

2005

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Kathryn H. Taffs  
*Southern Cross University*

Murray C. Cullen  
*Southern Cross University*

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## Publication details

Post-print of: Taffs, KH & Cullen, MC 2005, 'The distribution and abundance of marine debris on isolated beaches of northern New South Wales, Australia', *Australasian Journal of Environmental Management*, vol. 12, no. 4, pp. 244-250.

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**Taffs, K.H.** and Cullen, M.C. (2005). The distribution and abundance of marine debris on isolated beaches of northern New South Wales, Australia. Australian Journal of Environmental Management. 12(4): 244-250.

## **The distribution and abundance of beach debris on isolated beaches of northern New South Wales, Australia.**

Kathryn H. Taffs\* and Murray C. Cullen

School of Environmental Science and Management  
Southern Cross University  
PO Box 157  
Lismore NSW 2477  
Australia

\* Contact Author:

Phone 02 66203045

Fax 02 66212669

Email [ktaffs@scu.edu.au](mailto:ktaffs@scu.edu.au)

Keywords: beach, debris, litter, Australia, source, pollution, distribution, density

## **Abstract**

Beach debris items were collected and categorised during surveys of five isolated beaches on the northern New South Wales coastline in September 2003. The selected beaches covered more than 21 km of contiguous coastline. Litter density and distribution per 500 metres segment were calculated. The highest density of litter was found on the most isolated beaches with little public access but with no protection by headlands from the ocean swells. Litter density was highest at the northern extent of each beach, transported in that direction by longshore drift. Litter found was predominantly composed of plastics (72-86%) followed by glass (1-4%) and cigarette butts (1-11%). Plastics were primarily composed of soft drink and water bottle lids and seal caps. Glass materials were highest at beaches open to the ocean swells where transportation of heavier materials is more likely. Cigarette butt density was highest at the beaches with high public usage. Beach debris was of terrestrial origin but had been transported by the ocean. Results indicate that management of beach debris needs to focus on reducing the litter entering the marine environment from ocean outlets.

## **Introduction**

Beach debris is an obvious sign of the impact human activities have upon the coastal environment. It is recognized as a significant pollution issue that has an array of environmental consequences. Biologically, beach debris may maim and kill wildlife and degrades habitats (Laist 1987, Goldstein *et al.* 1999, Page *et al.* 2004). The economic impacts are wide ranging with negative impacts upon both the fishing industry and recreational fishers (Jones 1994). The loss of aesthetic values and the potential impact on human health through needle stick and other injuries is also of concern (Garrity & Levings 1993, Palmquist *et al.* 1997, Haynes 1997).

Beach debris is normally sourced from either ocean transported waste disposed of at sea, or terrestrial waste originating from coastal users or urban centres (Claereboudt 2004). Differentiation of the two sources can sometimes be difficult but can be assumed based upon the type, condition and sometimes language of the packaging (Edyvanne *et al.* 2004). O'Callaghan (1993) and Liffman *et al.* (1997) both identified that the source of the majority of beach debris was of terrestrial origin and transported to the coast by coastal and urban drainage systems. The Santa Monica Bay Restoration Project (SMBRP) (1998) recorded that beachgoers to Santa Monica Bay were responsible for most of the 4000 tons of trash collected from the beaches annually. However, a study by Frost and Cullen (1997) in Australia, found that the

level of beach usage was not a significant factor in explaining beach debris distribution along four beaches in eastern Australia.

The majority of beach debris, that is of anthropogenic origin, falls predominantly into the categories of: plastics, glass and metal. While plastics are by far the dominant item in beach debris, other, heavier, components may be under represented as it is less transportable in the marine environment. Typical levels of plastics amongst debris are 50 to 80% (Wace 1994, Faris & Hart 1995, Zann 1996, Frost & Cullen 1997, Madzena and Lasiak 1997, Whiting 1998, Moore *et al.* 2001, Convey *et al.* 2002) with levels as high as 90% recorded by Cunningham (2000).

