Estuarine Flora and Fauna of Smiths Lake, New South Wales

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Data on the distribution of benthic invertebrates and aquatic macrophytes in Smiths Lake were collected during the summer of 1979/1980. These data are discussed in relation to information on past distributions and hydrological conditions. Qualitative data on the lagoon's fish community are presented.

The distribution of aquatic macrophytes has varied over recent years, probably as a result of salinity changes associated with opening or closure of the lagoon entrance. Under the present salinity regime, seagrass distribution is probably limited by the degree of light penetration and wave action.

Benthic invertebrate communities are related to substrate type and vegetation. Seagrass and sand habitats support more diverse and abundant communities than mud sediments.

Both the benthic and fish communities recorded in Smiths Lake are typically estuarine, and resemble communities in other lagoons along the N.S.W. coast. The absence of several benthic and fish species commonly associated with N.S.W. estuaries is attributed to intermittent closure of the lagoon to oceanic influence.

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INTRODUCTION

In recent years there has been an accumulation of ecological data on the aquatic flora and fauna of New South Wales coastal lagoons. Although some data have been published (MacIntyre, 1959; Thomson, 1959; Wood, 1959; Higginson, 1965, 1970; Weate and Hutchings, 1977; Hutchings *et al.,* 1978; Powis and Robinson, 1980; Harris *et al.,* 1980; Collett *et al.,* 1981; Atkinson *et al.,* 1981), much still remains in the form of theses and student reports. This paper combines unpublished data on Smiths Lake with surveys of the macrobenthic fauna and flora of that lagoon undertaken in the summer of 1979/1980.

STUDY AREA

Smiths Lake is a marine-dominated coastal lagoon (32°24'S, 152°22'E), 130 km north of Newcastle, N.S.W. The lake is 10 km^2 in area with its catchment extending just beyond its perimeter (Bell and Edwards, 1980). Freshwater input is provided by swamps on the southern shore, and during rainy periods by several small creeks (Fig. 1). The median annual rainfall in nearby Bulahdelah is 1251 mm, the wettest months being in late summer and early autumn (Atkinson *et al.,* 1981).

The lagoon is divided into two main regions by a sandbar at Simons Point. The seaward end comprises a wide shallow lagoon (1-2 m deep) with deeper holes (3-4 m) at its northern and southwestern extremities. The western region of the lagoon is twice the area of the seaward region with an average depth of 3-4 m and a maximum depth of 5 m off Big Island.

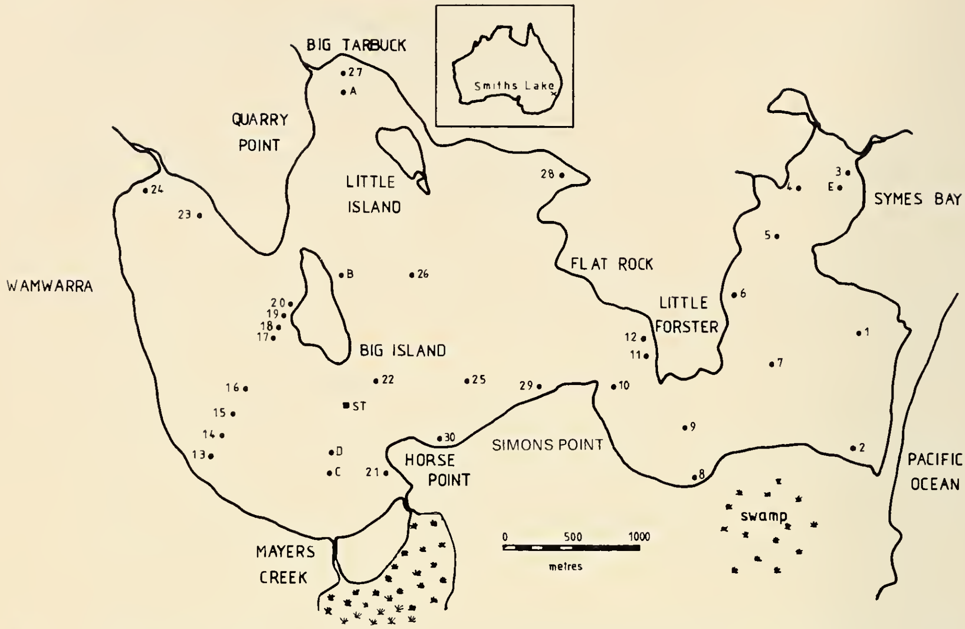

Fig. 1. Smiths Lake showing benthic fauna and salinity/temperature sampling sites (1-30), *Zostera* abundance sites (A-E) and two-year salinity and temperature sampling site (ST).

Smiths Lake is one of many lagoons on the southeast coast of Australia that are closed to the sea by sand barriers. It is opened naturally to the sea when the pressure of flood waters after heavy rain causes the sandbar to give way (Bird, 1967). Since early this century fishermen have periodically opened the sandbar at Smiths Lake to allow the movement of fish from the sea into the lagoon; more recently (1959) it has been breached artificially to prevent flooding. Since 1932, the lagoon has been opened to the sea on an average of once every 1.5 years, with the longest closure being 4 years and the shortest one month. Depending upon the weather conditions, the lagoon has remained open to the sea for periods ranging from one to 11 months.

Hydrology

Materials and Methods

In December 1979, surface and bottom temperatures and salinity readings were recorded at 30 sites (Fig. 1) throughout the lagoon using a salinity — temperature bridge (Hamon, 1956). During this survey the lagoon was closed to the sea, and its waters were approximately one metre above sea level. The most recent connection to the sea occurred between June and August 1978. For two years prior to this survey, surface temperature and salinity readings were recorded monthly at one station (Fig. 1).

