THE NEMATODE FAUNA OF TWO ESTUARINE MANGROVE MUD-FLATS ON THE SOUTH COAST OF NEW SOUTH WALES.

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ABSTRACT

The nematode fauna inhabiting mangrove mud in two NSW South Coast estuaries, at Waterfall Creek on the Clyde River and nearby Candlagan Creek, was sampled four times in 1979/80 and again 12 years later in 1991. In 1979/80 the total populations were not large by world standards, but comparable with other Australian mangrove muds (1.2×10^6 - 2.8×10^6 m $^{-2}$) comprising 20-30 species at one time. The total population was fairly constant with season in 1979/80 but had declined by 35-40% by 1991. The faunal composition and feeding patterns had also changed after 12 years at both estuaries, but without a decrease in the number of species present. Civil engineering work had been undertaken at one of the creeks, but not the other, during the interval. Diversity and maturity indices plus feeding patterns have been compared and an attempt has been made to retrospectively separate the possible effects of human interference from other changes in the nematode assemblages.

INTRODUCTION

In this paper we compare the nematode fauna of two geographically close, but physically rather different, estuaries. As in estuaries everywhere, taxonomically very diverse populations of nematodes dominate the meiofauna, comprising over 80% of the fauna. The initial collections were made in 1979 and 1980 and the long delay in writing has been partly due to the time it has taken to become confident of our taxonomy and partly because we were working on other mangrove systems. We have subsequently been able to compare our specimens with museum collections in the UK, Germany, and Belgium. In 1991 we returned to both estuaries to make another collection to see what changes might have taken place in 12 years. The only comparable longterm study of meiofaunal changes that we can find is an 11 year study of estuarine meiofauna in South Carolina (Coull, 1985).

When we made our first collection there was only a single publication on the nematodes of Australian mangroves from a Belgian expedition to Lizard Island on the Great Barrier Reef (Decraemer and Coomans, 1978). Since then, numerous papers have been published. The ecology of nematodes from mangroves in Queensland has been described by Alongi (1987), in the Hunter Estuary by Hodda and Nicholas (1985; 1986 a & b; 1990) and in Darwin by Hodda and Nicholas (1987). Several papers have been published on nematodes from the two estuaries used in this study, i.e. Waterfall Creek on the Clyde River and Candlagan Creek, however, they focus on different issues to those discussed in this paper. The ecology and physiology of several selected species from Waterfall Creek have been studied by Nicholas *et al.* (1987) and Nicholas *et al.* (1988). Hodda (1990a) included our collections from both estuaries, with others, in a statistical (but non-taxonomic) study of inter-estuary variation. Nicholas *et al.* (1991) described the distribution of nematodes within 1 m^2 at different tide levels and different vegetative cover, but only on one day in mid-winter.

We shall discuss seasonal variation in the nematode fauna. In Northern Europe and North America, where much more work has been done on intertidal and shallow sub-littoral marine nematodes, the populations are usually denser than in Australian estuarine habitats. They also show marked seasonal changes in density and metabolism that have been ascribed to changes in both temperature and primary production. In contrast, water temperatures and day length are much less variable at our study site. The collection site at Waterfall Creek was chosen because of the similarity of its fine sediment and estuarine location to that of the Lyner Estuary in England where very detailed work on meiofauna has been conducted.

Wieser (1953) apportioned marine nematodes into four feeding categories, namely :

1A selective deposit feeders;
1B non-selective deposit feeders;
2A epistrate feeders; and
2B omnivore/predators,

using the structures of their mouth parts in combination with observations on feeding. This classification has been widely used in meiofaunal studies to compare nematode faunas, although it is well recognised that there is a great deal of uncertainty in the classification. Recently Jensen (1987) revised the classification, recognising deposit feeders, epistrate feeders, omnivores and predators. The revised classification used in this paper more accurately defines omnivores, predators and epistrate feeders, but does not distinguish between those that feed by ingesting suspensions of bacteria from those that swallow particles. The latter probably feed largely on bacteria, but are also capable of swallowing diatoms whole. Epistrate feeders, in contrast, prise open the cells of diatoms and other unicellular algae. Despite the lack of precision, the classification probably does give a useful general picture of dietary preferences within a nematode assemblage.

Numerous studies of nematode assemblages in European marine, estuarine and river sediments have been undertaken to monitor environmental disturbance, especially that caused by pollution. Diversity indices have been used on the assumption that disturbance will reduce diversity. Calculation of Bray-Curtis similarity coefficients coupled with group average clustering algorithms have proved a useful way of comparing nematode assemblages because they use both the relative abundances, as well as the presence or absence of species (Hodda, 1990b). For example, Austen and Wibdom (1991) used Bray-Curtis similarity cluster analysis along with Shannon-Wiener's H' and Pielou's J diversity indices in a study of the effects of temporary hypoxia on marine assemblages in a Swedish fjord.

In a quite different approach, Bongers (1990) proposed a maturity index to compare assemblages in which each species was ascribed a number between 1, for colonisers, and 5, for persistors, and a weighted mean score was calculated for each assemblage. Colonisers correspond to *r*-strategists with short generation times and high fecundity, while persistors correspond to *k*-strategists with long generations and low fecundity. Initially, the numbers were based on the nematode family for both marine, freshwater and terrestrial nematodes, but later the method was further developed to allow for differences at the generic level in life strategies within families (Bongers *et al.*, 1991). Examples of the application of this method to compare nematode assemblages were given.

