

Investigating the ecological implications of wrack removal on South Australian sandy beaches

H. L. Stephanie Duong
BSc(MarBiol), Hons



A thesis submitted for the degree of Doctor of Philosophy, School of Biological Sciences, Faculty of Science and Engineering, Flinders University

September 2008

TABLE OF CONTENTS

Table of contents	i
Abstract.....	iv
Declaration.....	viii
Acknowledgements	ix
Chapter One: General introduction	1
What is wrack?.....	1
The role of wrack in the sandy beach ecosystem.....	2
Beach morphodynamics.....	2
Decomposition of wrack	3
Provision of habitat and incorporation into trophic webs.....	4
Wrack removal: Beach cleaning and wrack harvesting	6
Potential effects of wrack removal	7
Background to this project.....	9
Approach taken in this thesis	11
Aims of this thesis	13
Thesis structure	13
List of Figures	16
Figures	17
Tables.....	21
Chapter Two: Patterns of wrack on South Australian sandy beaches.....	23
Abstract.....	23
Introduction.....	24
Methods	26
Sampling design	26
Field methods	27
Laboratory methods.....	29
Statistical analyses	31
Results	36
Rapid visual assessment of wrack cover: Photopoint method	36
Transect sampling: Percent wrack cover and wrack depth.....	38
Percent wrack cover.....	38
Wrack composition.....	40
Discussion.....	46
Photopoint method.....	46
Wrack cover and composition.....	48
Conclusion	51
List of Figures	52
Figures	55
Tables.....	70

Chapter Three: Beach morphology and the effects of wrack deposits on sediment characteristics.....	79
Abstract.....	79
Introduction.....	80
Methodology	83
Site selection & sampling design	83
Field methods	83
Laboratory methods.....	85
Statistical analyses.....	87
Results	90
Beach profiles: Width, fall and beach-face slope.....	90
Organic matter content	93
Mean particle size.....	94
Sand compaction	95
Discussion.....	97
Conclusion	102
List of Figures	103
Figures	106
Tables.....	119
Chapter Four: Macrofaunal communities: Surface-active macrofauna associated with wrack deposits.....	126
Abstract.....	126
Introduction.....	127
Methods	129
Study 1: Pilot study and sampling of beach levels	129
Study 2: Main study: 4 beaches sampled in 4 seasons	130
Field methods	131
Laboratory methods.....	132
Statistical data analysis	132
Results	135
Study 1	135
Study 2	138
Discussion.....	142
Conclusion	145
List of Figures	146
Figures	148
Tables.....	155
Chapter Five: Effects of sandy beach cusps on wrack accumulation, sediment characteristics and macrofaunal communities	166
Abstract.....	166
Introduction.....	166
Methods	169
Site selection	169
Pilot study	170
Field methods.....	170
Laboratory methods.....	172

Statistical analyses	172
Results	175
Wrack deposits	175
Cusp morphology	175
Effects of cusp morphology on wrack deposits	176
Sediment OM content and particle sizes.....	176
Macrofauna	177
Discussion	179
Conclusion	182
List of Figures	183
Figures	185
Tables.....	193
Chapter Six: Assessing the incorporation of wrack into beach and nearshore ecosystems	198
Abstract.....	198
Introduction.....	199
Methods	204
Litterbags	204
Trophic webs: Wrack, macroinvertebrates and fish.....	210
Results	213
Litterbags	213
Trophic webs: Wrack, macroinvertebrates and fish.....	217
Discussion.....	223
Conclusion	229
List of Figures	230
Figures	234
Tables.....	249
Chapter Seven: Effects of wrack removal on macrofaunal communities	258
Abstract.....	258
Introduction.....	260
Methods	262
Kingston: Pilot study	262
Kingston: Cleared vs. natural areas	262
Main study: Experimental removal of wrack- 4 beaches sampled in 2 seasons	263
Field methods	265
Laboratory methods.....	265
Statistical data analysis	266
Results	269
Kingston Pilot study	269
Kingston: Cleared vs. natural areas	270
Main study: Experimental removal of wrack- 4 beaches sampled in 2 seasons	272
Discussion.....	278
Conclusion	281

List of Figures	283
Figures	285
Tables.....	295
Chapter Eight: General discussion	305
Summary of main findings	305
Synthesis of findings	308
Photopoint method.....	308
Wrack cover and composition.....	309
Wrack provides habitat and food.....	310
Interactions between beach morphology and sediments and wrack, and implications for macrofauna	314
Effects of wrack removal.....	317
Management implications.....	324
Conclusions.....	325
List of Figures	327
Figures	328
References.....	329
Appendices	342

ABSTRACT

Accumulations of seagrass, macroalgae and other matter, collectively known as wrack, commonly occur on many sandy beaches, and can play an important role in coastal and nearshore ecosystems. Despite this, wrack removal from sandy beaches is a widespread and increasingly common practice globally, and there is little information regarding the ecological effects of such wrack removal on sandy beaches. The aim of this thesis was to establish the ecological importance of wrack in South Australian (SA) sandy-beach ecosystems. As a first step in furthering our understanding of the effects of wrack removal, I aimed to assess the importance of wrack, independent of the effects of wrack removal. The second over-riding aim of this thesis was to assess the ecological effects of wrack removal on aspects of these systems.