Light penetration through the water was measured with a Secchi disc. Between December 1979 and October 1980 Secchi extinction depths were recorded approximately every six weeks at four sites in Smiths Lake (Fig. 1). No readings were taken at Site D because of its close proximity to Site C.

Results and Discussion

The mean and standard deviation of surface and bottom temperatures during

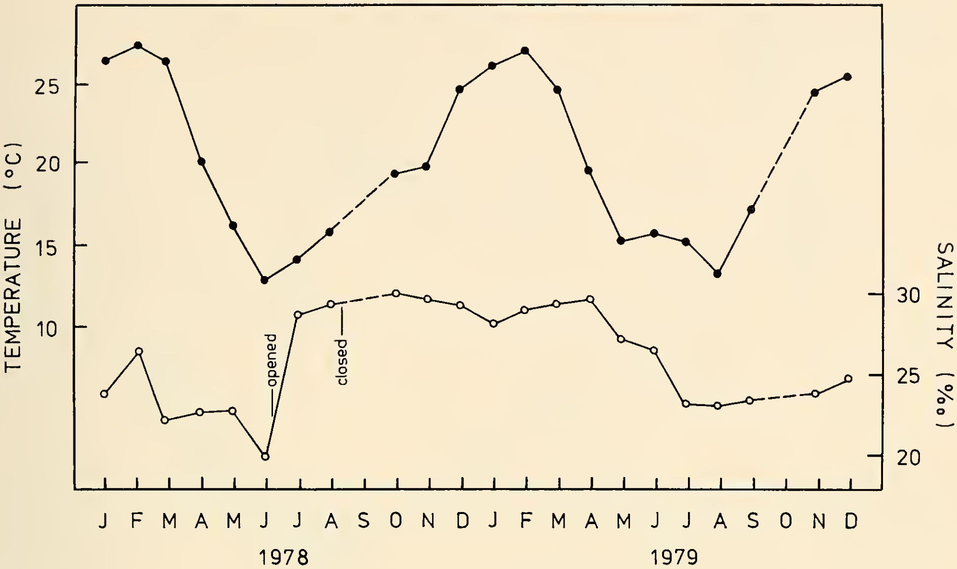

Fig. 2. Salinity and temperature readings at site ST taken over a two-year period.

December 1979 were 26.0 ± 0.67°C and 25.7 ± 0.67°C respectively; salinities were 25.28 ± 0.13‰ and 25.25 ± 0.15‰. This shows that the lagoon was homogeneous with regard to salinity and temperature at that time. However, when the lagoon has been open, salinity and temperature have varied with depth. Haloclines particularly have occurred due to the intrusion of oceanic water (e.g. 25‰ salinity on surface, 31‰ on bottom during February 1973) (U.N.S.W. unpublished student reports).

The monthly surface temperature and salinity readings for 1978-1979 are given (Fig. 2). Seasonal changes in temperature were observed with a maximum of 27°C occurring in February and winter minima of 12°C in June 1978 and 13°C in August 1979. Surface salinity fluctuated between 20-30‰ throughout this period due to rainfall, evaporation and the opening of the lagoon. Minima of 8.5°C and 10‰ have been recorded during the winter of 1967 (Dixon, 1975).

Heavy rainfall prior to June 1978 resulted in a drop in salinity (20‰) and a rise in water level of approximately one metre. Breaching of the sandbar in June 1978 caused an abrupt change. The water level dropped by approximately 2 m and the salinity increased from a minimum of 20‰ to a maximum of 29‰ within 7 weeks.

Light penetration readings ranged between 2.1 m and 2.4 m at the three western sites, but were much higher (3.8 m) at the northeastern site (Table 1). The implications of this for plant growth will be discussed in the next section.

Aquatic Macrophytes

Materials and Methods

In mid December 1979 the occurrence of vegetation was recorded by a SCUBA diver towed on a manta board along transects both perpendicular and diagonal to the shore line. The minimum and maximum depths at which species were found were noted. In February 1980, the abundance of the seagrass *Zostera capricorni* Aschers. was estimated by two methods:

TABLE 1

Estimates of Zostera *abundance in Smiths Lake in February 1980, and Secchi extinction depth taken from December 1979 to October 1980*

Site	N	Depth (m)	Density (shoots/m^2) Mean ± S.E.	Leaf Height (m)	Mean Biomass g/m^2 (dry wgt) Living leaf	Detritus	Root	Total	Secchi Extinction Depth m. Mean ± S.E.
A.	24	1	379 ± 45	—	—	—	—	—	2.2 ± 0.1
B.	24	2	207 ± 233	0.50	60	20	118	198	2.1 ± 0.2
C.	24	2	281 ± 16	0.25	30	30	71	131	2.4 ± 0.2
D.	12	3	115 ± 28	0.30	12	10	6	28	—
E.	24	2	186 ± 15	0.55	72	12	176	260	3.8 ± 0.7

(1) Density (number of upright shoots) was determined in 24 quadrats (0.25 × 0.25 m) randomly distributed in 2.0 m of water at each of 3 sites, 3.0 m at one site and 1.0 m at another (Fig. 1). Comparisons between sites were made using a l-way Analysis of Variance. A test for homogeneity of variance was not significant so untransformed data were used. At each site leaf heights of the longest intact leaves were measured to the nearest 50 mm.

(2) The biomass of *Zostera* was estimated at 4 of the 5 sites from three samples taken at each site with a cylindrical corer, 0.03 m^2 and 100 mm deep. The samples were pooled and sorted into living leaf, detritus and root material. Wet weights were measured to the nearest gram and expressed as dry weight (gm^{-2}) using conversion factors (live leaf × 10.5%; detritus × 8.2%; roots × 9.6%) determined by Barclay (1978).