It so happens that at Waterfall Creek the mangroves and immediate hinterland have remained undeveloped during the 12 year interval, while at Candlagan Creek there has been civil engineering work. We did not foresee this difference when we undertook our study in 1978, however, we think it worthwhile to examine whether changes in the nematode assemblages reflect differences in the development of the hinterland. With this in mind, we have applied each of the above numerical comparisons to our data.

MATERIALS AND METHODS

Nematodes were collected by driving a 2.25 cm diameter plastic corer into the mud to a depth of 5 cm at Waterfall Creek and 15 cm at Candlagan Creek. Preliminary sampling had shown that almost all the nematodes were to be found within these depths of sediment, differences being due to the fact that the mud at Candlagan was sandy, while that at Waterfall Creek was of a much finer grain size. One set of samples was taken at low tide in April, July, October 1979, January 1980 and October 1991. On each occasion five replicate cores were taken close together (within a few square metres) at the respective sites. Cores were fixed at once with an equal volume of 10% formalin in sea water in screw capped jars. In the laboratory, nematodes were extracted by a combination of sedimentation in tap water, sieving and centrifugal flotation. Material, including nematodes, that passed a 1mm sieve and collected on a 0.05 mm sieve was transferred to a centrifuge tube and resuspended together with some kaolin. After centrifuging at 6000 rpm on a bench centrifuge for 7 minutes, the supernatant was discarded and the pellet resuspended in an aqueous solution of colloidal silica, specific gravity 1.15 (Ludox, T. M., Du Pont de Nemours, Delaware, USA), recentrifuged and the supernatant retained. The pellet was mixed with more Ludox and centrifuged again. The combined supernatants from these two steps were pooled and passed through a 0.05 mm sieve. Nematodes retained on the sieve were back-washed into a petri dish, picked up individually with an eyebrow hair mounted on a wood stick and transferred to 5% aqueous glycerol (estimated recovery 75%). The water was evaporated in an oven at 37°C, the nematodes mounted on slides in anhydrous glycerol and the cover slips ringed with Glyceel. Nematodes were subsequently identified and counted in half the sample.

Many of the nematode species recognised can be given only generic names because the existing taxonomic literature is inadequate to do otherwise. In 1991 we found that there were two species of *Sabatieria* present which we had failed to distinguish in 1980, i.e. *S. wieseri* and *S. pulchra.*

Kendall's coefficient of concordance (W) was calculated as described by Siegel (1956); diversity indices, and their significance according to Poole (1974); and Bray-Curtis similarity index analysis, as well as group average cluster analysis, after Greig-Smith (1983) using the GENSTAT 5 statistical package. A maturity index has been assigned to each species and a weighted mean calculated for each nematode assemblage according to Bongers *et al.* (1991).

GENERAL DESCRIPTION OF THE STUDY AREAS

Both study areas are on estuarine creeks on the South Coast of NSW, just south of Batemans Bay (Figure 1). A very comprehensive study of estuaries along the New South Wales South Coast, including both the Clyde River estuary and Candlagan Creek, has been published by Gunn (1978). Volume 2 of this work describes the local flora, macrofauna and hydrology.

The study area on the Clyde estuary lies in a small embayment off Waterfall Creek into which a very small freshwater creek empties. It has been described in greater detail by Nicholas *et al.* (1990). Mature mangroves (*Avicennia marina*) occur sporadically along the edge of the drainage channel from the creek, but much of the mudflat consists of closely-spaced, small mangroves about 1m high. The collecting site was amongst the small mangroves. The embayment is surrounded by State Forest and lacks nearby habitation. It is not used for either commercial (e.g. oyster farming) or recreational purposes. The absence of the Sydney welk *Pyrazus ebeninius* is a notable feature. Mud oysters are not found, but crabs (*Heloecius cordiformis*) are present and their holes are abundant. Small shrimps and tiny fish occur at high tide. At the sampling site the sediment forms a soft, tenacious, silty clay with a median grain size of 0.030 mm and 3.4% organic matter (Hodda, 1990a). Salinity is about 20 ‰ (Gunn, 1978).

Candlagan Creek is a small tidal inlet, several kilometres long, fed by a very small freshwater stream and, except immediately following heavy rain, its salinity is that of sea water. For much of its length it is bordered by mangroves (*Avicennia marina*). The area selected for sampling is on the south side where the mangroves widen. It lies within a commercial oyster lease, but well upstream from the area used for commercial purposes. Behind the mangroves there is an area of salt marsh, which is flooded at high water spring tides, and further inland *Casuarina glauca*.. On the opposite bank there are houses. In 1979, a road bridge had just been constructed across the mouth of the creek. By 1991, a second road bridge was under construction upstream from the study site, a sewage system had replaced the septic tanks that previously served the houses and more houses had been built. Candlagan Creek had therefore seen considerable "development" in the intervening period, although the actual study area remained relatively undisturbed as part of an unutilised commercial oyster lease.