To date, the methods used for quantifying the size of wrack deposits on sandy beaches have had limited use due to the time and expertise required to conduct thorough sampling. In Chapter 2, I thus tested the accuracy of a rapid “photopoint” method to visually estimate percentage wrack cover as well as provide an archived record. Comparisons of results obtained from conventional transects with those from photopoints indicated that the photopoint technique can be used to rapidly and accurately estimate % wrack cover on sandy beaches. The photopoint method has a wide range of potential applications and represents a valuable advance in the field.

Currently our knowledge of the amounts and types of wrack on SA shores is limited, despite these accumulations being a feature of some SA beaches. Wrack deposits in three biogeographical regions of SA were thus repeatedly surveyed to assess spatial (between and within regions) and temporal (seasonal and inter-annual) variation (Chapter 2). Both wrack cover and the composition of wrack deposits varied spatially and temporally. Wrack deposits contained a diverse array of seagrass, algal, other biotic materials and anthropogenic debris. The South East region of SA had distinctly-different wrack deposits compared to the Metropolitan and Fleurieu Peninsula regions; in general, the cover of wrack was higher, and the diversity and biomass of kelps, red algae and green algae was higher in this region compared to the

other two regions. South Australian wrack deposits are thus dynamic and complex.

The amount of wrack deposited and retained on a beach may be affected by the beach morphology but, to date, few studies have investigated this link. I assessed wrack cover on beaches with a range of morphodynamic types and found that beaches that were more dissipative in nature had a greater cover of wrack than beaches of the reflective type. I also examined whether wrack deposits affected the sediment characteristics of underlying and nearby sediments. Wrack deposits had little measurable effect on underlying sediments and did not affect particle-size distribution or organic-matter content. There was, however, a trend for beaches in the South East region of SA to have higher organic matter content in their sediments, and these beaches also have higher wrack cover and higher proportions of algae in their deposits. There was also a trend for beaches with higher wrack cover to have less compacted sediments, although this trend was not consistent.

Overnight pit-fall trapping surveys of the macrofauna on four SA sandy beaches indicated that local macrofaunal communities were diverse (representing 72 species from 19 Orders in total), abundant, and variable in both time and space. The macrofauna encountered were mostly terrestrial taxa with only 2 truly marine species, and spanned multiple trophic levels, concurring with the results of previous studies. Macrofaunal abundances were higher where associated with wrack than in bare sand, and macrofaunal communities differed between the driftline of wrack and wrack patches away from the driftline. Within the driftline itself, there were few differences between bare sand and wrack-covered areas, suggesting that the entire driftline area is important as a habitat and food resource. Thus, wrack deposits provide an important habitat and food source for macrofauna, and the driftline provides an area of beach with concentrated resources, which in turn concentrates a distinct macrofaunal community.

Wrack deposition on sandy beaches varies spatially and is affected by morphological features on the beach-face such as cusps. In Chapter 5, I thus tested a series of hypotheses regarding the differences in wrack deposits, sediments and macrofaunal communities between cusp bays and horns. Bays had greater cover and larger pieces of wrack than horns. Sediment organic-matter content was greater on horns than in

bays but mean particle size did not differ consistently between bays and horns. Macrofaunal diversity was higher in bays and this pattern was probably driven by differences in the cover of wrack between bays and horns. Cusp morphology thus influences the distribution of wrack on the beach-face, which in turn influences the distribution of macrofauna. Studies of sandy beaches with cusps should therefore be explicitly designed to sample cusp features and their associated wrack deposits.

Chapter 6 assesses the incorporation of wrack into beach and nearshore ecosystems via two pathways: decomposition and incorporation into trophic webs. I assessed the decomposition of algal and seagrass wrack using litterbag experiments and found that after a very rapid initial loss of mass, likely due to cell lysis and leaching, the rate of decomposition of wrack was much slower. Most release of nutrients from organic matter decay thus appears to occur in the first few days after deposition and the processes affecting the rate and nature of wrack decomposition vary among taxa (i.e. algal versus seagrass and among species). Stable isotopes of C and N were used to assess whether beach macrofauna or nearshore macro-invertebrates and fish might rely on wrack as a source of nutrition. I found that seagrasses did not provide a food source for any consumers but algae, particularly brown algae including kelps, appeared to be potential sources of nutrition for beach and nearshore consumers. The incorporation of wrack into beach and nearshore ecosystems may thus occur primarily through consumption of algal wrack by herbivores such as amphipods and dipterans, with predation on them being important pathways for the transfer of nutrients and energy into higher trophic levels. The amount of wrack in the surf zone did not affect the abundance and species richness of fish and invertebrates netted there.