Results and Discussions

A conspicuous feature of the macrophytic community of Smiths Lake is the abundance of the seagrasses *Zostera capricorni* Aschers. and *Halophila ovalis* (R. Br.) Hook f. *Ruppia* sp. which can tolerate waters of high salinity (Aston, 1973) is also present. The algal flora of the lagoon is dominated by a species of *Dictyota* (Phaeophyta) which resembles most closely *D. furcellata* (C. Agardh) J. Agardh. *Laurencia* spp., *Sargassum* sp. and *Chaetomorpha* sp. occur in some shallow areas, however the taxonomy of these groups is not definitive.

Distribution: The macrophytes were restricted to the soft sediments of the lagoon perimeter and exhibited a general zonation pattern of *Dictyota, Zostera* and *Halophila* with increasing depth (Fig. 3). *Zostera* formed dense beds in the western sector of the lake and in Symes Bay but was absent from the eastern sandflat. *Ruppia* was found at the mouth of both Mayers Creek and the creek in Symes Bay. Clumps of *Dictyota* and *Laurencia* occurred infrequently on the extensive shallow (0.6 m depth) sandflat in the eastern end of Smiths Lake. *Dictyota* also occurred as a continuous band along the southwestern shore. *Laurencia, Sargassum* and *Dictyota* covered the rocks adjacent to Horse Point.

The shallowest occurrence of *Zostera* was 1.1 m in the lee of Little Island and along the northeastern shore (Quarry Pt to Little Forster); along the southwestern shore (Simons Pt to Wamwarra) the minimum depth was 2.0 m. *Zostera* grew to its maximum depth (3.4 m) in Symes Bay and in the southwest region *Halophila* generally occurred as a narrow band 0.5 m deeper than the *Zostera* but extending to 4.0 m depth off Little Island.

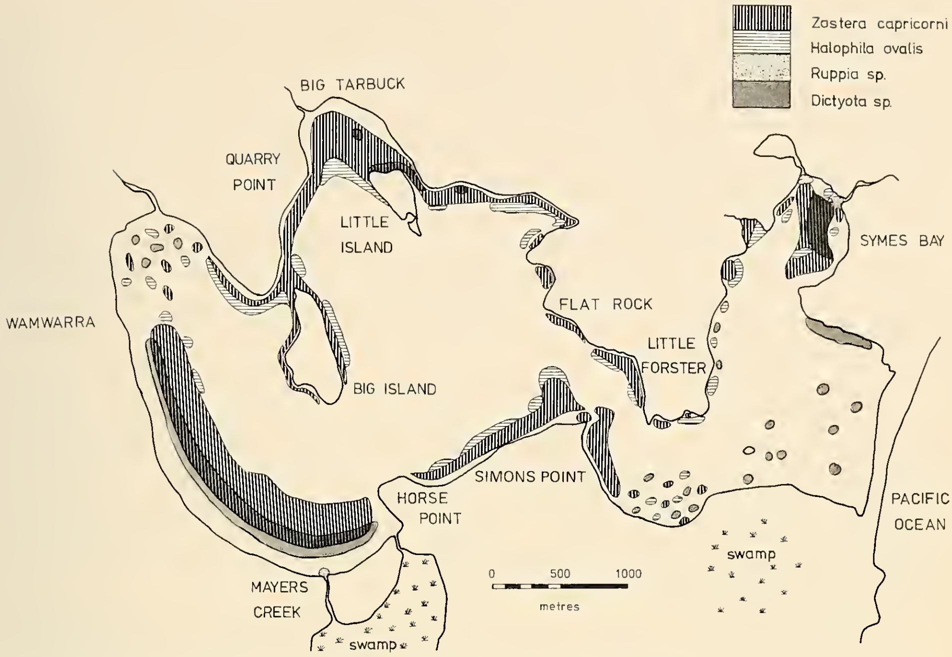

Fig. 3. Distribution of aquatic macrophytes in Smiths Lake, summer 1979/1980.

Local fishermen have reported a change in the distribution of seagrass species over the last 30 years. Before 1960, *Zostera* dominated the steppe (shallow perimeter of the southwestern sector of the lake at a depth of 3.5 m). In the mid 1960s the *Zostera* beds declined and *Ruppia* became the conspicuous angiosperm. Fishermen related this change to a lower salinity for an extended period. In summer 1968, *Ruppia* was the dominant macrophyte on the steppe (U.N.S.W. unpublished student reports), but it was not until February 1970 that the exact distribution of aquatic vegetation was first mapped. This showed that *Zostera* was present in the deeper water and as sparse patches amongst the more dominant *Ruppia* (U.N.S.W. unpublished student reports).

In mid 1970s the *Ruppia* beds disappeared and the steppe was devoid of vegetation for some years, although some *Zostera* was present near Big Island around this time (Dixon, pers. comm.). Fishermen reported the recolonization of the rest of the lake by *Zostera* in the late 1970s and, in February 1979, *Zostera* beds were recorded to a depth of 2.5 m around Big Island (U.N.S.W. unpublished student reports).

Abundance: Shoot density readings of *Zostera* at Site A (one metre deep) were excluded from the ANOVA as they were very much greater than the readings from the 2 m and 3 m sites (Table 1). The 1-way ANOVA of the remaining 4 sites indicated a highly significant difference (9.835, $p < 0.001$) in shoot density. A Student-Newman-Keuls test showed shoot density at the 3 m site (Site D) was less than those at both Sites B and E which in turn were less than that at Site C. The biomass estimate at the 3 m deep site (Site D) was also much less than all the other sites but Sites B and E both had a greater biomass than Site C. Sites B and E were similar in shoot density and total biomass although Site B had a higher detrital biomass and lower root biomass than Site E.