The problem of plastic in the ocean is of increasing concern. Page *et al.* (2004) estimates that millions of tons of plastics enter the ocean each year. Its impact upon marine wildlife, including fish, has been well studied, particularly in the southern polar regions (Tomas *et al.* 2002, Eriksson and Buton 2003, Edyvane *et al.* 2004) and has been extensively reviewed by Derraik (2002).

Beach debris research in Australia has tended to concentrate on studies into the impacts of debris on wildlife (Pemberton *et al.* 1992, Jones 1994), as well as debris from fishing activities (Slater 1991, Wace 1994). Geographical based studies have been undertaken including those of O'Callaghan (1993) who examined debris near three Australian cities, Frost and Cullen (1997) who examined northern New South Wales beaches, Herfort (1997) who examined beaches along the New South Wales coast, and Cunningham (2000) who surveyed several beaches in the Sydney region. Whiting (1998) examined litter from remote areas in northern Australia, and Edyvane *et al.* (2004) reported on long term monitoring of remote South Australian beaches.

Australian beach debris studies show similar patterns to those conducted in the northern hemisphere, however, the beach user litter component is much reduced, excepting beaches within the major cities. Australian beach surveys have reported between 20 to 40% of plastic debris that was marine sourced (Jones 1994), and surveys of 1,612 Australian beaches organised by the Surfrider Foundation concluded that offshore debris was a major contributing factor (Legge-Wilkinson 1966). This conclusion is contrary to expectations as the disposal of plastic waste in Australian waters is prohibited by the *Protection of the Sea (Prevention of Pollution from Ships)*

*Act, 1983* which implements the International Convention for the Prevention of Pollution from Ships (MARPOL, Annex V).

Beach debris density has been widely reported with considerable variation in methods used to calculate it (Velandar and Mocogni 1999). Bowman *et al.* (1998) reported both numbers of items per 1 m beach front as well as numbers per 100 m<sup>2</sup> beach area. Using the former method they found density levels of up to 35 items per 1 m beach front. Willoughby *et al.* (1997) also used numbers of items per 1m of strandline and reported values of up to 29.1 items per 1 m. Whiting (1998) and Cunningham (2000) used numbers of items per kilometre of beach. Whiting (1998) reported a range of values with the lowest numbers being 52 items per kilometre and the highest being 149 items per kilometre. Cunningham (2000) found 2664 items per kilometre. Edyvane *et al.* (2004) recorded weights of various classes of litter and also reported kilograms per kilometre of beach.

Considering the vastness of the Australian coastline, our knowledge of the amounts of litter present is very limited. With a few exceptions noted above, surveys have tended to concentrate on the more public beaches near the larger population centres, but this means our knowledge of the more isolated beaches is lacking. Studies of isolated beaches can provide valuable information about the source and density of beach debris.

This study compares the types and density of beach litter found on five relatively isolated beaches in northern New South Wales. Comparison with the results of other studies is made to improve our knowledge of beach debris distribution.

## **Methods**

A beach litter survey was conducted on five beaches on the north coast of New South Wales, Australia (Figure 1). The beaches selected were: Illaroo Sandon Beach, Minnie Waters Main Beach, Minnie Back Beach, Diggers Camp Beach and Wooli Beach. Wooli beach was broken into the northern and southern halves as the two have very different uses. The northern half is adjacent to national park, and the southern half is adjacent to the town of Wooli. Together these beaches constitute more than 21 kilometres of coastline. Surveys were conducted within a 4 day period, outside of school holidays, in September 2003.

Table 1 shows the length of coastline surveyed and the type of activities conducted adjacent to the beach areas. Minnie Waters, Diggers Camp and the southern extent of Woolli beaches are adjacent to small villages and are used for recreational activities, particularly in the summer months. Illaroo Sandon Beach is adjacent to a NSW National Parks and Wildlife Service camping area hence has small levels of recreational use. All of these beaches had 4WD access. Minnie Back Beach was isolated from urban areas and did not have public 4WD access. Table 1 also provides a brief description of the geomorphology of each beach surveyed, with the level of protection offered by headlands for the beach environment noted.

