Macrophytes, fishes and invertebrates of Wallis Lake, New South Wales

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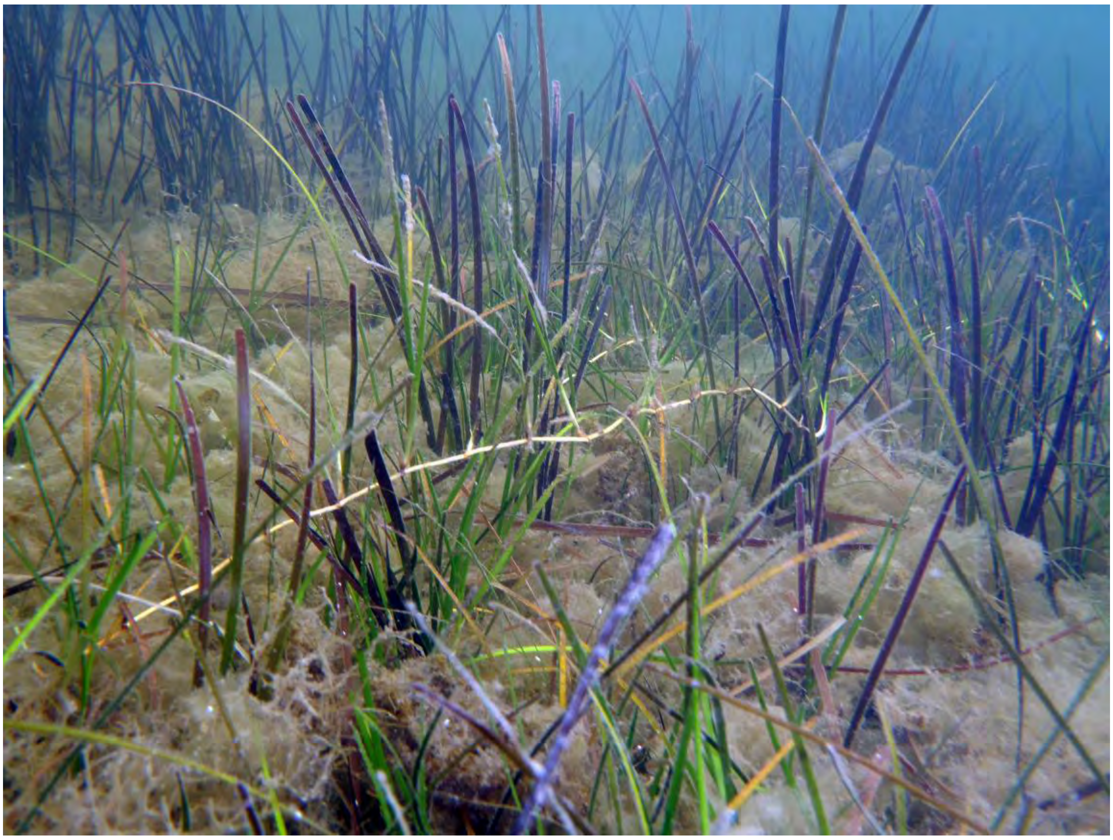

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1. Introduction

A review of biological information about Wallis Lake is underway with the aim of ascertaining whether Wallis Lake might have appropriate biological values to justify its addition to the nearby Myall Lakes Ramsar site. This report contributes to that review by compiling recent information about macrophytes, invertebrates and fishes. Specifically, the Department of Industry & Investment (I&I NSW) was contracted by NSW Department of Environment, Climate Change and Water (DECCW) to:

1. Map the current distribution of sponges and macrophytes in the central-southern basin of Wallis Lake.
2. Provide an assessment of fishes and macroinvertebrates in Wallis Lake compared to other NSW estuaries.
3. Compare sponges in Wallis Lake to other NSW estuaries.

This report describes the results of Parts 1 and 2 and summaries the main results for Part 3. The complete sponge report (prepared by Dr Peter Barnes) has been provided separately. This report is not a comprehensive review of biological information available for Wallis Lake, but rather a summary of recent studies done by I&I NSW and Dr Peter Barnes. All results have been provided to Suzanne Fiebig (Pacific Blue Design) for incorporation into a broad review of information available on Wallis Lake.

2. Methods

2.1 Fish and macroinvertebrate survey data

Data from selected estuarine surveys done by I&I NSW over the last 15 years were used to create a list of fishes and macroinvertebrates sampled in Wallis Lake. These studies used a combination of gill nets and seine nets and included sites scattered throughout Wallis Lake, from the Wallamba River in the north down to Booti Island in the south (Fig. 1, Table 1).