It has been suggested that there is a relationship between *Zostera* abundance and water turbulence and turbidity in N.S.W. coastal lagoons such as Tuggerah

(Higginson, 1965, 1967) and Illawarra Lakes (Harris *et al.,* 1980). Strong northeasterly winds and associated water turbulence occurred prior to the seagrass biomass sampling and if this impeded the normal growth of seagrass, it is likely that sampling took place during a period of regrowth. This would account for the high detrital stock, short leaf lengths and high shoot densities. Site E was protected from the prevailing winds and had the lowest detrital and highest living leaf biomass. Site B, while not as exposed as Site C, seemed to show some effects of the wind in that living leaf biomass was greater and detrital biomass less than at Site C.

Wave action may be a determining factor controlling the inshore limit to which seagrass can grow by not allowing propagating material of seagrass to establish at shallow depths. Thus, the absence of seagrass on the eastern sandflat and the lower depth to which *Zostera* was found on the southwestern shore is possibly due to the prevailing northeasterly winds.

It has been suggested that the availability of light may determine the maximum depth to which *Zostera* grows (Higginson, 1965; Harris *et al.,* 1980). This may account for *Zostera* growing to its greatest depth in the less turbid waters of Symes Bay and the southwestern region of the lagoon. Also, *Zostera* was less abundant at site D, perhaps due to the increase in depth and presumably a decrease in light. *Halophila,* in contrast, was still present at 4 m. This ability of *Halophilia* to tolerate a lower light intensity than *Zostera* has also been observed in Tuggerah Lakes (Higginson, 1965, 1967; Barclay, 1978) and in Lake Macquarie (Barclay, 1978).

On the southwestern shore, the upper distribution of *Zostera* may also be limited by reduced light due to the prolific growth of *Dictyota* forming a blanket across the bottom. This appears to be a spring and summer phenomenon and coincides with the major growth period of *Zostera.*

MACROZOOBENTHOS

Materials and Methods

Two 200 mm diameter sediment cores were taken at each of 30 sites (Fig. 1) in the lagoon during December 1979. Each core was washed through a one-millimetre sieve, the residue sorted and identified as far as possible to species level. Sediment type, seagrass cover and depth were recorded for each site.

A hierarchial monothetic divisive method (DIVINF-Williams, 1976) was used to classify sites using information gain as a dissimilarity index. This indicates the degree of similarity of sites based on presence/absence of species.

The community indices species number (S), number of individuals (N) and evenness (J') (Pielou, 1975) were calculated for each site.

As the faunal classification provided groupings that could be related to habitat types (see Results), the three community indices for each of six randomly chosen sites from each habitat type were compared using 1-way ANOVA. The null hypothesis was that there was no significant difference between habitat types for each of the indices. Tests for homogeneity of variances required N values to be log transformed. For S and J' untransformed data were used.

To provide a more extensive characterization of the fauna of each habitat, the 6 sites from each were lumped and S, N and J' determined for the lumped data in each habitat type. The numerically dominant species in each habitat were also determined.

Results and Discussion

43 species of macrozoobenthos were recorded in this survey (Appendix 1), but many were present only in low numbers or in few sites.

The dendrogram of the classification is shown as Fig. 4 and the classification site

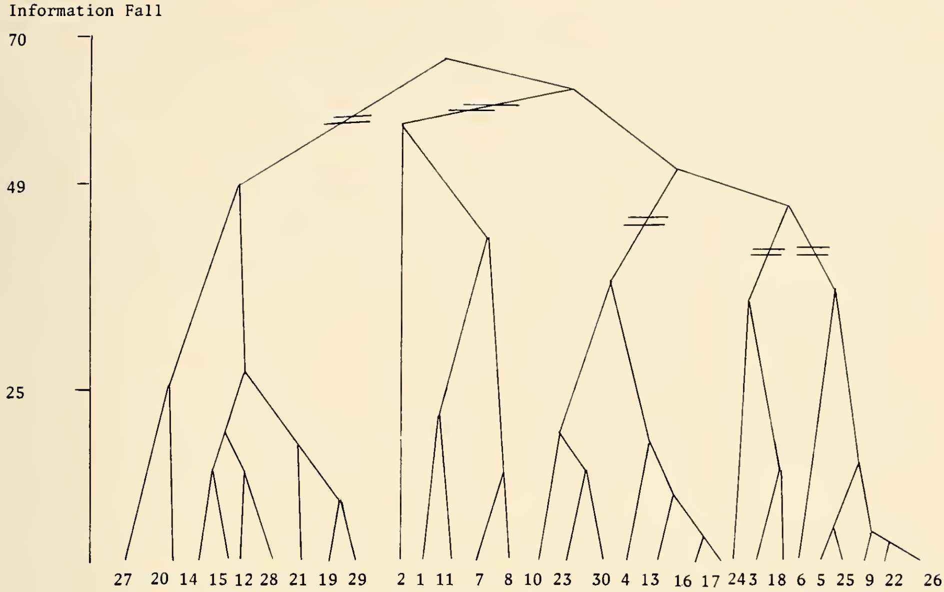

Fig. 4. Dendogram showing macrozoobenthic site groupings.

groupings, habitat type, location, divisive species and other species common to each site group are shown in Table 2. Site groupings were split into 5 groups on the basis of faunal characteristics and these groupings corresponded with habitat type.

Site groups I, II and V showed a very pronounced habitat preference by the fauna. Groups III and IV, however, were evidently quite distinct from the main habitat groups defined by I, II and V. The sand sites in site group II were from the eastern side of the lake whereas the sand sites in site group III were from the central and western areas. The mud in the site group III and the seagrass sites in group IV were both from outlying areas compared with mud in group V and the seagrass sites in Group I.