No known surveys of litter had been conducted on these beaches prior to this survey. Regular cleaning of the beaches is unknown hence it is likely that some of the litter found may have been present for some time. A storm event had occurred the week prior to the survey and may have contributed greatly to the amount of litter found on the beaches at the time of the survey, or removed some items.

Beaches were divided into 500 metre segments beginning at the northern end of each beach using a GPS to measure the segment length. Collection of litter was conducted at low tide. Litter was collected from the low tide mark to the base of the primary fore dune at each site. Within each segment litter was collected, removed and classified according to the construction material and its use. The density of litter of each of the surveyed beaches was calculated as the number of items per kilometre. The distribution of litter was mapped per 500 metre segment.

## **Results**

### *Distribution of beach debris*

Most litter found on the beaches was located between high tide and the storm surge mark. Few litter items were found below high tide mark except for some fragments being washed ashore with the current tide.

Figure 2 shows the distribution of litter on each of the beaches per 500 metre segment. Illaroo Sandon beach had the highest density of litter in its southern-most 500 metre segment, an area protected from the southerly swells but open to the northerly swells. Density of litter per 500 metre segment then decreased northward. Minnie Waters beach had an even distribution of litter throughout the beach extent.

This beach is protected from the open ocean and has three public access points, one within each surveyed segment. Minnie Waters Back beach had the highest density of litter at the northern extent. Diggers Camp beach had the highest amount of litter in the second most southerly, segment. The most southerly segment is protected from the ocean by a lagoon environment hence not open to the ocean swells. The segment frequented by swimmers and surfers has the highest density of debris. Wooli beach had the greatest density of litter at the most northern segment.

#### *Density of beach debris*

Table 2 shows the density of litter of each of the surveyed beaches. Minnie Back Beach had the highest density of litter, closely followed by Illaroo Sandon Beach. Most litter present on these beaches was found behind a storm surge mound, possibly transported to the beach on the recent storm event and trapped in this hollow. The southern end of Wooli Beach, adjacent to the town of Wooli, had the lowest density of litter.

#### *Types of beach debris*

Figure 3 shows the types of litter found on the surveyed beaches. The majority of litter found consisted of plastic materials. Many of these were fragments and were quite small, or were whole drink containers, either water or soft drink bottles. The next highest category was cigarette butts, which were particularly high at Minnie Waters Beach that has a high level of public usage. Products constructed of paper, metal and glass were minor components. Litter derived from fishing activities was most prevalent at boat launch sites and popular beach fishing locations. Material in the other category was most often sawn timber that had not been at sea for very long (no barnacles were apparent).

## **Discussion**

### *Litter Distribution*

Most litter found on the beaches occurred between the high tide and storm surge mark suggesting that litter found on these beaches was derived from the ocean and transported to the beaches during storm events. Litter deposited during normal tidal events must be washed out again on the outgoing tide.

Beaches with an easterly aspect and open to the predominantly southerly ocean swells (Illaroo Sandon, Minnie Back beach and Wooli beach) had the greatest density of litter in the northern sectors. This pattern suggests that most litter is transported to the coastline on ocean swells and deposited on the beach. In addition, the northward action of longitudinal drift will transport beach litter to the northern end of the beach, causing the greatest litter density. Where public access is greatest (Wooli south and MinnieWaters beaches) this pattern is interrupted by an increase in the density of litter found near access points to the beaches.

#### *Density of beach debris*

The density of beach litter on these beaches of northern new South Wales varied between 138 and 197 items per kilometre of beach. This density is much higher than that found in comparable studies by Bowman *et al.* (1998), Willoughby *et al.* (1997) and Edyvane *et al.* (2004) who all surveyed areas in Israel, Indonesia and South Australia respectively. The values are much lower than that found by Cunningham (2000) on Sydney beaches but similar to that found by Whiting (1998) at Fog Bay in northern Australia, another area of isolated coastline. Higher values were also reported by Frost and Cullen (1997) who found 498 items per kilometre, and Hertfort (1997) who found 1080 items per kilometre.