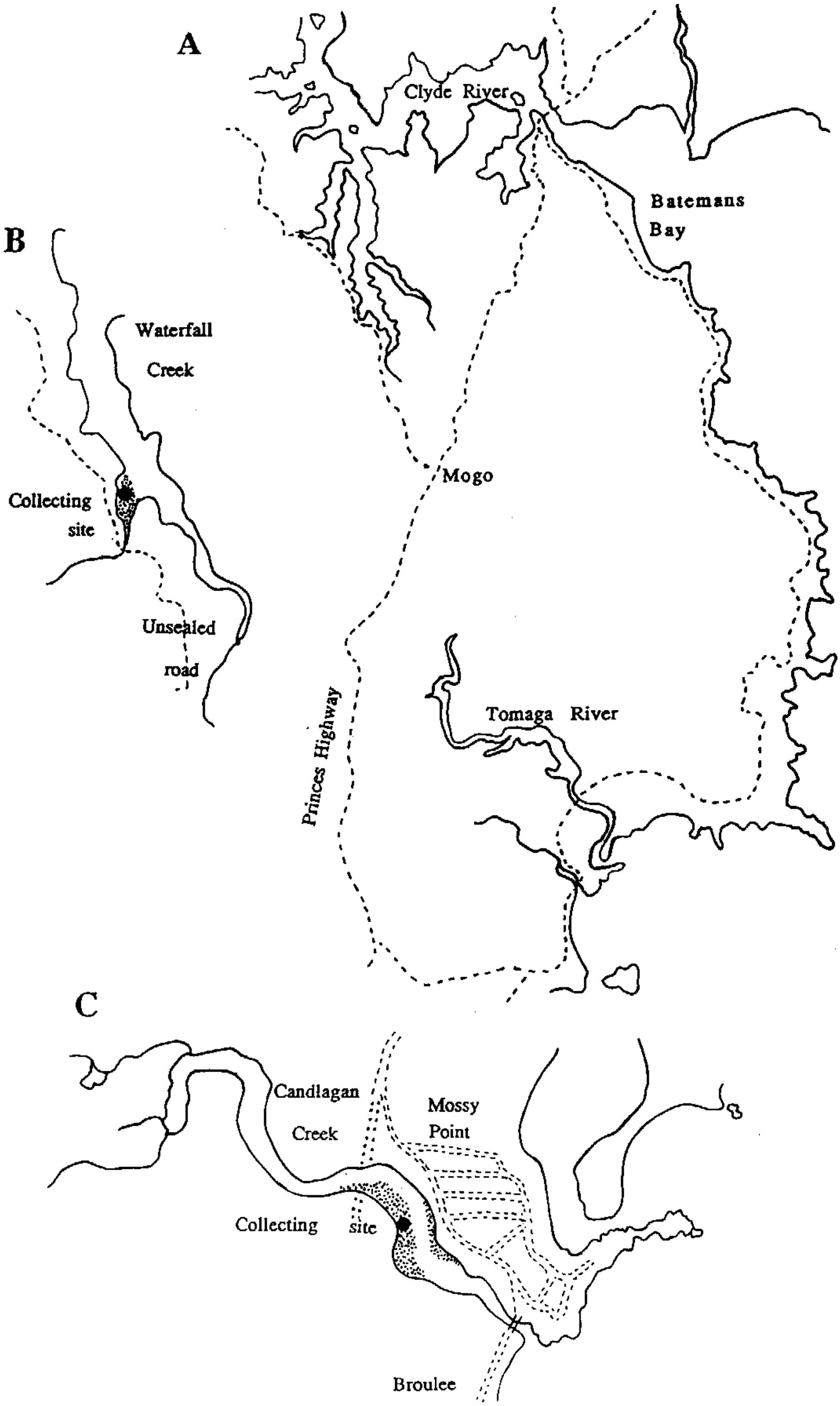

Figure 1 **A** : the location of Waterfall Creek and Candlagan Creek on the New South Wales south coast
B : the collecting site on Waterfall Creek
C : the collecting site on Candlagan Creek

Samples were taken from the same restricted area between mature mangroves.The area sampled is sandy, with much organic matter. Oysters (*Crassostrea commercialis*) are scattered over the mud surface and welks (*Pyrazus ebeninius*) and crabs (*Heloecius cordiformis*) are numerous. The sediment is muddy sand with a median grain size of 0.228 mm and about 2.4 % organic matter (Hodda, 1990a). Salinity is 30-35‰ (Gunn, 1978).

RESULTS

The estimated population densities are shown in Table 1. The estimates are not precise because of the small numbers of cores from which they are derived. However, a reasonable conclusion is that densities were between 1,500,000 and 3,000,000 nematodes per m^2 at Waterfall Creek and 1,000,000 to 2,000,000 nematodes per m^2 at Candlagan Creek, without recognisable seasonal variation in 1979/80, but had become substantially less by October 1991. The numbers of species varied between 20 and 30, of which 6 to 14 were consistently common during different seasons, while others occurred with a relatively much lower frequency, so that the precise number of species present is uncertain and the numbers given must be the lowest limits.

The number of each species collected in April, July and October 1979 and January 1980 at Waterfall Creek are shown in Table 2. To save space we have given only the total of each species in all 5 replicate cores. Column P/5 (the number of cores in each set of 5 in which a particular species was present) shows that the common species usually occurred in all 5 replicate cores, though in very variable numbers. Consequently, we have been able to use rank order statistics to assess the degree of correlation between replicate cores. Kendall's coefficient of concordance (W) was calculated for each set of replicate cores for the 12 commonest species (Table 3) and shows values 0.75 and 0.93, indicative of a high degree of association. The less common species occurred sporadically, a natural consequence of over-dispersed distributions, but showed no clear evidence of local or temporal high aggregations. Two species of epistrate feeders were consistently ranked one and two in numbers, *Desmodora cazca* and *Microlaimus capillaris*, respectively. Deposit feeders consistently accounted for about 25%, epistrate feeders about 75%, with 1% omnivores and 1.4% predators (Table 4).