The separation between sand sites was due to the polychaete *Scoloplos simplex* and the filter feeding bivalve *Sanguinolaria donacioides,* neither of which appeared in the central or western sand sites. The geographical separation amongst seagrass and amongst mud sites was due mainly to the presence or absence of numerically unimportant species. Both seagrass site groups have the same characteristic species regardless of where they were located in the lagoon, as did both mud site groups.

Means and standard errors of community indices for each habitat are shown in Table 3. 1-way ANOVA between habitat types for species number was significant (6.759, $p < 0.01$). S-N-K test showed mud sites to have significantly fewer species than either sand or seagrass sites, while there was no difference between sand and seagrass. N also showed a significant difference (21.674, $p < 0.001$), mud having significantly fewer individuals than sand, which in turn had significantly fewer than seagrass sites. Although the ANOVA for evenness was significant (5.075, $p < 0.05$), the only significant difference was between mud and seagrass sites, the former being greater. High numbers of *Velacumantus australis* in seagrass beds probably accounted for the low evenness.

Table 4 shows community indices and dominant species for lumped data in each

TABLE 2

Macrobenthic Site Groupings

(Z = *Zostera;* H = *Halophila;* S = sand; M = mud; R = *Ruppia*)

Site Group	Site	Habitat	Site Location	Comment
I	27	Z	Mostly seagrass	Presence of *Marphysa sanguinea* separating characteristic.
	20	H, gravel	sites in west	Other common species *Velacumantus australis, Notomastus*
	14	Z	or central part	*torquatus, Owenia fusiformis, Nassarius burchardi.*
	15	Z	of lagoon.	
	28	Z	21 in area	
	19	Z, H	adjacent to seagrass.	
	29	Z	12 at junction of	
	21	S	central/east.	
	12	M/S		
II	2	S, some H	All eastern	Presence of *Scoloplos simplex.*
	1	S	side of lagoon.	Others common: *Sanguinolaria donacioides, N. burchardi.*
	11	S		
	7	S		
	8	S		
V	6	M	Central and	Absence of *O. fusiformis.*
	5	M	east side	Common species: *Tellina deltoidalis, Notospisula trigonella,*
	25	M	of lagoon.	*N. burchardi.*
	9	M		
	22	M		
	26	M		
III	10	S	Central and western	Presence of nemerteans.
	23	M/S sparse Z	areas of lagoon.	Others common: *V. australis, N. burchardi, Tellina*
	30	S		*deltoidalis, N. trigonella.*
	13	S		
	16	M		
	17	M		
	4	M	— N.E. arm.	
IV	24	H, M/S	— N.W. corner	Presence of *O. fusiformis*
	3	H, R, S	— N.E. corner	Others common: *V. australis, T. deltoidalis, N. burchardi.*
	18	Z, H	— West	

habitat type. Total species number in sand and seagrass areas are the same and very much higher than in mud, while evenness in seagrass is reduced compared with the other habitats.

Habitat appeared to play a major part in the structure of infaunal benthic communities within the lagoon. The communities in each of the three main habitat types comprised species which displayed differences in relative abundances, although there was considerable overlap in that a number of species, while dominating one habitat type, could still be found in small numbers in other habitats. This same pattern is found in a number of N.S.W. coastal lagoons (Powis and Robinson, 1980; Robinson, 1982; Gibbs, unpub. data).

Reduced species diversity and/or density in mud habitats have been recorded in N.S.W. coastal lagoons (MacIntyre, 1959; Hutchings *et al.,* 1978; Powis and Robinson, 1980; Robinson, 1982) and elsewhere (cited in Gray 1974; Rhoads, 1974). A variety of theories has been provided to account for this (see Gray, 1974; Rhoads,

TABLE 3

Mean ± standard error of mean for Species Number (S), *Number of Individuals* (N) *and Evenness* (J')*for 6 sites in each habitat*

Habitat type	N	Community Indices	Mean ± S.E.
Seagrass	6	S	9.00 ± 0.73
	6	N	58.83 ± 9.38
	6	J'	0.65 ± 0.04
Sand	6	S	8.50 ± 1.23
	6	N	32.33 ± 5.71
	6	J'	0.77 ± 0.05
Mud	6	S	4.67 ± 0.67
	6	N	10.83 ± 2.21
	6	J'	0.84 ± 0.04

1974), the most often cited being related to habitat diversity. It is possible that limited habitats available in the mud zone provide fewer niches in which species can coexist.

Common species: The gastropod *Nassarius burchardi* was common in all habitats in the lagoon in this (up to 144 specimens per m^2) and past surveys (Hutchings *et al.,* 1978; U.N.S.W. unpub. student reports). A very similar species *N. jonasi,* was found at two sites near the entrance. In the past there has been some confusion in identifying these two species, and often no attempt was made to separate them (Hutchings *et al.,* 1978). *N. jonasi* is more marine than *N. burchardi* and has been found near the entrances to a number of other coastal lagoons (Gibbs and Robinson, unpub. data).

The two bivalves *Tellina deltoidalis* and *Notospisula trigonella* both appeared in a variety of habitats, although they were more abundant in muddy areas (up to 134/m^2 and 32/m^2 respectively). Student reports over the last 12 years confirm this distribution. *T. deltoidalis* was always common, although the numbers of *N. trigonella* were variable. Hutchings *et al.* (1978) did not record *N. trigonella* in Smiths Lake, although it was present there at that time (Dixon, pers. comm.) and in nearby Wallis Lake.