Minnie Back Beach, which had the greatest density of litter, has limited public access, has an easterly aspect and is open to the ocean swells. Most litter found on this beach must be ocean derived due to the limited amount of access to the beach (walkers and beach fishers only).

Illaroo Sandon beach had the second highest density of litter. This beach also has few users (walkers, surfers and beach fishing). The southern end of the beach is protected from ocean swells by a headland but the remainder of the beach has an easterly aspect and is open to the ocean swells.

Minnie Waters beach has the next highest density of litter and also has the highest level of public usage. There are three locations of public access and multiple users of the beach environment (fishing, surfing/swimming, picnicking). This beach is quite protected from the open ocean with rocky headlands at the northern and southern ends and a lagoon environment at the southern end. The high level of public usage may account for the high density of litter found at this beach.



Diggers Camp beach also has a high level of public usage, particularly surfers, swimmers and walkers. The beach is quite protected by a lagoon environment to the south and a series of headlands to the north, which may account for the lower level of litter found on this beach.

Wooli beach is open to the easterly swells. The northern and southern sections are protected by a rocky headland and the river mouth respectively. Surprisingly, this beach had the lowest density of litter, with the southern end, adjacent to the town of Wooli, cleaner than the northern end, adjacent to national park. This could indicate that most litter found is marine derived with levels of public usage not significantly affecting the density of litter. Also possible is the effect of longshore drift that moves material to the north, possibly conveying debris with it.

Beaches with the highest density of litter were those with an easterly aspect and open to large ocean swells. Beaches most protected from the swells by headlands were also those with the highest levels of public usage. These beaches had the least density of litter.

#### *Litter type*

An overwhelming majority of litter found on the beaches was derived from plastic materials. This is a similar finding to that of other beach litter surveys (Willoughby *et al.* 1997, Bowman *et al.* 1998, Whiting *et al.* 1998, Cunningham 2000, Edyvane *et al.* 2004). As this litter survey simply counted pieces of litter found, no measure was taken of size or weight. An assessment of total weight of litter found would be more useful to assess dominant litter materials. Plastics may have been the dominant litter type because it is more readily transported in the water than glass and metal material that is heavier.

However, the small fragments of plastic that dominated the litter found (such as bottle caps, seal rings, soft drink and water bottles) are significant for their impact to the marine and coastal environment, particularly to wildlife and beach aesthetics. As plastics were the overwhelming majority of litter found, they are most likely to present the largest problem to environmental management of beach debris.

Glass had the highest frequency at Illaroo Sandon and Minnie Back beach. These beaches are not protected by headlands and are open to large swells. Material is more readily transported from the marine environment to the beach due to the velocity of

swells allowing heavier material to be carried onto the beach. The largest materials such as sawn timber and car tyres were also found on these beaches.

The next most dominant litter type was cigarette butts. This was particularly the case at Minnie Waters Beach where most cigarette butts were found near the beach access points. This type of litter appeared to be derived from beach users as they were concentrated at swimming locations and were found throughout the beach profile. Also, of interesting note was the increase of fishing related litter which was prominent at locations of boat launch sites and areas of popular beach fishing sites.

A majority of litter appeared to be of terrestrial origin but transported to the beach from the ocean. Most waste, excepting some cigarette butts at Minnie Beach, appeared bleached and/or waterlogged or contained amounts of sea water.

