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Seasonality of beachwrack at Oakajee in the mid-west region of Western Australia

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Abstract – This study examines seasonal fluctuations in beachwrack accumulations near Oakajee, Western Australia (28°34'S; 114°34'E). Twelve monthly samples were made of beachwrack concentrations at Drummonds Cove and Coronation Beach from 5 May 1998 until 10 April 1999. Four weekly samples were made from 23 July to 12 August 1998 to measure short-term variations in beachwrack volumes. There was no seasonality in beachwrack accumulations at Drummonds Cove. At Coronation Beach beachwrack concentrations were high in late summer and early winter, but declined sharply from late winter to early spring. There was considerable movement of wrack onto and off the beaches. Beachwrack accumulations migrated along the beach within Drummonds Cove, but there was no evidence of such longshore movement on the open coast. Beachwrack accumulates in bays and other protected areas and at the tip of peninsulas, such as Point Moore. Macroalgae and the seagrass genera *Amphibolis* and *Posidonia* dominated the wrack.

Keywords: beachwrack, macrophytes, Western Australia, seagrass, seaweeds, macroalgae

INTRODUCTION

Oceanic waters off Western Australia are nutrient poor, at levels characteristic of the open ocean. Consequently, phytoplankton production is minimal (Rochford, 1980; Pearce 1991; 1997). Instead benthic plants, both seagrass and macroalgae, provide most of the primary production. The plants are torn from the bottom during storms and then moved about by currents and waves. A portion is transported to shore where it accumulates as beachwrack. The beachwrack is reworked by wind and waves, accumulating in some areas and being absent in others. It is mobile, often alternating between the water and the beach. Volumes change considerably over short periods of time (Hansen, 1984).

Beachwrack in the Perth area develops an abundant invertebrate fauna which feeds on it. The invertebrates are dominated by amphipods, particularly *Allorchestes compressa* (Robertson & Lucas, 1983; McLachlan, 1985; Fong, 1999). Nearshore the beachwrack and associated invertebrates provide shelter and food for a variety of fish species (Lenanton, 1982; Lenanton et al., 1982; Robertson & Lenanton, 1984), including the commercially important cobbler *Cnidoglanis macrocephalus* (Lenanton & Caputi, 1989), and abalone (Wells & Keesing, 1989). Nutrients are released back into the water column as the beachwrack decomposes (Robertson & Hansen, 1982). This recycling is important in the low nutrient environment off Western Australia.

The present study extends our knowledge of beachwrack accumulations to Oakajee, just north of Geraldton. The study tested the hypotheses that beachwrack accumulates seasonally, with a maximum due to winter storms, and once on the beach, the beachwrack migrates longshore in response to prevailing wave and wind directions.

THE OAKAJEE MARINE ENVIRONMENT

The Oakajee region (Figure 1) is an open, exposed coastline subject to the full force of sea conditions, particularly during storms. It is thus a very high energy environment. Virtually the entire shoreline from Geraldton north to the mouth of the Bowes River is composed of intertidal sand. Beachrock platforms occur along the shoreline throughout the Oakajee region but are more common north of the Oakabella River. They range from small platforms of a few square metres to an extensive platform just south of Coronation Beach. The platforms begin at the low tide level and continue into the subtidal region. Large portions may be exposed by winter wave action then recovered by sand the following summer. The platforms at Oakajee have a greatly reduced biota, possibly due to the dynamic wave