Table 5 shows the numbers of each species found at Candlagan Creek in 1979/80. Many species occur at both creeks, but generally with a different relative frequency. The two commonest species at Waterfall Creek, *D. cazca* and *M. capillaris*, were also present at Candlagan Creek, but were much less common, while *Spirinia* sp. and *Gomphionema* sp., the dominant species at Candlagan Creek, were less common at Waterfall Creek. All four are classed as epistrate feeders. The correlation between replicates was not as consistent as for Waterfall Creek, with Kendall's coefficient of concordance (W) varying from 0.59 to 0.96 (Table 3). At Candlagan Creek, deposit feeders were relatively more numerous, though still fewer, than epistrate feeders (Table 4) with the exception being

Table 1 Estimated population densities and numbers of species recorded at various times from sampling sites on the Clyde River Estuary and Candlagan Creek

	April '79	July '79	Oct. '79	Jan. '80	Oct.'91
Waterfall Creek					
Nematodes m^{-2} /1000	2615	1820	2861	2509	846
Number of species	22	21	22	24	29
Species accounting for 90%	6	10	7	9	14
Candlagan Creek					
Nematodes m^{-2} /1000	1380	1257	1868	1638	623
Number of species	26	26	28	23	21
Species accounting for 90%	10	13	13	12	6

Table 2 Nematodes collected from mangrove mud at Waterfall Creek

Taxa	Apr-79				Jul-79				Oct-79				Jan-80					All Seasons			Food	MI
	Total	%	Rank	P/5	Total	%	Rank	P/4	Total	%	Rank	P/5	Total	%	Rank	P/5	MI	Total	%	Rank	Jensen	Bongers
Chromadoridae																						
Actinonema longicaudata					11	0.81	11.5=	3										11	0.15	22.5=	EF	4
Ptycholaimellus lizardensis	4	0.21	15.5=	1	4	0.29	17=	3	6	0.28	15.5=	4	6	0.32	18.5=	2	3	20	0.27	18	EF	3
Others	2	0.10	19.5=	2					6	0.28	15.5=	2	7	0.37	17	4	3	15	0.21	21	EF	3
Neotonchidae																						
Gomphionema	105	5.38	5	5	52	3.83	6	4	145	6.80	4	5	15	0.80	13	5	2	317	4.33	6	EF	2
Cyatholaimidae																						
Paracyatholaimus	2	0.10	19.5=	2	1	0.07	22	1	2	0.09	20=	2	1	0.05	23	1	2	6	0.08	24	Ef	2
Other					4	0.29	17=	3										4	0.05	25	EF	3
Desmodoridae																						
Desmodora cazca	751	38.51	1	5	483		1	4	923	43.27	1	5	581	31.00	1	5	2	2738	37.44	1	EF	2
Onyx	41	2.10	7	5	42	3.10	7	4	100	4.69	5	5	144	7.68	3	5	3	327	4.47	5	EF	3
Spirina	13	0.67	13	3					2	0.09	20=	2	4	0.21	21	3	3	19	0.26	19	EF	3
Microlaimidae																						
Microlaimus capillaris	565	28.97	2	5	404	29.77	2	4	439	20.58	2	5	547	29.19	2	5	2	1955	26.73	2	EF	2
Xyalidae																						
Daptonema	33	1.69	9	5	32	2.36	9	4	54	2.53	8	5	44	2.35	6	4	2	163	2.23	7	DF	2
Filipjeva					4	0.29	17=	3					7	0.37	16	3	2	11	0.15	22.5=	DF	2
Theristus a	48	2.46	6	5	6	0.44	13.5=	2	29	1.36	9	5	37	1.97	8	5	2	120	1.64	8	DF	2
Theristus b	3	0.15	17	3	11	0.81	11.5=	3	7	0.33	14	3	2	0.11	22	2	2	23	0.31	13	DF	2
Theristus c	38	1.95	8	5	37	2.73	8	4	21	0.98	11	5	21	1.12	12	4	2	117	1.60	9	DF	2
Theristus d	1	0.05	22	1	6	0.44	13.5=	2	1	0.05	22	1	13	0.69	14	3	2	21	0.29	16=	DF	2
Shaerolaimidae																						
Sphaerolaimus papillatus	20	1.03	11	5	15	1.11	10	4	20	0.94	12	4	25	1.33	9.5=	4	3	80	1.09	10	PR	3
Doliolaimus	7	0.36	14	4	4	0.29	17=	2	5	0.23	17	3	5	0.27	20	4	3	21	0.29	16=	PR	3
Linhomoedae																						
Terschellingia longicaudata	29	1.49	10	4	61	4.50	4	4	58	2.72	7	5	43	2.29	7	5	3	191	2.61	7	DF	3
Terschellingia b	4	0.21	15.5=	2	2	0.15	20.5=	1	2	0.09	20=	2	10	0.53	15	4	3	18	0.25	20	DF	3
Axonolaimidae																						
Parodontophora xenotricha	133	6.82	3	5	58	4.27	5	4	78	3.66	6	5	135	7.20	5	5	2	404	5.52	4	DF	2
Comesomatidae																						
Sabatieria	120	6.15	4	5	114	8.40	3	4	194	9.10	3	5	143	7.63	4	5	2	571	7.81	3	DF	2
Oxystominidae																						
Halalaimus	2	0.10	19.5=	2	2	0.15	20.5=	1	4	0.19	18	4	25	1.33	9.5=	5	4	33	0.45	12	DF	4
Oxystomina	2	0.10	19.5=	2	4	0.29	17=	3	9	0.42	13	4	6	0.32	18.5=	3	4	21	0.29	16=	DF	4
Oncholaimidae																						
Viscosia	19	0.97	12	5					24	1.13	10	3	23	1.23	11	4	3	66	0.90	11	OM	3
Unidentifiable	8	0.41		5					4	0.19		2	30	1.60		5		42	0.57			
Total	1950	100.00		22	1357	100.00		22	2133	100.00		22	1874	100.00		23		7314	100.00	25		

EF=epistrate feeder
DF=deposit feeder
OM=omnivor
PR=predator

Table 3 Kendall coefficient of concordance (W)

	Waterfall Creek	**Candlagan Creek**
Apr. '79	0.927	0.803
Jul. '79	0.917	0.960
Oct. '79	0.806	0.589
Jan. '80	0.748	0.643
Oct. '91	0.522	0.646

April 1979 due to the presence of many *Spirinia* sp., whose designation as an epistrate feeder is open to question.