## **Conclusions**

The density of beach debris found on isolated beaches of northern New South Wales was between 138 and 197 pieces per kilometre, a value lower than other surveys of New South Wales beaches (Frost & Cullen 1997, Hertfort 1997) and much lower than city beaches (O'Callaghan 1993, Cunningham 2000). Litter density was highest on the beaches not protected by headlands. Beach debris was of terrestrial origin but appeared to have been in the marine environment for some time, suggesting that most debris is transported to the beach from the ocean. This is in contrast to other studies of beach debris in isolated areas where most litter was attributed to ship sourced pollution (Whiting 1998, Edyvane *et al.* 2004). Litter deposited from public use of the beach environment is a minor component of total debris, as was found by Frost and Cullen (1997). Litter was predominantly deposited in the dune swale between the high tide and the storm surge marks. The density of litter was greatest at the northern extent of most beaches, accumulating as it is transported from the length of the beach by longitudinal drift. Predominantly litter found was derived from plastic materials. This concurs with other litter studies conducted throughout the world. Plastic is also the most readily transported material by the ocean. Plastic materials pose a high threat to marine mammals through entrapment and digestion (Laist 1987, Goldstein *et al.* 1999).

In order to reduce the amount of debris on isolated beaches in northern New South Wales efforts need to be directed at reducing waste being washed into drainage systems with ocean outlets. A greater understanding of beach debris in isolated areas needs to be obtained by further studies examining size and weight of litter found, particularly of plastics.

### **Acknowledgements**

The Resource Assessment Techniques II first year class of Southern Cross University, School of Environmental Science and Management 2003 collected and classed the litter found during this survey. Many thanks to Russell Hasthorpe for providing technical support for the survey period.

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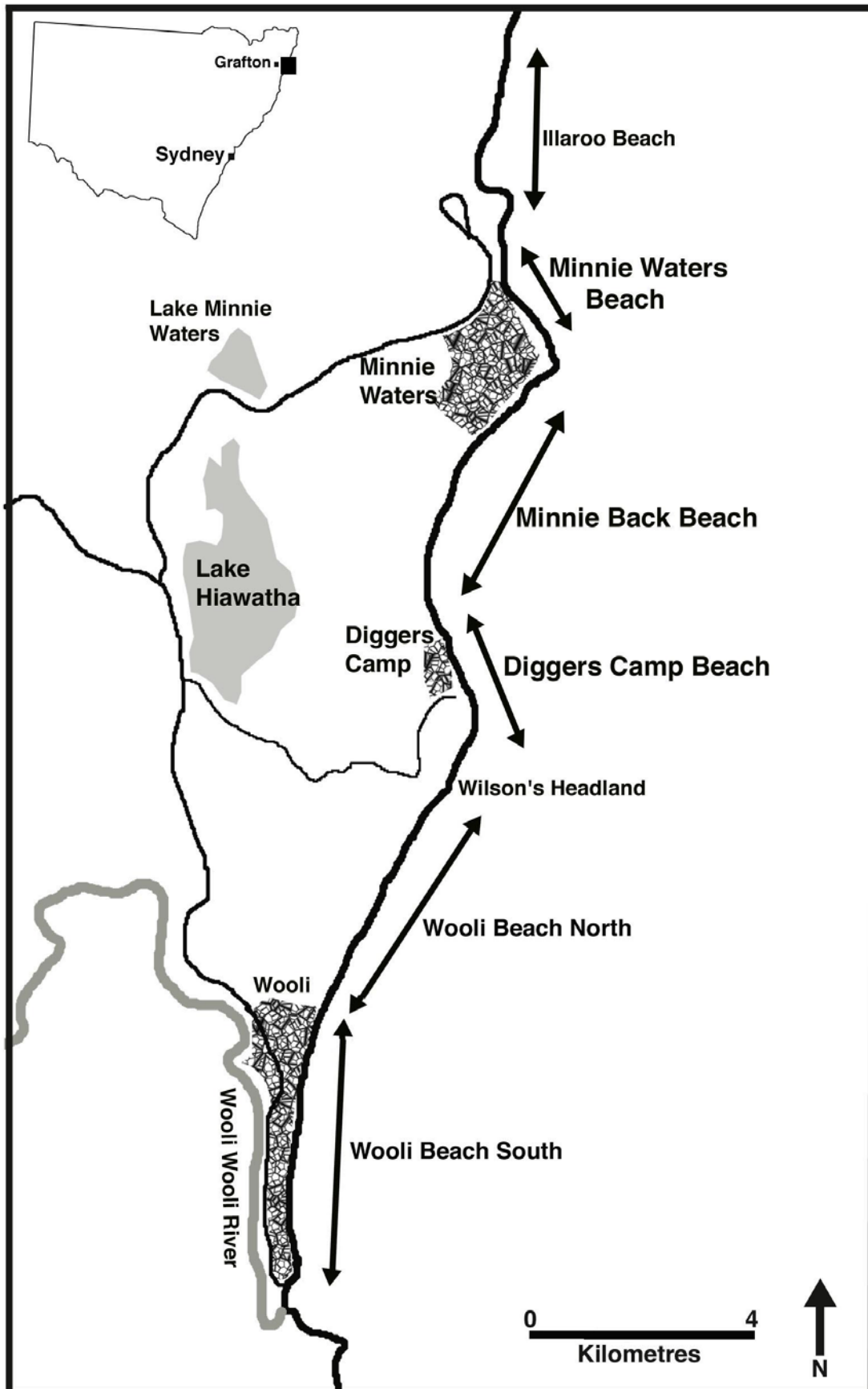