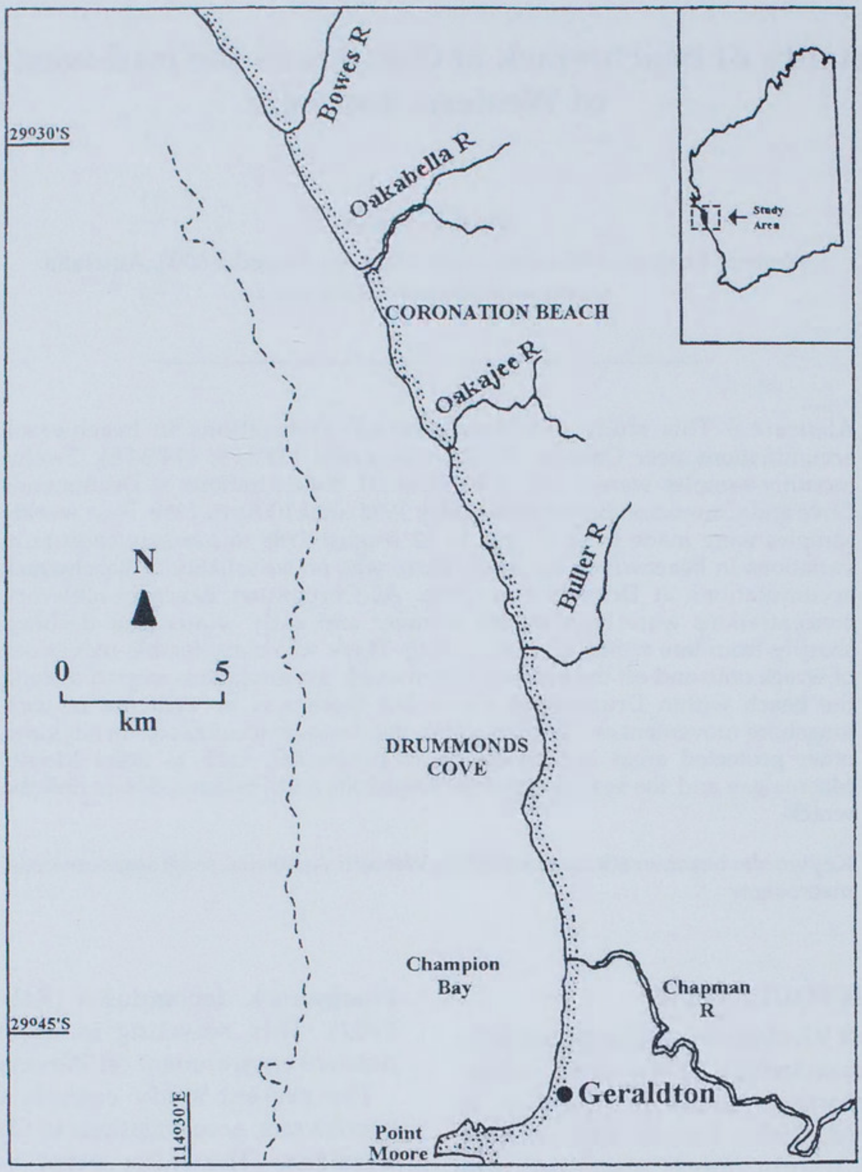

Figure 1 Map of the Oakajee coastline showing localities mentioned in the text.

action at Oakajee that would physically remove much of the macroalgae and fauna. In addition, sand moved about by the waves would provide a considerable scouring force.

In the nearshore environment the substrate is limestone that may or may not be covered with sand. While considerable local variation in depth occurs, there is a steady progression of habitats from the intertidal sand beach out to the 20 m line. A shallow lagoon up to 5 m deep occurs near the shore. The lagoon is more distinct south of the Oakajee River. North of the Oakajee, the lagoon is less distinct and has numerous bombies, many of which nearly reach the sea surface. An indistinct limestone reef occurs to the west of the lagoon. The reef runs north to south parallel to the shore, and is absent only off the mouth of the Oakajee River. In most areas the reef shoals to a depth of 2 m or less, but in some localities it is less distinct.