In both Tables 2 and 5 some nematodes are listed as either 'other Chromadoridae' or 'other Cyatholaimidae'. This is because only juveniles were found and sexually mature males are required for correct generic identifications.

The nematode fauna at both creeks in October 1991 is shown in Table 6. The dominance of *D. cazca* and *M. capillaris* at Waterfall Creek has declined, but all the species making up more than 1% in October 1979 are also more than 1% in 1991. In contrast, at Candlagan Creek there has been a substantial change, 7 of the 14 species making up 1% or more were not in the list for 1991, but *Metalinhomoeus* sp. has become much more numerous. The correlation between replicates was lower (W = 0.52). The changes in feeding categories after a 12 year interval are compared in Figure 2. The percentage of epistrate feeders has fallen, while that of deposit feeders has risen at both creeks. This is especially marked at Candlagan Creek, where the numbers of epistrate feeders recovered decreased substantially corresponding to a fall in their proportion from 60 to 17% and a rise in the proportion of deposit feeders from 36 to 82% (see Table 4 and Figure 2).

Diversity and maturity indices for each collection are compared in Table 7. The diversity at Waterfall Creek, as measured by Shannon-Wiener H', was significantly higher in October 1991 than at any time in 1979/80 and Evenness was lower. At Candlagan Creek, H' was significantly lower in October 1991 than for three of the four earlier collections, and just outside the $p = 0.05$ level for April 1979, while Evenness was lower. The maturity indices for the collections at Waterfall Creek in 1979/80 were significantly different to those for the collections at Candlagan Creek from the same time periods. However, while the index for Waterfall Creek in October 1991 was significantly different to those for the earlier collections at Waterfall Creek, it does not differ significantly to the value for Candlagan Creek in October 1991. Waterfall Creek is less variable in

Table 4 Nematode assemblages partitioned (as percentages) into Jensen's (1987) feeding categories

	Deposit feeders	Epistrate feeders	Omnivores	Predators	Plant feeders
Waterfall Creek					
April '79	21.3	76.4	0.98	1.4	
July '79	24.8	73.8	0	1.4	
Oct. '79	21.5	76.2	1.1	1.2	
Jan. '80	26.4	70.8	1.3	1.6	
Oct. '91	34.3	48.6	1.5	11.4	4.2
Candlagan Creek					
April '79	20.6	78.3	0.39	0.68	
July '79	44.1	55.3	0.11	0.54	
Oct. '79	36.1	60.5	3.10	0.29	
Jan. '80	44.2	55.5	0.16	0.16	
Oct. '91	82.3	17.1	0.22	0.22	0.22