TABLE 4

Community Indices and dominant species for the three habitat types

(S = No. of species; J' = evenness index; N = No. of individuals)

Habitat	Seagrass	Sand	Mud
S	22.0	22.0	12.0
J'	0.58	0.78	0.78
N	301.0	176.0	51.0
Dominant species. (ranked in order of dominance)	1. *V. australis* 2. *O. fusiformis* 3. { *N. torquatus*, *N. burchardi* } 5. *T. deltoidalis*	1. *Tanytarsus* sp. 2. *S. simplex* 3. *S. donacioides* 4. *N. torquatus* 5. { *V. australis,* *N. burchardi* }	1. *T. deltoidalis* 2. *V. australis* 3. *N. trigonella* 4. *N. torquatus* 5. *N. burchardi*

TABLE 5

The dominant fish species in Smiths Lake, listed in taxonomic order

Species
Harengula abbreviata
Hyporhamphus ardelio
Centropogon australis
Platycephalus fuscus
Sillago ciliata
Pomatomus saltatrix
Acanthopagrus australis
Rhabdosargus sarba
Girella tricuspidata
Mugil cephalus
Achlyopa nigra
Monacanthus chinensis
Torquigener hamiltoni

The potamid whelk *Velacumantus australis* was common, particularly in shallow water and seagrass beds (up to 900/m^2). This same habitat preference was also recorded in past years (U.N.S.W. unpub. student reports), although taxonomic problems related to distinguishing juvenile *Pyrazus ebeninus* from *V. australis* have complicated the issue. In the present survey no definite records of *P. ebeninus* were noted, probably due to limited sampling in habitats preferred by this species, i.e. shallow sand/mud flats.

Two common filter feeders, the bivalve *Sanguinolaria donacioides* (up to 160/m^2) and the polychaete *Owenia fusiformis* (up to 800/m^2) were found in sand and seagrass habitats respectively, indicating a distinct preference for areas where a filter feeding life style would be less affected by fine sediments.

The only other common species was a chironomid larva *Tanytarsus* sp. (up to 430/m^2). The polychaete *Ceratonereis mirabilis* and the molluscs *Ostrea angasi* and *Eumarcia fumigata* have been recorded previously from the lagoon (Hutchings *et al.*, 1978), but were not collected during this study.

FISH FAUNA

Materials and Methods

Fish records for Smiths Lake were obtained from the following sources:

(i) University of N.S.W. Summer School Reports (1968-1979),

(ii) Specimens obtained from commercial fishermen, 1978-1979,

(iii) Occasional fishing between 1978-1979.

Between 1968-1979 the fish were sampled in all habitats using gill, seine and dip nets and a miniature otter trawl. As gear and effort varied between collections, only presence or absence of each species is recorded here. The fish species were grouped, according to their frequency of occurrence, as: common (present in greater than 70% of collections); frequent (20% to 70%); rare (less than 20%).

Results and Discussion

Seventy-eight species of fish were recorded in Smiths Lake (Appendix 2). Of these, 13 species (16.6%) were common, 21 species (27%) frequent, and 44 species (56.4%) rare. The 13 common species (Table 5) are all representative of a typically estuarine fish fauna with warm-temperate (Peronian) zoogeographic affinities. Only seven tropical (Solanderian) and four cool-temperate (Maugean) fish species were recorded in the lagoon (Appendix 2).

The fish fauna of Smiths Lake is similar to that of Tuggerah Lakes (Henry and Virgona, 1981) and to that of the *Zostera* seagrass beds in Lake Macquarie (Friedlander, 1980), with the same common species present. It differs, however, from the fish fauna of these and other N.S.W. estuaries (Young, 1981; State Pollution Control Commission, 1981; Paxton, Gibbs, Young and Collett, unpub. data), in the absence of many tropical (e.g. *Leiognathus moretoniensis, Lethrinus nebulosus, Chaetodon* spp., *Heniochus accuminatus* and *Pomacentrus coelestris*) and cold temperate species (e.g. *Gymnapistes marmoratus, Arripis trutta, Neodax semifasciatus* and *Ammotretis rostratus*).

General Discussion

In their study of the Myall Lakes system, Atkinson *et al.* (1981) discussed the possibility of there being characteristic lagoon benthic species, but concluded that this was not the case. The species of benthic fauna present in that study were related to salinity, aquatic vegetation and sediment type and were generally found in other N.S.W. estuaries with similar conditions. Similarly, in Smiths Lake the distribution and abundance of benthic fauna within the lagoon is strongly influenced by the vegetation and sediments. The benthic flora and fauna are also present in other N.S.W. estuaries and no species appear characteristic of Smiths Lake or of coastal lagoons generally.

Although the absence of some species common in other estuaries would be due to the generally low salinity of Smiths Lake, some euryhaline species common in other estuaries, e.g. the polychaete *Barantolla lepte,* have also been consistently absent. Hutchings *et al.* (1978) suggested this was due to the species having pelagic larvae and the sand barrier preventing entrance of these larvae into the lagoon at the appropriate time. This probably applies to other benthic species, however little is known about the breeding behaviour of estuarine benthic fauna.

Similarly, the absence of many estuarine fish species is probably due to the sand barrier restricting migration. The lagoon is usually opened to the sea during midwinter or sometimes in midsummer, but rarely during Autumn or Spring (May, unpub. data). Hence, species that spawn at sea during these latter periods have little opportunity to colonize the lagoon. Even if spawning coincides with the opening, colonization by post-larvae, especially tropical species, would be dependent upon suitable oceanic currents (see Jeffrey, 1981).

Not only are sediment type, vegetation and salinity associated with composition and distribution of biota within Smiths Lake, but also the periodic opening of the sand barrier is important, indirectly by altering salinity and hence vegetation and directly by controlling migration of species into the lagoon.

