis rubricollis* (hooded plovers).
Commercial harvest	The total dry tonnes of bull kelp that have been harvested from 2007 to 2010 for the King Island Fishery are; 2007 – 2223.0 tonnes (t) 2008 – 1922.0 t 2009 – 1605.5 t 2010 – 1900.0 t
Value of commercial harvest	The small number of operators in the fishery currently prevents the public release of this data.
Take by other sectors	The amount of cast bull kelp harvested by the recreational and Indigenous sectors is considered negligible.

Commercial licences issued	Collection is permitted through the use of 100 registered licenses. Four of the licenses are full-time collectors, 40 are part time collectors and the remainder are inactive.
Management arrangements	Kelp Industries Pty Ltd is the only licensed processor of kelp on King Island. All kelp collectors must apply for harvesting licenses annually and abide by all restrictions listed on harvesting licenses. Kelp Industries works to a collector's code of conduct as well as the *Tasmanian Living Marine Resources Management Act 1995*. In 2000 the then Tasmanian Department of Primary Industries and Water drafted a discussion paper titled *Management Options for the King Island Cast Bull Kelp Fishery* which set out policy objectives and management strategies as well as options for future management of the fishery. A preliminary draft policy paper on the management of marine plants in Tasmania has since been written by the Department of Primary Industries, Parks, Water and Environment (DPIPWE). This paper outlines the possible management approaches to marine plants in Tasmania, including King Island and will soon be circulated for public consultation.
Export	The majority of retained product is exported to the United Kingdom.
Bycatch	As this operation collects cast bull kelp which has already washed ashore, there are no bycatch species harvested.
Interaction with protected species[3]	There is the possibility of interactions with *Thinornis rubricollis* (hooded plover) and other migratory birds in the area. Harvesting is restricted to areas where it is considered that it will not be detrimental to migratory birds, i.e. harvesting and transporting of kelp and/or equipment is prohibited from September to March (inclusive) on sandy beaches, except the north-end of British Admiral Beach and any other sandy beach for which a representative from the Department of Primary Industries, Parks, Water and Environment had verified in writing that harvesting would not be detrimental to nesting hooded plovers.
Ecosystem impacts	The collection of bull kelp by hand and assisted by winches and mechanical grabs are unlikely to have any impacts on the ecosystem. In addition, conditions four, five and six of the previous wildlife trade operation have been added to the harvesting licence. A code of conduct has also been put in place to ensure that the impacts to the ecosystem are minimal.

Harvest volumes

Current Miscellaneous Fishery operators are required to provide statistical catch and effort data to PIRSA Fisheries and Aquaculture on a monthly basis. The data for the two operators are provided in Table 1 and 2. PIRSA Fisheries and Aquaculture has gained authorisation to use the submitted data from the two operators as part of the export assessment process.

Note that Kingston District Council (Y080) has recorded their take in estimated cubic metres of wrack and not in tonnes.

Licence Y080

Harvest volumes for licence Y080 are sporadic as the licence holder only harvests wrack at times when the foreshore requires clearing for amenity purpose. 100% of wrack is cleared from the permitted area for this licence, in addition there is a secondary area where exclusion zones are required (Fig 1). The totals

[3] 'Protected species' means all species listed under Part 13 of the EPBC Act, including whales and other cetaceans and threatened, marine and migratory species.

and average for the period the licence has been operating are outlined below. Annual harvest varies from 2000m^3 in 2003 to 22,510m^3 in 2009. In 2013, 18,854m^3 was harvested. Harvest is variable due to the deposition of wrack on the beach through storms and wave deposition.

Table 1. Statistical Catch and effort information for Miscellaneous Fisheries Licence Y080.

Year	Total (m^3)
2003	2,000
2004	11,341
2005	10,113
2006	3,128
2007	16,000
2008	13,450
2009	22,510
2010	14,257
2011	11,278
2012	18,970
2013	18,854
Average	**12,900**

Licence Y078

The table below outlines the total harvest of seagrass and macro-algal wrack for the past 14 years by Australian Kelp Products Pty Ltd. The average yearly harvest is calculated below.