Table 5 Nematodes collected from mangrove mud at Candlagan Creek

Taxa	Apr-79				Jul-79				Oct-79				Jan-80				All seasons			Food	MI
Samples	Total	%	Rank	P/5	Total	%	Rank	P/5	Total	%	Rank	P/5	Total	%	Rank	P/5	Total	%	Rank	Jensen	Bongers
Chromadoridae																					
Ptycholaimellus lizardensis	2	0.19	23	1	31	3.31	9	4	89	6.39	5	5	57	4.67	10	5	179	3.91	8	EF	3
Chromadora macrolaimus	21	2.04	9	3													21	0.46	19	"	3
Others	10	0.97	13	2	24	2.56	13	4	19	1.36	14	4	19	1.56	13	3	72	1.57	17	"	3
Neotonchidae																					
Gomphionema	28	2.72	5	4	167	17.82	2	4	191	13.71	2	5	248	20.31	1	5	634	13.84	2	"	2
Cyatholaimidae																					
Propomponema	90	8.75	3	5	10	1.07	16	3	14	1.01	16	4					114	2.49	11	"	3
Other Cyatholaimudae	13	1.26	12	3	6	0.64	18	3	6	0.43	22	3	3	0.25	19	2	28	0.61	18	"	3
Selachinematidae																					
Halichoanolaimus	7	0.68	14	1													7	0.15	25.5=	PR	3
Desmodoridae																					
Desmodora casca	4	0.39	19=	3	20	2.13	14	3	22	1.58	12.5=	5	61	5.00	8.5=	5	107	2.34	12.5=	EF	2
Onyx	1	0.10	24.5=	1													1	0.02	29	EF?	3
Spirinia a	565	54.91	1	5	203	21.66	1	4	359	25.77	1	5	198	16.22	2	5	1325	28.93	1	EF	3
Spirinia b	3	0.29	21.5=	1	4	0.43	21=	3	2	0.14	25.5=	2	4	0.33	17.5=	2	13	0.28	20	"	3
Microlaimidae																					
Microlaimus capillaris	18	1.75	11	5	29	3.09	10	4	17	1.22	15	4	43	3.52	11	5	107	2.34	12.5=	"	2
Microlaimus b	20	1.94	10	5	11	1.17	15	4	57	4.09	7.5=	5	37	3.03	12	5	125	2.73	10	"	2
Leptolaimidae																					
Camacolaimus	1	0.10	24.5=	1					8	0.57	20						9	0.20	23.5=	"	3
Xalidae																					
Daptonema	3	0.29	21.5=	2	60	6.40	5	4	9	0.65	18.5=	2	64	5.24	5	2	136	2.97	9	DF	2
Theristus a	98	9.52	2	5	36	3.84	8	4	48	3.45	10	5	63	5.16	6.5=	5	245	5.35	5	"	2
Theristus b	22	2.14	8	5	28	2.99	11	4	22	1.58	12.5=	3	12	0.98	15	3	84	1.83	15	"	2
Theristus c	6	0.58	15.5=	3	26	2.77	12	4	83	5.96	6	5	67	5.49	4	5	182	3.97	7	"	2
Theristus d					57	6.08	6	3	12	0.86	17	5	11	0.90	16	3	80	1.75	16	"	2
Sphaerolaimidae																					
Sphaerolaimus anterides					3	0.32	23	2	2	0.14	25.5=	2	2	0.16	21=	2	7	0.15	25.5=	PR	3
Doliolaimus					2	0.21	24.5=	2	2	0.14	25.5=	2					4	0.09	27	PR	3
Linhomoeidae																					
Terschellingia longicaudata	5	0.49	17	2	7	0.75	17	4	9	0.65	18.5=	5	18	1.47	14	3	39	0.85	17	DF	3
Terschellingia b	26	2.53	6.5=	3	62	6.62	4	4	57	4.09	7.5=	5	63	5.16	6.5-	5	208	4.54	6	"	3
Terschellingia c	6	0.58	15.5=	3	4	0.43	21=	2	7	0.50	21	4					17	0.37	20	"	3
Metalinhomoeus	16	1.55	11	3	69	7.36	3	4	131	9.40	3	4	61	5.00	8.5=	3	277	6.05	4	"	2
Axonolaimidae																					
Parodontophora xenotricha	26	2.53	6.5=	3	50	5.34	7	4	113	8.11	4	5	170	13.92	3	5	359	7.84	3	"	2
Comesomatidae																					
Sabatieria	4	0.39	19=	2	2	0.21	24.5=	2	1	0.07	28	1	2	0.16	21=	1	9	0.20	23.5=	"	2
Ironidae																					
Dolicholaimus	30	2.92	4	3	4	0.43	21=	1	53	3.80	9	3	1	0.08	23	1	88	1.92	14	EF?	2
Oxystominidae																					
Oxystomina									2	0.14	25.5=	2					2	0.04	28	DF	4
Oncholaimidae																					
Viscosia	4	0.39	19=	4	1	0.11	26	1	43	3.09	11	5	2	0.16	21=	2	50	1.09	16	OM	3
Tefusiidae																					
Trefusia					5	0.53	19	3	5	0.36	23	3	4	0.33	17.5=	2	14	0.31	21	DF	4
Unidentifiable					16	1.71			10	0.72		2	11	0.90		2	37	0.81			
Total	1029	100.00	26		937	100.00	26		1393	100.00	28		1221	100.00	23		4580	100.00	29		

EF=epistrate feeder
DF=deposit feeder
OM=omnivor
PR=predator

Table 6 Nematodes collected at Waterfall and Candlagan Creeks, October 1991.

Waterfall Creek

Taxa	Total	%	Rank	P/5	Food	MI
Chromadoridae						
Dichromadora	6	0.95	17	4	EF	3
Chromadora	12	1.90	12	2	EF	3
Ptycholaimellus	9	1.43	13.5=	3	EF	3
Neotonchidae						
Gomphionema	21	3.33	10	5	EF	2
Cyatholaimidae						
Paracyatholaimus	5	0.79	18=	3	EF	2
Cyatholaimid b	1	0.16	28=	1	EF	3
Cyatholaimid c	2	0.32	23.5=	2	EF	3
Desmodoridae						
Desmodora cazca	46	7.29	5	5	EF	2
Onyx	62	9.83	4	5	EF	3
Microlaimidae						
Microlaimus capillaris	141	22.35	1	5	EF	2
Xyalidae						
Daptonema a	17	2.69	11	4	DF	2
Daptonema b	7	1.11	15.5=	3	DF	2
Theristus interstitialis	2	0.32	23.5=	2	DF	2
Theristus b	2	0.32	23.5=	1	DF	2
Theristus c	7	1.11	15.5=	2	DF	2
Sphaerolaimidae						
Sphaerolaimus anterides	67	10.62	3	5	PR	3
Sphaerolaimus gracilis	5	0.79	18.5=	3	PR	3
Desmoscolecidae						
Desmoscolex	1	0.16	28=	1	DF	4
Linhomoeidae						
Linhomoeus	2	0.32	23.5=	1	DF	2
Terschellingia l	70	11.09	2	5	DF	3
Terschellingia b	42	6.66	6	5	DF	3
Axonolaimidae						
Ascolaimus	3	0.48	20	2	DF	2
Parodontophora x	22	3.49	9	5	DF	2
Comesomatidae						
Sabatieria pulchra	35	5.55	7	5	DF	2
Sabatieria weiseri	1	0.16	28=	1	DF	2
Oxystominidae						
Halalaimus	2	0.32	23.5=	2	DF	4
Oncholaimidae						
Viscosia	9	1.43	13.5=	5	OM	3
Tripyloididae						
Tripyloides	2	0.32	23.5=	2	DF	2
Nordiidae						
Enchodelus coomansi	26	4.12	8	4	PF	4
Unidentified	4	0.63		4		
Total	631	100	29			