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Appendix 1

Macrofaunal Species List

Phylum PORIFERA
- Unknown species 1

Phylum CNIDARIA
- Unknown species 1

Phylum ANNELIDA
- Class POLYCHAETA
  - *Australonereis ehlersi* (Augener, 1913)
  - *Ceratonereis* sp.
  - *Marphysa sanguinea* (Montagu, 1815)
  - *Phyllodoce novaehollandiae* Kinberg, 1866
  - *Sigambra parva* (Day, 1963)
  - *Nephtys australiensis* Fauchald, 1965
  - *Lumbrineris latreilli* Audouin & Milne Edwards, 1834
  - *Scoloplos (Scoloplos) simplex* (Hutchings, 1974)
  - *Magelona dakini* Jones, 1978
  - *Notomastus torquatus* Hutchings & Rainer, 1979
  - *Armandia intermedia* Fauvel, 1902
  - Family Cirratulidae Unknown species 1
  - *Owenia fusiformis* delle Chiaje, 1841-1844

Phylum NEMERTINEA
- Unknown spp.

Phylum MOLLUSCA
- Class GASTROPODA
  - *Velacumantus australis* (Quoy & Gaimard, 1834)
  - *Nassarius burchardi* (Dunker in Phillipi, 1849)
  - *Nassarius jonasi* (Dunker, 1846)
  - *Bedeva hanleyi* (Angas, 1867)
- Class BIVALVIA
  - *Anadara trapezia* (Deshayes, 1840)
  - *Xenostrobus securis* (Lamarck, 1819)
  - *Saccostrea commercialis* (Iredale & Roughley, 1933)
  - *Laternula tasmanica* Reeve, 1818
  - *Tellina (Macomona) deltoidalis* Lamarck, 1818
  - *Sanguinolaria donacioides* (Reeve, 1857)
  - *Notospisula trigonella* (Lamarck, 1818)
  - *Theora fragilis* (A. Adams, 1855)

Phylum ARTHROPODA
- Class CRUSTACEA
- Order Decapoda
  - *Metapenaeus bennettae* (Racek & Dall, 1965)
  - *Callianassa arenosa* Poore, 1975
  - *Amarinus laevis* (Targioni Tozzetti, 1877)
- Order Amphipoda
  - *Megamphopus* sp.
  - *Melita* sp.
  - *Oediceropsis* sp.
  - *Victoriopisa australiensis* Karaman & Barnard, 1979
  - *Cymadusa* sp.
  - Family Aoridae Unknown species 1
- Order Isopoda
  - *Cyathura* sp.
  - Family Sphaeromidae Unknown species 1
- Class INSECTA
  - Family Chironomidae
  - *Tanytarsus* sp.

Phylum UROCHORDATA
- Class ASCIDIACAE
  - *Styela plicata* Lesueur, 1803

Phylum CHORDATA
- Class PISCES
  - *Parkraemaria ornata* (Whitley, 1951)
  - *Urocampus carinorostris* Castelnau, 1872

APPENDIX 2

Checklist of fishes collected in Smiths Lake

S = Tropical (Solanderian); P = Warm temperate (Peronian);
I = Introduced; M = Cold temperate (Maugean);
C = Common; F = Frequent;
R = Rare.

SCIENTIFIC NAME	COMMON NAME	OCCURRENCE	ZOOGEOGRAPHIC AFFINITY
ANGUILLIDAE			
Anguilla australis Schmidt, 1928	Short finned eel	F	M
Anguilla reinhardti Steindachner 1867	Long finned eel	F	P
ELOPIDAE			
Elops australis Regan, 1909	Giant herring	R	S
CLUPEIDAE			
Harengula abbreviata Valenciennes, 1847	South herring	C	P
Hyperlophus translucidus McCulloch, 1917	Translucent sprat	R	P
Hyperlophus vittatus (Castelnau, 1875)	Sandy Sprat	R	P
ENGRAULIDAE			
Engraulis australis (Shaw, 1790)	Australian anchovy	R	P
SYNODONTIDAE			
Trachinocephalus myons (Schneider, 1801)	Painted grinner	R	S
GONORHYNCHIDAE			
Gonorhynchus greyi (Richardson, 1845)	Beaked salmon	R	P
BATRACHOIDIDAE			
Batrachomoeus dubius (Shaw, 1790)	Frogfish	R	P
ANTENNARIIDAE			
Antennarius striatus (Shaw, 1794)	Anglerfish	R	P
HEMIRHAMPHIDAE			
Hyporhamphus ardelio (Whitley, 1931)	River garfish	C	P
BELONIDAE			
Tylosurus macleayanus (Ogilby, 1886)	Stout long tom	F	S
POECILIIDAE			
Gambusia affinis (Baird & Girard, 1854)	Mosquito fish	F	I
ATHERINIDAE			
Atherinosoma microstoma (Gunther, 1861)	Small mouthed hardyhead	F	M
Pranesus ogilbyi Whitley, 1930	Ogilby's hardyhead	F	P
Pseudomugil signifer Kner, 1867	Blue-eye	F	P
FISTULARIDAE			
Fistularia petimba Lacepede, 1803	Smooth flute-mouth	R	P
SYNGNATHIDAE			
Syngnathus altirostris Ogilby, 1890	Steep nosed pipefish	R	P
Syngnathus margaritifer Peters, 1869	Mother-of-pearl pipefish	R	P
Urocampus carinirostris Castelnau, 1872	Hairy pipefish	F	P
Hippocampus whitei Bleeker, 1855	Common seahorse	R	P
SCORPAENIDAE			
Centropogon australis (White, 1790)	Fortesque	C	P
Notesthes robusta (Gunther, 1860)	Bullrout	R	S
TRIGLIDAE			
Chelidonichthys kumu (Lesson & Garnot, 1826)	Red gurnard	R	P
PLATYCEPHALIDAE			
Platycephalus arenarius Ramsay & Ogilby, 1886	Sand flathead	R	P
Platycephalus fuscus Cuvier, 1829	Dusky flathead	C	P
AMBASSIDAE			
Priopodichthys marianus (Gunther, 1880)	Yellow perchlet	R	P
Velambassis jacksoniensis (Macleay, 1881)	Perchlet	R	P
THERAPONIDAE			
Pelates quadrilineatus (Bloch, 1829)	Four lined trumpeter	F	S
Pelates sexlineatus Quoy & Gaimard, 1824	Six lined trumpeter	R	P
APOGONIDAE			
Siphamia roseigaster (Ramsay & Ogilby, 1866)	Pink breasted siphonfish	R	P