Seaward of the reef crest is a low relief platform. While the platform surface is not uniform, it tends to have a gradually increasing depth seaward. Small crevices and depressions occur throughout the surface of the limestone. The platform is channelled with a very small spur and groove formation in some areas, where the undulations may be 30 cm or less in height. The surfaces of the crest are exposed limestone. The channels are either exposed limestone or are covered by a thin layer of sand. Sand accumulates in the depressions, some of which are large, tens of metres across. In some low energy areas of the bottom the entire limestone platform is covered by a layer of sand several centimetres deep. In deeper waters, where depths are between 15 and 20 m, the platform gives way to a level bottom that is predominantly covered with sand, but there are exposed areas of flat limestone.

The bottom habitats can change considerably over a space of a few metres, particularly in the shallow inshore waters and the high relief reef. Over a space of 100 to 200 m going seaward, the bottom can vary from high relief reef with sand patches in the depressions, to a low relief reef dominated by the seagrass *Amphibolis antarctica*, to areas co-dominated by *A. antarctica* and macroalgae, to areas where only macroalgae are present. There may also be sandy bottoms where *A. antarctica* forms a dense seagrass meadow. The ability of *A. antarctica* to live on either sandy or rocky bottoms is well demonstrated at Oakajee.

Shallow vertical columns, which occur near the shore south of the Oakajee River, are one of the most distinctive features of the marine environment in the Oakajee area. The columns, which may have a diameter of 5–10 m or more, emerge vertically from sand at a depth of up to 5 m to near the lower intertidal level. This is an area of breaking waves during even moderate seas. The upper surfaces of the columns are largely devoid of macroalgae, but may be colonised by small patches of *Sargassum* which are kept to short lengths by the continuous wave action. The *Sargassum* is longer on the sides of the columns than on the upper surfaces. On the leeward side of the columns is a mixture of low encrusting species of macroalgae, including *Caulerpa*. The base of the columns is at a depth of approximately 6 m and is surrounded by sand mixed with some *Amphibolis*. There may be small patches of *Sargassum* inshore. Invertebrate diversity on the tops of the columns is low.

MATERIALS AND METHODS

Twelve aerial flights were made at approximately monthly intervals over the coastline at Oakajee (28°34'S; 114°34'E) from 5 May 1998 until 10 April 1999 using a Cessna 172 aircraft. Most flights were made at 140–165 km h^{-1} at an altitude of 100 m from south of the Port of Geraldton to the mouth of the Bowes River, a distance of approximately 40 km. A video recording was made of the entire shoreline on the flight north. A still camera was used on the flight south to photograph major beachwrack accumulations. Four weekly flights were made from 23 July to 12 August 1998 to measure short-term variations in beachwrack volumes.

The only major accumulations of beachwrack on the first flight were at Drummonds Cove and at Coronation Beach. As vehicle access to the shore was possible, the two beaches were chosen for ground truthing. On most occasions the two sites were the locations with the greatest beachwrack concentrations. Methods used by Hansen (1984) were used to determine beachwrack volumes on the shoreline. Length and width of beachwrack accumulations at Drummonds Cove and at Coronation Beach were measured. Length was stepped off and compared with the number of steps required to cover a known distance. Width and depth were measured at consistent intervals with a tape measure marked to the nearest 1 cm. The intervals were calculated to provide at least 6 measurements at each of the two localities; usually 8–10 measurements were made. Width of beachwrack was measured to the nearest 10 cm from the seaward to the landward edge of the beachwrack. Depth was normally measured to the nearest 1 cm at three locations: top of the seaward beachwrack crest, middle of the accumulation, and the landward margin; only two measurements of depth were made in small accumulations where there was little beachwrack present. Total volume of beachwrack on each beach was then calculated.

To measure the composition of beachwrack, four samples were collected each at Drummonds Cove and at Coronation Beach on 12 June 1998 and 16 January 1999, placed in labelled plastic bags and frozen until analysis. Samples were collected from freshly deposited areas of wrack to minimise the proportion of unidentifiable detritus. The samples were washed in freshwater then sorted to five major plant types: macroalgae, the seagrass genera *Amphibolis*, *Posidonia* and *Halophila*, and unidentified plant material. Individual components were placed on aluminium foil and dried for 48 hours in a drying oven at 80°C. They were then weighed to the nearest 1 mg on a Sartorius electronic balance.