Fish and macroinvertebrate survey data from the central-southern basin of Wallis Lake were also compared to those from other NSW lakes. Only those lakes that were deemed similar to Wallis Lake in their geology, geomorphology and hydrology (i.e. classified as lakes by Roper *et al.* 2010) were compared. Comparisons were done in two ways. First in a qualitative manner by examining all the species caught across multiple studies in Wallis Lake and 11 similar lakes (Table 1). These studies were done in different years, by different people, using different methods over a range of habitats. Any species that were sampled only in Wallis Lake were noted. Second, data from the Estuarine Monitoring Evaluation and Reporting (MER) program in 2007/2008 which were collected in a standardised manner were compared among estuaries using a quantitative multivariate analysis. The MER study was done in Wallis Lake and five other estuaries (Table 1). MER sampling used seine and gill nets to sample fish in the central mud basin zone of each lake. The sampling design consisted of three seagrass (*Zostera capricorni*) sites in each lake with $n = 5$ replicate seines per site. Fish were also sampled in non-vegetated habitats using seine nets or gill nets as part of this MER study, but the data were not analysed formally as there were too many replicate samples with no catch. Quantitative comparisons were made using the PRIMER 6 + PERMANOVA software package using untransformed data and Bray Curtis similarities. Two random factors, “Lake” and “Site nested within Lake” were analysed, in addition to the asymmetrical contrast “Wallis Lake vs other lakes”.

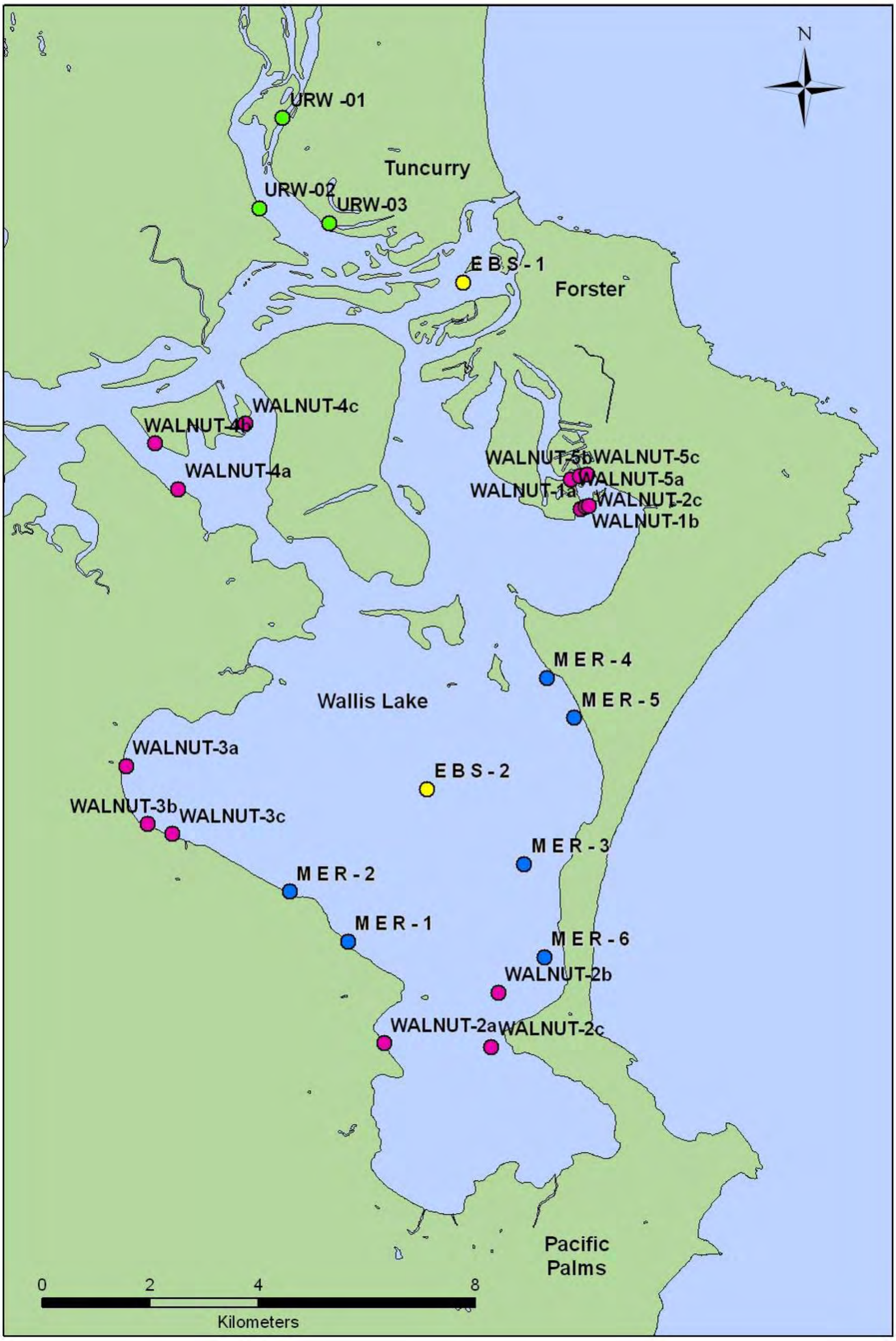

Fig. 1: Fish and macroinvertebrate sampling sites in Wallis Lake. Data from all sites were used to create a list of species present in Wallis Lake, whereas data from only the six blue (MER) sites in the central basin were used in quantitative (multivariate) comparisons with other NSW lakes.