Harvest tonnage has been variable ranging from no harvest in 2007 to 305 tonnes in 2008. The average annual harvest volume for this licence has been 79.5 tonnes.

Table 2. Statistical Catch and effort information for Miscellaneous Fisheries Licence Y078.

Year	Total (tonnes)
2000	27.1
2001	24.6
2002	14.5
2003	5
2004	32.5
2005	108
2006	135
2007	0
2008	305
2009	25
2010	103
2011	94.6
2012	47
2013	260
2014	10.8
Average	**79.5**

Both licences are permitted to sell the wrack commercially, although in recent years the Kingston District Council has been placing the wrack on land to aid in stability during wet periods (pers comm). The volume the council removes as part of its operation reflects the geomorphology of the area, which acts as a

catchment area (man-made and natural) this sees a large accumulation of wrack where naturally there would be far less build up (Duong, 2008).

When comparing the South Australian wrack harvest to other similar fisheries in Australia the percentage of take and effort compared to that of King Island Fishery is significantly lower in both the tonnage and the number of fishers taking the tonnage. It is therefore important to note the level of harvest given the available area where the licence holders are permitted to operate.

Conclusions

South Australia's beachcast seagrass and macro-algal wrack fisheries consist of two separate licences.

Seagrass

The seagrass wrack fishery is limited in spatial scale being restricted to a 7.2 km extent of beach around the town of Kingston where the harvest of seagrass wrack is undertaken primarily to address a beach amenity issue. The build-up of wrack in this region is a result of the development of groynes along the coast which results in the trapping of seagrass wrack. An assessment of the seagrass wrack removal at Kingston (Duong 2008) concluded that wrack removal at this location was acceptable because:

1. The cover of wrack at Kingston is probably un-naturally high due to the breakwater at the northern end of the beach acting as a wrack trap;
2. Macro-faunal abundance and diversity in the wrack banks is low;
3. The wrack is mostly old, refractory seagrass which does not input nutrients into the beach ecosystem via either decomposition or incorporation into trophic webs;
4. Management arrangements require that within harvest areas a proportion of wrack remains on the beach; and
5. Wrack harvest occurs infrequently.

Macroalgae

The macroalgal fishery occurs across a more extensive length of coastline comprising some 102 km from Cape Jaffa in the north to Kingston in the south. Historically, the macro-algal wrack fishery, although covering a larger coastal extent than the seagrass fishery, is very small in comparison to similar fisheries elsewhere (being on average about 1/25th the size of the King Island based southern bull kelp fishery). This smaller size means that there is a concomitantly smaller number of operators with much less time being spent on beaches undertaking harvesting operations.

There have been no reported TEPS interactions with the macro-algal wrack fishery but it is acknowledged that the fishery does take place along a coastline where there is potential for interactions with a number of shore-bird species. These interactions can be managed through licence conditions to ensure that operators do not impact on nesting birds and that interactions with feeding / foraging birds are mitigated to an acceptable level. The most vulnerable species are the Hooded Plover and the Orange-bellied Parrot and there is a particular need to ensure that management of the harvest operations (including transport to and from beaches) is undertaken to ensure that there are no adverse interactions with these species.

Recommendations

Licence conditions for the fishery should be revised in the light of recent work including the advice from DotE and key stakeholders. Such a revision should include the adoption of a spatial management strategy that would ensure that areas of coast with high conservation significance are protected through the use of explicit harvest exclusion zones. The area to be protected through harvest exclusion zones should comprise 50% of the coastal extent of the Licence Y078. This management proposal is aimed at mitigating against adverse interactions with protected species utilising the coastal environment, specifically seagrass and macroalgae wracks.

Future Research

There are a number of research opportunities which have been identified as a result of this review including:

1. Wrack processes and species utilisation specific to South Australia.

2. Understanding of the contribution of both seagrass and macro-algal wracks to broader coastal trophodynamic processes.

PIRSA Fisheries and Aquaculture will endeavour to work with the relevant stakeholders and other government departments to collect information to inform management decisions.

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