Figure 1: Location of beaches surveyed on the north coast of New South Wales.

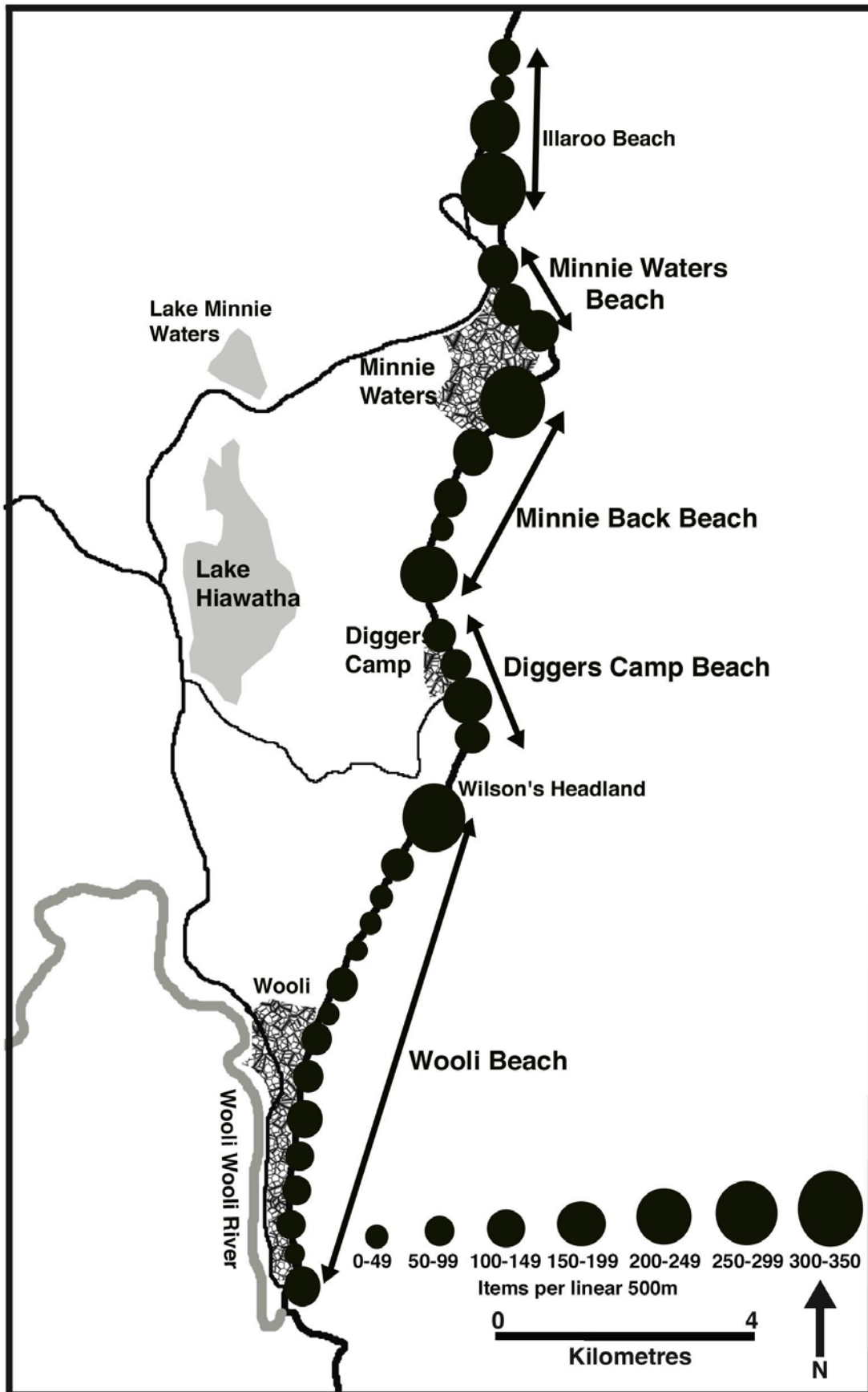
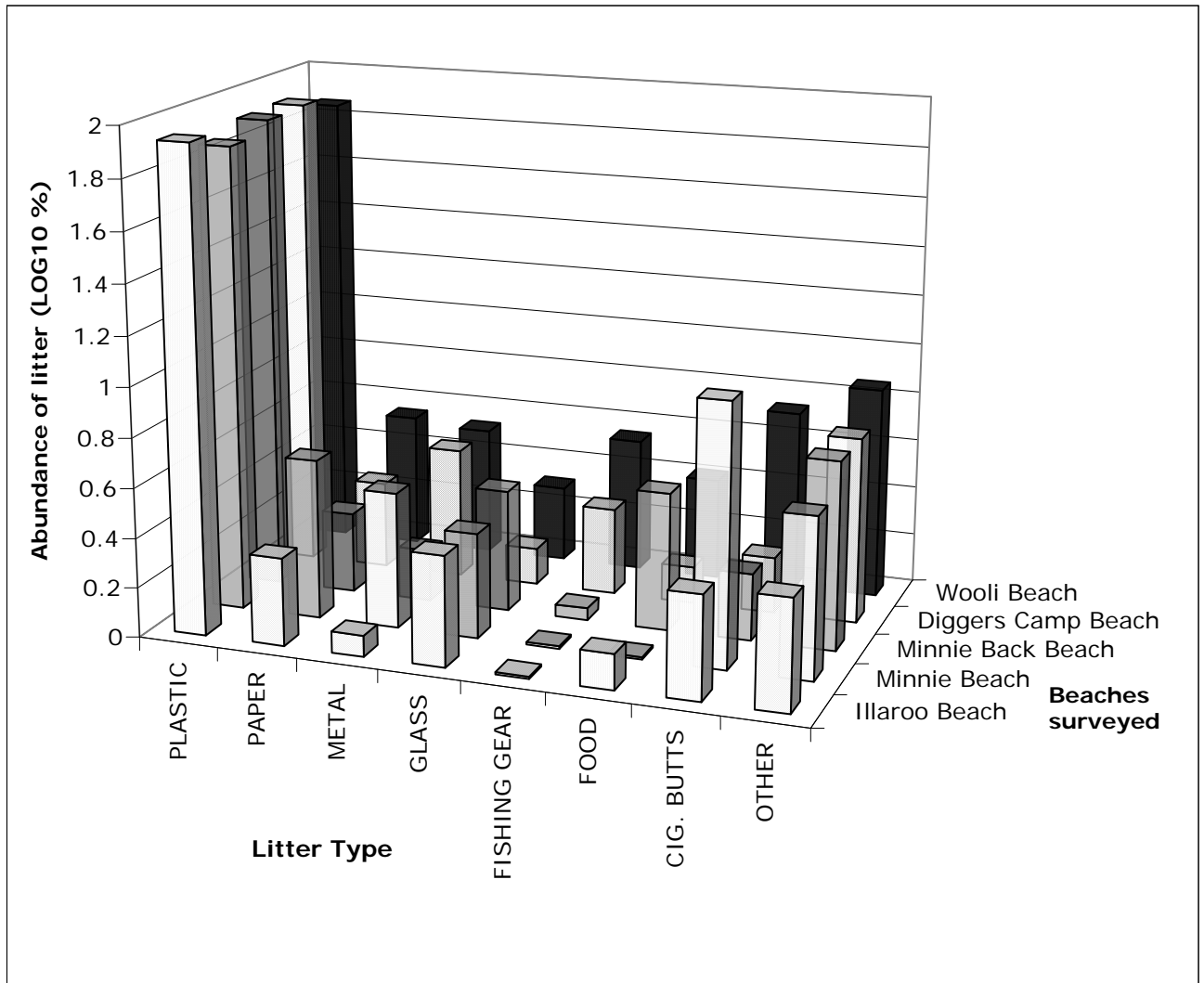