The aim of Chapter 7 was to determine the effects of wrack removal on sandy beach macrofaunal communities. In the first study the effects of large-scale commercial harvest of wrack on the macrofaunal communities at Kingston were assessed. The macrofaunal communities present in the 'Natural' area of Kingston beach were far more diverse and abundant, and included different species, compared to the 'Cleared' area at Kingston. In the second part of Chapter 7, I experimentally removed wrack from the driftline of beaches to assess short-term effects on macrofaunal communities. The experimental treatment did not appear to have any measurable

effects on the macrofaunal communities. I also analysed material that was removed from the beach in the raking experiments and found that a large proportion of the material (e.g. 81% of the DW) was sand. I recommend that future studies into the effects of wrack removal use large cleared areas of beach, attempt to use the same wrack removal methods and/or machinery used locally, and assess the macrofaunal communities repeatedly and over longer times following wrack removal activities.

In Chapter 8, I attempt to assess the effects of removal of wrack for beach ‘cleaning’ or commercial ‘harvest’ of wrack by comparing key indicators from Chapters 2 to 7. Implications and recommendations for the management of wrack are discussed, including with regard to the techniques used in this thesis and their applicability in managing wrack deposits. I attempt to identify the shortcomings of this research as well as directions for further research.

Thus I have demonstrated that wrack in SA provides an important link between offshore habitat and nearshore, beach and terrestrial habitats via the transfer of organic matter and nutrients. Wrack interacts with beach morphology and sediments, provides habitat for macrofauna, remineralises nutrients through its decomposition, and provides the basis of a complex trophic web. I conclude that wrack is a key component in beach ecosystems.

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Stephanie Duong
September 2008

ACKNOWLEDGEMENTS

To the many, many people who supported, encouraged, looked after and put up with me throughout my PhD thank you.

First and foremost, thank you to my supervisor Peter Fairweather. You have been a committed and enthusiastic advisor and teacher and I have appreciated your wealth of knowledge, patience and expertise. My PhD has been a wonderful learning experience and the skills which you have taught me will be invaluable in my career as a marine ecologist. I sincerely believe that you have made me a better scientist. Thank you for your hard work and for allowing me these opportunities.

Thanks to all the students who have worked and studied in the Fairweather marine ecology lab at Flinders Uni. Thanks to Tim Moore, Jan Barton and Rohan Henry for getting me off to a good start as a PhD student, for good advice and making me feel welcome. Thanks especially to Rohan for sharing his knowledge of this wonderful thing called wrack. Thanks also to Alastair Harry, Matt Nelson, Dennis Gonzalez, Mark Ellis, Robyn Morcom and Ben Hamilton. Thanks also to Angela Dutton (Oh, how we hate raking!) and Damian Woodberry and Angela Dutton for assistance with sample preparation, and for not making me feel like I was evil for making you do it. Thanks Gillian Napier for identifying my lovely beetles and explaining the jargon.

To my lab buddy, Tanith Ramsdale, who has been here with me from the start, cheers for the company, the laughs, the fun fieldtrips and for being a brilliant map-maker. Thanks to Rebecca Langley for all your help. You have been so generous and helpful with your time and friendship. Thanks especially for your mammoth effort the last few days. Thanks also to Jodi Lill for much love, support and friendship during this last year- I know I am not alone. Thanks also to Rebecca Lester for your advice and timely reminders that it's normal to go a bit, or even very, crazy. A special thanks to all of you who pulled together with me to help me get my thesis in on time- GO TEAM!

Many thanks to Hugh Kearnes and Maria Gardner for curing me (almost) of my fear of writing- I can't believe I actually got it done. Thanks to Sue Murray-Jones (Coast Protection Board) for her support of this research and for her interest in my research. Funding for this research was provided by DEH and PIRSA. Also, thank you to Sonja Venema at the South Australian Research and Development Institute for analysis of C and N samples and Daniel Jardine at the Flinders Advanced Analytical Laboratory for stable isotope analyses.

To my wonderful, supportive friends, Sarah Imgraben, Courtney Green and Star Butcher. Thanks for your love and friendship. I miss you all but I always know I can count on you- now I've finished we can catch up! Thanks to Bek Smith and Steve Brown from my gym who let me go crazy when I need to so I can stay sane (mostly) the rest of the time. Thanks Nan and Pa, Max and Meredith Lemon, Fiona Arney (who's been there and survived), just knowing you care helps.

Thanks to my wonderful sister Lisa. You have been a brilliant help and a loving sister, and I never realised how much I could count on you. Thanks for putting up with me and taking care of me, especially these past few months. Thanks also to Henry Boo, my baby dog, for learning to let me work, for making me get up and take you out, and for always keeping me company no matter what I am doing.

Finally, thank you to my wonderful, supportive and loving parents, Sharon and Jack Duong. Dad, I always felt how much you cared. I think Ongnoi and Banoi would be proud. Mum, thanks for always being my go to person. Thanks.