Candlagan Creek

Taxa	Total	%	Rank	P/5	Food	MI
Chromadoridae						
Actinonema	1	0.22	16.5=	1	EF	4
Dichromadora	21	4.52	4	4	EF	3
Chromadora	16	3.44	5	4	EF	3
Cyatholaimidae						
Paracanthonchus	7	1.51	9	4	EF	2
Cyatholaimid a	1	0.22	16.5=	1	EF	3
Cyatholaimid b	2	0.43	12	1	EF	3
Desmodoridae						
Onyx	4	0.86	10.5=	1	EF	3
Spirinia	27	5.81	3	5	EF	3
Xyalidae						
Daptonema	8	1.72	7.5=	3	DF	2
Theristus interstitialis	4	0.86	10.5=	1	DF	2
Theristus c	8	1.72	7.5=	3	DF	2
Sphaerolaimidae						
Sphaerolaimus anterides	1	0.22	16.5=	1	PR	3
Desmoscolecidae						
Desmoscolex	1	0.22	16.5=	1	DF	4
Lonhomoeidae						
Metalinhomoeus	257	55.27	1	5	DF	2
Terschellingia l	1	0.22	16.5=	1	DF	3
Terschellingia b	88	18.92	2	5	DF	3
Axonolaimidae						
Parodontophora x	13	2.80	6	4	DF	2
Comesomatidae						
Sabatieria pulchra	1	0.22	16.5=	1	DF	2
Oncholaimidae						
Viscosia	1	0.22	16.5=	1	OM	3
Nordiidae						
Enchodelus coomansi	1	0.22	16.5=	1	PF	4
Unidentified	2	0.43		2		
Total	465	100	20			

EF=epistrate feeder
DF=deposit feeder
OM=omnivor
PR=predator
PF=plant feeder

this respect than Candlagan Creek in 1979/80, but has become more like Candlagan Creek by 1991. Figure 2 displays the Bray-Curtis similarity coefficients for all ten collections as a dendrogram using a group average cluster algorithm. Interestingly, although the assemblages for each location in 1979/80 cluster together, in October 1991, Waterfall Creek and Candlagan Creek are more similar to one another than they are to any of the earlier collections. Using this method of comparison, it appears that after 12 years the collections at both creeks have converged with respect to faunal composition.

DISCUSSION

The nematode population density, although low when contrasted with population densities in estuaries of the northern temperate regions, was higher than that found by Alongi (1987) in many estuaries in tropical Queensland, but within the range found by Hodda and Nicholas (1985) in the Hunter estuary. Tietjen and Alongi (1990) attribute the low population density to the inhibitory effects of tannins released from fallen mangrove leaves. They found *Rhizophora stylosa* leaves much more potent than *Avicennia* leaves and it is noteworthy that in the SE NSW estuaries *Avicennia marina* occurs, but not *Rhizophora stylosa*.

The population density was also lower than that found by Nicholas *et al.* (1990) at Waterfall Creek in June 1986, both within and below the mangroves. These differences are very probably accounted for by the correlation between density and tide level reported by Hodda & Nicholas (1985). We did not find large, irregular differences in the total population at different sampling times during 1979/80 like those reported by Hodda & Nicholas (1986a) for the Hunter estuary, although the variation in population composition is well within the large degree of stochastic variance already reported by Hodda (1990a) for these two estuaries. However, by 1991 there had been a marked fall in population at both creeks. A significant difference between these estuaries and the Hunter is that they are fed by a much smaller river catchment and therefore probably experience far less variation in nutrient inputs.

The genera found are common, cosmopolitan estuarine ones which have also been reported from other estuaries in Australia. There has been too little work done on the taxonomy of Australian marine nematodes to identify many of the species with confidence. Of those that can be named, *D. cazca* and *M. capillaris* were first described from mangroves in Brazil, *P. lizardensis* from the Great Barrier Reef and *Enchodelus coomasi* from the Clyde estuary, but they are not necessarily

Table 7 Diversity and Maturity indices

	Date	No. species	H'	J	Maturity Index
Waterfall Creek	Apr '79	22	1.836	0.592	2.08
"	Jul '79	22	1.908	0.617	2.12
"	Oct '79	22	1.866	0.638	2.11
"	Jan '80	23	2.005	0.639	2.18
"	Oct '91	29	2.596*	0.770	2.54
Candlagan Creek	Apr '79	26	1.856***	0.573	2.73
"	Jul '79	26	2.572	0.769	2.40
"	Oct '79	28	2.530	0.759	2.47
"	Jan '80	23	2.488	0.796	2.31
"	Oct '91	20	1.556**	0.520	2.32

t-tests of significance
* Significantly different from other WC collections, p<0.01
** Sig. diff all other CC collections except Apr. '79, p<0.01
*** Sig. diff. CC Apr., Jul., Oct. '79, Jan. '80, p<0.01
Maturity Indices : WC 1979/80 sig. diff. CC 1979/80, p<0.01
" " WC 1979/80 plus 1991, not sig. diff. CC.

restricted to mangroves. *D. cazca* occurs in the absence of mangroves in the Murray River estuary and most of the other named species have been described from non-mangrove habitats around the world. There does not seem to be a specific mangrove fauna.