Figure 2: Density of marine debris per 500 metre sector of each surveyed beach.



**Figure 3: Types of litter (%) found on surveyed beaches**

**Table 1: Characteristics of Beaches surveyed**

<b>Beach</b>	<b>Length (km)</b>	<b>Average width of transect (m)</b>	<b>Geomorphology</b>	<b>Beach Use</b>
Illaroo Beach	3.0	55	<ul style="list-style-type: none"> <li>• Southern segment protected by headland.</li> <li>• Remainder of beach has easterly aspect</li> </ul>	<ul style="list-style-type: none"> <li>• Adjacent to NPWS camping area</li> <li>• Public 4WD access</li> <li>• Main access to village of Sandon, to the north</li> </ul>
Minnie Waters Main Beach	1.7	40	<ul style="list-style-type: none"> <li>• Protected by headlands at the north and south ends</li> <li>• Tidal lagoon protected by rock platforms at south end</li> </ul>	<ul style="list-style-type: none"> <li>• Adjacent to village of Minnie Waters (pop. 200)</li> <li>• 4WD access</li> <li>• popular for swimming/surfing activities</li> <li>• southern end recreational fishing vessel launch</li> </ul>
Minnie Back Beach	5.0	60	<ul style="list-style-type: none"> <li>• Easterly aspect</li> </ul>	<ul style="list-style-type: none"> <li>• Walker access to beach only</li> </ul>
Diggers Camp Beach	3.5	30	<ul style="list-style-type: none"> <li>• Protected by headlands at the north and south ends</li> <li>• Tidal lagoon protected by rock platforms at south end</li> </ul>	<ul style="list-style-type: none"> <li>• Adjacent to village of Diggers Camp (pop. 12)</li> <li>• public 4WD access</li> <li>• Popular for swimming/surfing activities</li> </ul>
Wooli Beach (north)	3.0	40	<ul style="list-style-type: none"> <li>• Protected at northern end by headland.</li> <li>• Easterly aspect</li> </ul>	<ul style="list-style-type: none"> <li>• 4WD access</li> <li>• popular for beach fishing</li> </ul>
Wooli Beach (south)	4.5	40	<ul style="list-style-type: none"> <li>• Protected by barrier walls at river mouth at southern end</li> <li>• Easterly aspect</li> </ul>	<ul style="list-style-type: none"> <li>• Adjacent to town of Wooli at southern end (pop. 600)</li> <li>• Public 4WD access</li> <li>• popular for swimming, surfing and dog walking activities</li> </ul>



**Table 2: Density of litter on surveyed beaches**

<b>Beach</b>	<b>Density (items/km)</b>
Illaroo Beach	288
Minnie Waters Beach	227
Minnie Back Beach	298
Diggers Camp Beach	178
Wooli (north end) Beach	154
Wooli (south end) Beach	138