RESULTS

The greatest accumulations found during the first survey on 5 May 1998 were at Drummonds Cove, where 7559 m^3 of beachwrack occurred on the shoreline, and at Coronation Beach, where there was 2477 m^3 (Figure 2). Smaller accumulations occurred in other areas. Accumulations at Drummonds Cove were consistently the largest along the shoreline between Drummonds Cove and the Bowes River, some 25 km of coastline.

Seasonal variation

The predicted pattern of seasonality was not clearly demonstrated at Drummonds Cove during the study (Figure 2). The accumulation at Drummonds Cove on 7 May 1998 was spread over an estimated 1786 m of beach. As expected, the beachwrack increased to 8510 m^3 on 12 June, but instead of continuing to increase during the winter, wrack volumes declined sharply, reaching a low of 817 m^3 on 6 August. Wrack accumulations at Drummonds Cove increased to 3154 m^3 one week later on 13 August. They continued to increase until 9 October, when a peak of 7436 m^3 was reached. Significant accumulations remained for the remainder of the study, varying from 3196 m^3 to 5780 m^3 over

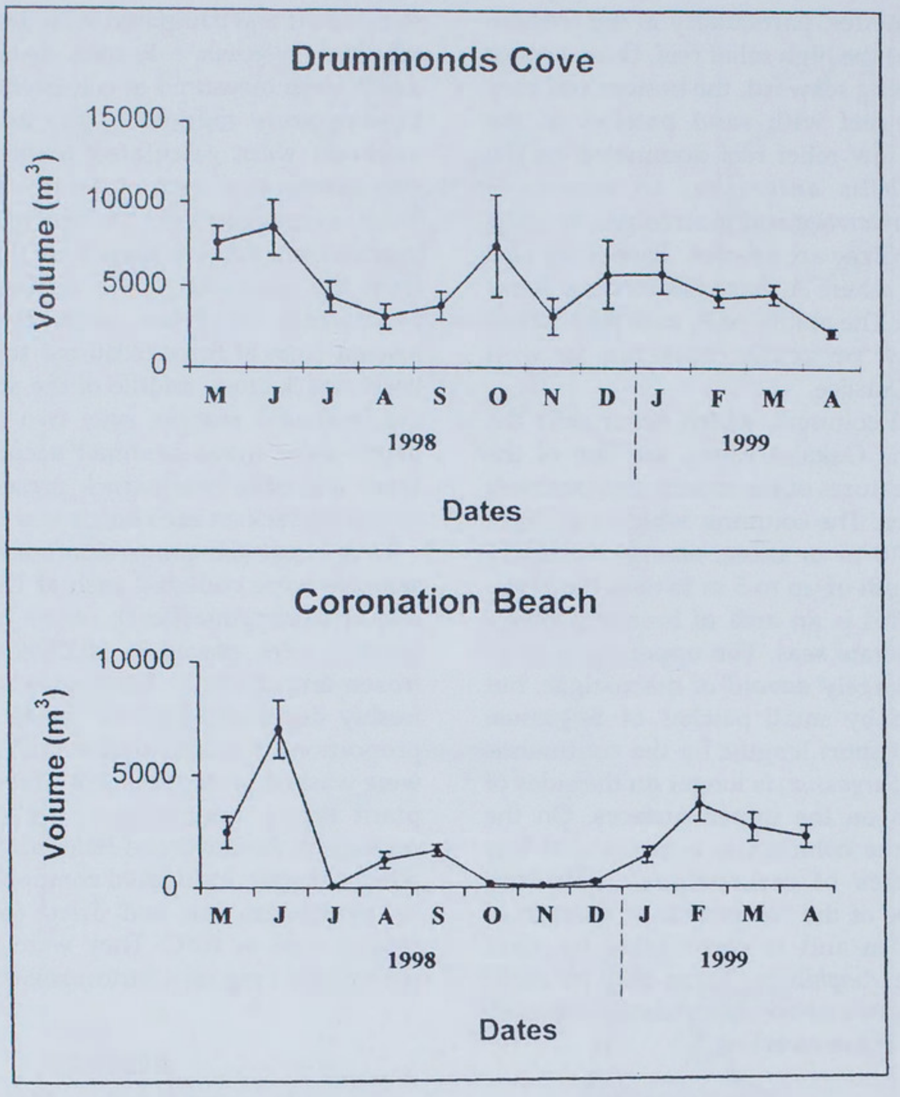

Figure 2 Seasonal patterns of accumulation of beachwrack at Drummonds Cove and Coronation Beach from May 1998 to April 1999. Means and standard errors are shown.

summer, declining to 2221 m^3 on the final month of the survey (10 April 1999).