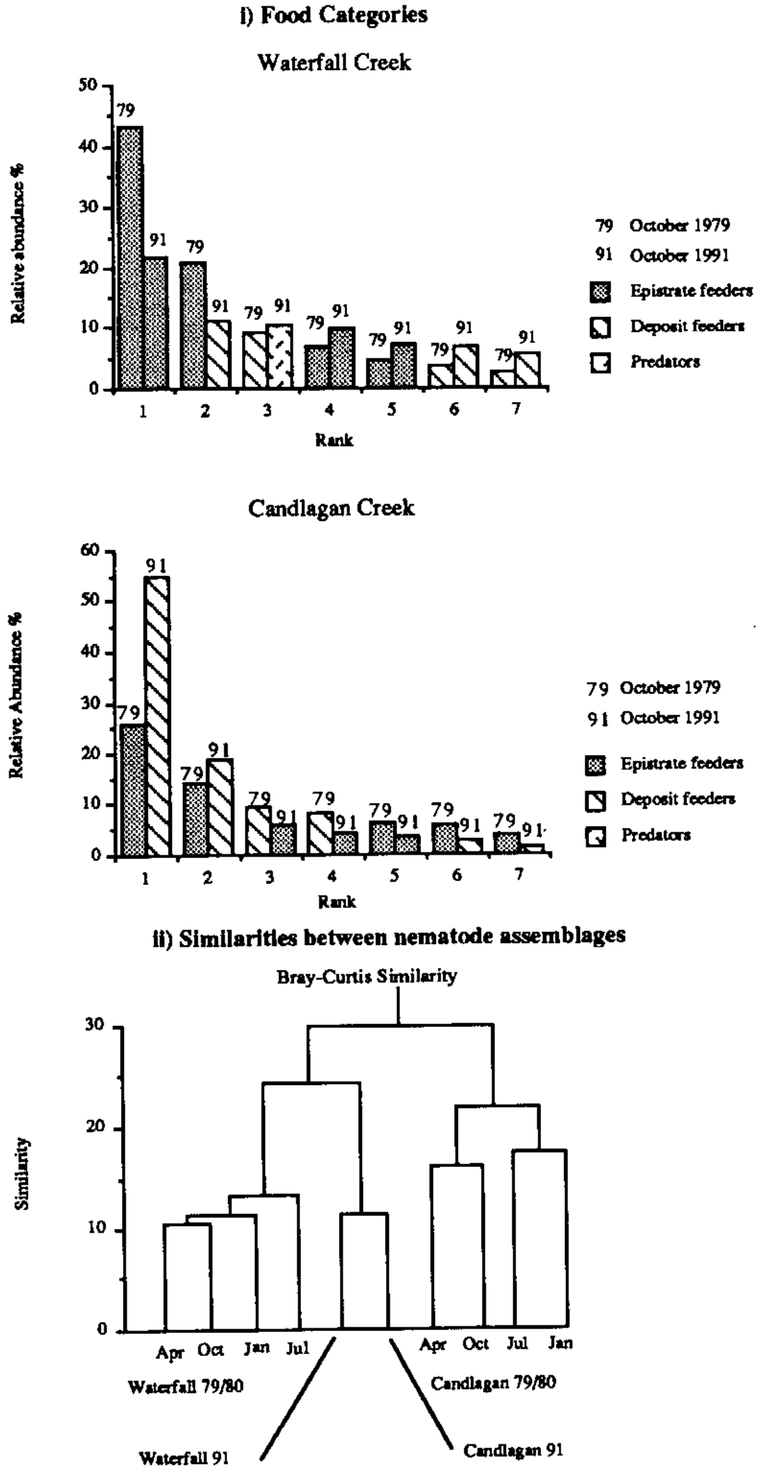

Figure 2 i) Changes in the feeding categories of the dominant nematodes after 12 years at the two creeks
ii) Similarities between the nematode assemblages at different times. Bray-Curtis similarity indices; group average clustering

After 12 years, there have been changes in the faunal composition at both creeks, but in some ways more so at Candlagan than at Waterfall Creek. At Waterfall Creek there has been a highly significant increase in diversity (as measured by Shannon-Wiener H'), with a decrease in diversity occurring at Candlagan Creek, plus corresponding changes in the rank order of species present. The number of epistrate feeders has declined at both creeks, with a consequent increase in the proportion of deposit feeders, but much more so at Candlagan Creek than at Waterfall Creek. It may be that the civil engineering work at Candlagan is responsible for these differences. This is consistent with the observations of other researchers (Bongers *et al.*,1991) that environmental disturbance favours deposit feeders rather than epistrate feeders. Perhaps replacing the septic tanks draining into the creek with piped removal of sewerage has reduced the inflow of nutrients for algae.

In other ways, the faunas at both creeks have changed in a similar direction. There was a significant difference in the maturity index between the two creeks in 1979/80, but by 1991 the index for Waterfall Creek is closer to that at Candlagan Creek . Bray-Curtis cluster analysis shows that although the assemblages at each creek cluster separately in 1979/80, by 1991 the two creek faunas have become more alike, and less similar to either creek in 1979/80. The latter two observations occur at both creeks and consequently suggest responses to unknown environmental influences that have nothing to do with the civil engineering work. Coull (1985) observed non-cyclical changes in meiofaunal populations in a muddy and a sandy South Carolina estuary over 11 years. The meiofaunal assemblages, including the nematodes, showed changes in abundance over this period that exceeded seasonal changes and could not be related to any of the physical parameters measured. We conclude that there has been a change in the nematode assemblages at both creeks for unknown reasons, but that there has been a much greater decrease in the number and proportion of epistrate feeders relative to deposit feeders at Candlagan Creek, and this may well have been the result of civil engineering work.

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