Appendix 2 (Continued)

Checklist of fishes collected in Smiths Lake

S = Tropical (Solanderian); P = Warm temperate (Peronian);
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R = Rare.

Scientific Name	Common Name	Occurrence	Zoogeographic Affinity
SILLAGINIDAE			
Sillago ciliata Cuvier, 1829	Sand whiting	C	P
Sillago maculata Quoy & Gaimard, 1824	Trumpeter whiting	F	P
POMATOMIDAE			
Pomatomus saltatrix (Linnaeus, 1766)	Tailor	C	P
CARANGIDAE			
Trachurus mccullochi Nichols, 1920	Yellowtail	R	P
Caranx georgianus (Macleay, 1881)	Trevally	R	P
GERREIDAE			
Gerres ovatus Gunther, 1859	Silver biddy	F	P
SPARIDAE			
Acanthopagrus australis (Gunther, 1859)	Yellowfin bream	C	P
Chrysophrys auratus (Bloch & Schneider, 1801)	Snapper	F	P
Rhabdosargus sarba (Forskal, 1775)	Tarwhine	C	P
MONODACTYLIDAE			
Monodactylus argenteus (Linnaeus, 1758)	Silver batfish	R	P
KYPHOSIDAE			
Girella tricuspidata (Quoy & Gaimard, 1825)	Luderick	C	P
SCORPIDIDAE			
Microcanthus strigatus (Cuvier, 1831)	Stripey	R	P
ENOPLOSIDAE			
Enoplosus armatus (Shaw, 1790)	Old wife	R	P
CHEILODACTYLIDAE			
Cheilodactylus fuscus Castelnau, 1879	Red morwong	R	P
MUGILIDAE			
Aldrichetta forsteri (Valenciennes, 1836)	Yellow-eye mullet	R	M
Liza argentea (Quoy & Gaimard, 1825)	Flat tail mullet	F	P
Mugil cephalus Linnaeus, 1758	Sea mullet	C	P
Mugil georgii Ogilby, 1897	Fantail mullet	R	P
Myxus elongatus Gunther, 1861	Sand mullet	F	P
Myxus petardi (Castelnau, 1875)	Freshwater mullet	R	P
SPHYRAENIDAE			
Sphyranella obtusata (Cuvier, 1829)	Striped sea pike	R	P
LABRIDAE			
Achoerodus gouldii (Richardson, 1843)	Blue groper	F	P
ODACIDAE			
Heteroscarus acroptilus (Richardson, 1846)	Rainbow fish	R	M
URANOSCOPIDAE			
Ichthyscopus lebeck (Bloch & Schneider, 1801)	Stargazer	R	S
CLINIDAE			
Cristiceps australis Cuvier & Valenciennes, 1836	Crested weedfish	R	P
CALLIONYMIDAE			
Callionymus calcaratus Macleay, 1881	Spotted stinkfish	F	P
GOBIIDAE			
Arenigobius bifrenatus (Kner, 1865)	Bridled goby	F	P
Favonigobius exquisitus Whitley, 1950	Exquisite goby	R	S
Favonigobius lateralis (Macleay, 1881)	Goby	F	P
Favonigobius tamarensis (Johnston 1883)	Tamar river goby	R	P
Gobiopterus semivestita (Munro, 1949)	Goby	R	P
Parkraemaria ornata (Whitley, 1951)	Goby	R	P
Pseudogobius olorum (Sauvage, 1880)	Goby	P	P

APPENDIX 2 (Continued)

Checklist of fishes collected in Smiths Lake

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C = Common;
F = Frequent;
R = Rare.

SCIENTIFIC NAME	COMMON NAME	OCCURRENCE	ZOOGEOGRAPHIC AFFINITY
ELEOTRIDAE			
Philypnodon grandiceps (Krefft, 1864)	Flat headed gudgeon	R	P
BOTHIDAE			
Pseudorhombus arsius (Hamilton Buchanan, 1822)	Large toothed flounder	F	P
Pseudorhombus jenynsii (Bleeker, 1855)	Small toothed flounder	R	P
SOLEIDAE			
Achlyopa nigra (Macleay, 1881)	Black sole	C	P
MONACANTHIDAE			
Meuschenia freycineti (Quoy & Gaimard, 1824)	Variable leatherjacket	R	P
Meuschenia trachylepis (Gunther, 1870)	Yellow finned leatherjacket	F	P
Monacanthus chinensis (Osbeck, 1765)	Fanbellied leatherjacket	C	P
Scobinichthys granulatus (Shaw, 1790)	Rough leatherjacket	R	P
TETRAODONTIDAE			
Torquigener glaber (Freminville, 1873)	Toado	R	P
Torquigener hamiltoni (Gray & Richardson, 1843)	Toado	C	P
Torquigener pleurogramma (Regan, 1903)	Toado	R	P
Torquigener squamicauda (Ogilby, 1910)	Toado	R	P
DIODONTIDAE			
Dicotylichthys myersi Ogilby, 1910	Porcupine fish	R	P