In contrast, the pattern at Coronation Beach was seasonal (Figure 2). Accumulations totalled 2477 m^3 on 7 May 1998 and were along 629 m of beach. The beachwrack increased significantly to 7043 m^3 on 12 June. During the period of late winter to early summer beachwrack at Coronation Beach declined to low levels, ranging from 58 m^3 on 23 July to 443 m^3 on 11 September. Beachwrack volumes increased sharply to 3647 m^3 on 20 February (late summer) and remained relatively high for the duration of the study.

Short-term variation

Considerable short-term variation was found during the four week intensive survey at Drummonds Cove (Figure 3). Concentrations at Drummonds totalled 4372 m^3 on 23 July. Two weeks later they had dropped to 817 m^3. Beachwrack increased during the next week to 3154 m^3.

In contrast to Drummonds, the four week intensive survey at Coronation Beach showed little variation in beachwrack concentrations (Figure 3). During the first three weeks (23 July, 30 July and 6 August) there was essentially no beachwrack present. An increase to 1221 m^3 occurred by 13 August.

Longshore movement

There was no clear evidence of longshore movement of beachwrack along the Oakajee coastline, but the rapidly changing volumes, particularly during the short term study at Drummonds Cove, showed that there is considerably flux in wrack between the shore and the offshore waters.

At the beginning of the study, beachwrack occupied much of the bay at Drummonds Cove. It moved several hundred metres to the north during the winter and early spring, but remained in Drummonds Cove. In spring fresh build-ups

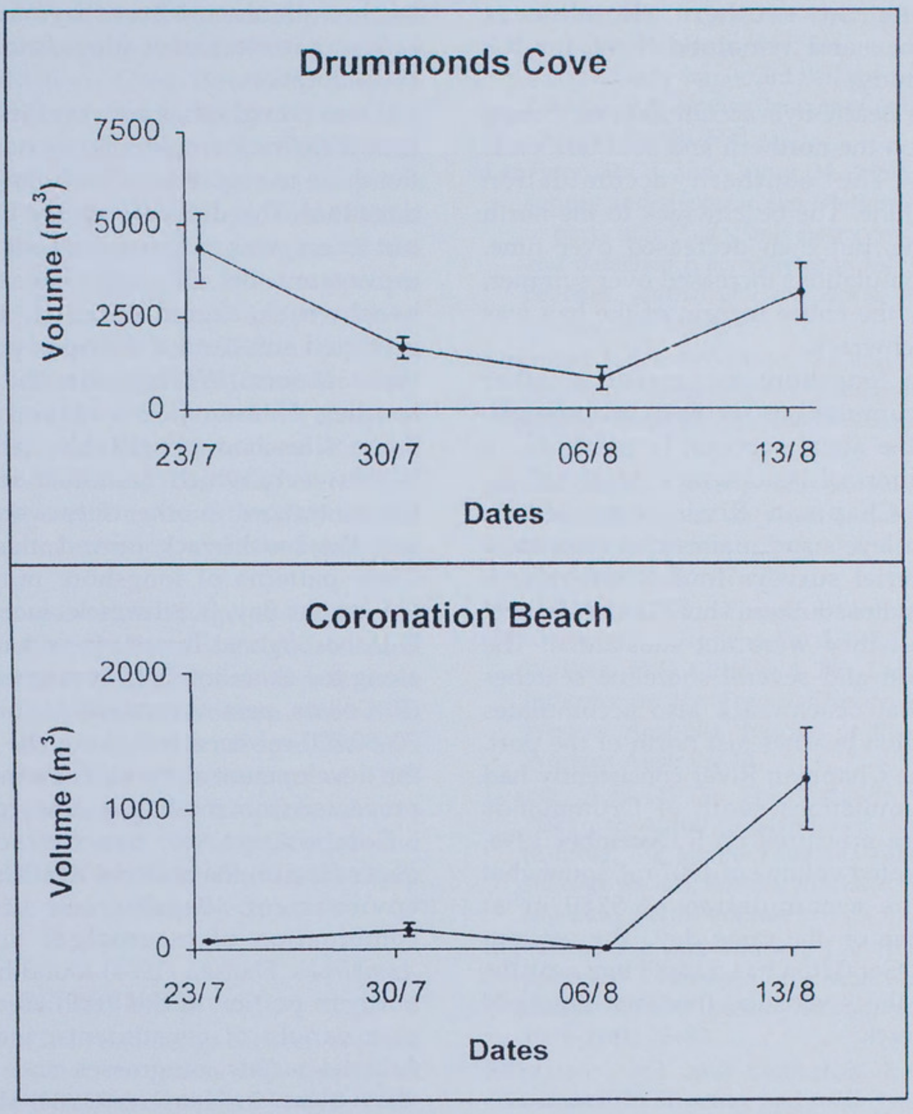

Figure 3 Short-term variations in accumulation of beachwrack at Drummonds Cove and Coronation Beach in July and August 1998. Means and standard errors are shown.

Table 1 Composition of beachwrack at two locations along the Oakajee coastline in winter 1998 and summer 1999.

	Algae	Seagrasses			Detritus	Total
		Amphibolis	*Posidonia*	*Halophila*		
DRUMMONDS COVE						
Winter 1998						
Mean (±SE) (gm)	10.5±1.5	3.9±0.3	2.7±0.8	0±0	3.8±1.3	20.9±3.1
Percentage	50.2	18.8	12.9	0.0	18.1	100.0
Summer 1999						
Mean (±SE) (gm)	11.5±1.7	8.8±1.4	0.7±0.2	0±0	2.3±0.7	23.3±0.9
Percentage	49.4	37.8	3.2	0.0	9.7	100.1
CORONATION BEACH						
Winter 1998						
Mean (±SE) (gm)	12.5±1.2	16.4±1.1	1.0±0.3	0±0	3.4±0.4	33.3±2.2
Percentage	37.6	49.1	3.0	0.0	10.2	99.9
Summer 1999						
Mean (±SE) (gm)	20.4±3.1	17.3±3.9	3.6±0.4	0±0	3.2±1.4	44.5±5.9
Percentage	45.9	38.8	8.1	0.0	7.2	100.0

developed along the southern shoreline of Drummonds Cove and remained there for the duration of the study.

At Coronation Beach two accumulations during May 1998 were on the northern and southern ends of the beach. The southern accumulation disappeared by June. The beachwrack to the north increased in June, but then decreased over time. Beachwrack accumulations increased over summer, and by February the entire margin of the bay was fringed with beachwrack.

There was no longshore movement of other beachwrack accumulations or drift macroalgae viewed during the aerial surveys. In particular, a major accumulation of beachwrack south of the mouth of the Chapman River remained at consistently high levels and maintained a constant position. The aerial surveys found beachwrack accumulations on the southern shoreline of the port of Geraldton, but they were not substantial. The aerial examination and several shoreline searches demonstrated that beachwrack also accumulates along the Geraldton beaches just north of the port. The mouth of the Chapman River consistently had the largest accumulations south of Drummonds Cove. These were measured on 5 December 1998, and had an estimated volume of 4907 m^3, somewhat smaller than the accumulation of 5780 m^3 at Drummonds Cove on the same day. The western tip of the port of Geraldton has a small bay near the southern tip of the peninsula; this area regularly trapped beachwrack.

DISCUSSION

The pattern of beachwrack accumulations varied between Drummonds Cove and Coronation Beach. There was no seasonality at Drummonds Cove. In contrast, at Coronation Beach beachwrack concentrations were high in late summer and early winter, but declined sharply from late winter to early spring. Experience in other areas of Western Australia has been similarly mixed. Some areas have winter maxima, but others do not. Beachwrack accumulates seasonally during winter at the southern groyne at Port Geographe in Busselton (P. Collins, pers. comm). Kirkman (1984) reported considerable interannual variation in beachwrack quantities in the Marmion lagoon. Different patterns of seasonality occurred during the years studied. Hansen (1984) examined beachwrack along 46 km of coast from Triggs to Two Rocks, and found similar variability between sites, seasonally and between years. A series of photographs published by Kirkman & Kendrick (1997) also demonstrates high short-term variability in beachwrack concentrations. The results of all these studies demonstrate that the timing and magnitude of beachwrack accumulations are highly dependent on local conditions and may vary considerably across a range of time scales (days/months/years) at a single location.

It was thought that once on the beach at Oakajee, the beachwrack would migrate north or south along the shore in response to prevailing wave and wind directions. This did occur within Drummonds Cove, but there was no evidence of such longshore movement on the open coast. Instead, the beachwrack accumulates in bays and other protected areas and at the tip of peninsulas, such as Point Moore. Working on the northern Perth beaches, Hansen (1984) obtained mixed results. Some sites had predictable, large quantities of beachwrack, which remained in the same area. Concentrations at other sites were less predictable and the beachwrack moved along the shoreline. Clear patterns of longshore movement occur in Geographe Bay. Beachwrack reaches the shore from Dunsborough to Busselton and moves northward along the shoreline until it reaches Port Geographe (P. Collins, pers. comm.). A major accumulation of 70–80,000 m^3 occurred along the southern side of the development at the end of winter in 1998; it was prevented from moving northwards by the groyne.

Composition of beachwrack is variable, depending on the material available in the offshore environment. Beachwrack at Oakajee is a combination of macroalgae and the seagrass *Amphibolis*. Hansen (1984) found beachwrack in the northern portion of the Perth area to be composed of a variety of constituents, including the kelp *Ecklonia radiata*, seagrasses and numerous small macroalgae. In Hansen's (1984) study of the Perth area, *E. radiata* was dominant over a full year, followed by other macroalgae, then seagrass. *Sargassum* was seasonally important during summer.

Only a small proportion of detached macrophytes ends up on the beach. For example, Kirkman & Kendrick (1997) released 5000 tagged *Ecklonia radiata* in the Marmion Lagoon in winter 1985. The tagged plants took 15 to 23 days to reach shore, but only 53 (1%) were recovered on beaches. In her detailed study of beachwrack in the Perth metropolitan area, Hansen (1984) found considerable variation in the amount of beachwrack, from 1.3 to 45.3 kg dry weight per metre of coastline. On average there was 74 to 80 tonnes of carbon per kilometre of coastline, equivalent to about 18% of the nearshore macrophyte production. These figures emphasise that the material in the beachwrack is only a fraction of total macrophyte production in nearshore waters.

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