Table 1: Lakes sampled by I&I NSW for fish and macroinvertebrates. ***** indicates data used for quantitative (multivariate) comparisons which involved the same sampling methods, effort and habitats. Data from all other times were used only for qualitative (descriptive) comparisons.

Estuary	Time sampled	Habitat sampled	Methods
Wallis Lake	1996-1997	Macrophytes, Wallamba River	Seine
	Feb-00	Entrance/lake	Seine
	Dec-07 *	Bare/*Zostera*	Seine/Gill
	Apr-08	*Zostera*	Seine
South West Rocks	Apr-04	Bare/seagrass	Seine
Camden River	Dec-01	Bare/seagrass	Seine
Smiths Lake	Nov-00	Bare/seagrass	Seine
Lake Macquarie	Feb-00	Bare/seagrass	Seine
	Dec-07 *	Bare/*Zostera*	Seine/Gill
Tuggerah Lake	Feb-00	Bare/seagrass	Seine
	Jan-08 *	Bare/*Zostera*	Seine/Gill
Brisbane Water	Feb-00	Bare/seagrass	Seine
	Jan-08 *	Bare/*Zostera*	Seine/Gill
Lake Illawarra	Mar-00	Bare/seagrass	Seine
	Jan-08 *	Bare/*Zostera*	Seine/Gill
St Georges Basin	Apr-00	Bare/seagrass	Seine
	Dec-07 *	Bare/*Zostera*	Seine/Gill
Swan Lake	Mar-01	Bare/seagrass	Seine
Lake Conjola	Nov-00	Bare/seagrass	Seine
Merimbula	Dec-00	Bare/seagrass	Seine

2.2 Commercial fish catch data

Total weights of species of finfish and invertebrates caught commercially in Wallis Lake during the 2008/2009 financial year were compiled from the I&I NSW commercial fishery (ComCatch) database. Data on the commercial finfish catches for Wallis Lake from 2004-2009 were compiled and compared to other NSW estuaries and lakes. Numbers of commercial fishing licences were also compared among estuaries.

2.3 Macrophyte mapping

Macrophyte mapping involved the delineation of habitat boundaries from scanned aerial photos. The most recent images available for Wallis Lake were captured in 2005. All features were delineated via onscreen digitising at a scale of 1:1500. All ‘presumptive’ maps were then validated in the field from a small boat in May 2010. The boat was navigated around the mapped patches with a trained operator annotating the presumptive map by adding areas, subtracting areas or changing the classifications (e.g. for different seagrass species) as required. These changes were captured within a real-time computer mapping system using ArcPad, a GPS, an underwater video system and an acoustic single beam depth sounder. The presumptive map was then updated with the field data as well as by additional reference back to the original photos to produce the final product. While the GPS used in the field has an accuracy of +/-1 m, accuracy arising from the orthorectification was of the order of +/-15 m and the onscreen digitising had an accuracy of +/-2 m (depending on the resolution of the image and the onscreen scale).

The final step in the mapping process was to assign each polygon in the GIS to a macrophyte category. For seagrass, this was done on the basis of presence or absence – if any seagrass at all is present in a polygon it is scored as being 'seagrass'. Subdivision within the 'seagrass' classification is based on the species composition. Thus, polygons may be classified as just one species of seagrass, or as a mixture of taxa. Mangroves and saltmarshes were mapped to the 'community' level rather than down to the level of species.

2.4 Sponge surveys

Sponges, ascidians and other conspicuous invertebrates (e.g. nudibranchs, seahares and octopus) were sampled in the southern basin of Wallis Lake in November 2007 and December 2009 using the methods outlined in Barnes (2010). Different sites were sampled in each year with the exception of those near to Earps and Booti Islands. Twenty one sites were sampled in 2007 south of Earps Island. In 2009, sampling was expanded to include and additional four sites north of Earps Island. Sites were chosen to provide a good representation of the habitats and invertebrate assemblages in the southern portion of Wallis Lake. Each site was approximately 60 metres in diameter and was sampled using a combination of six replicate 2 x 10 m transects and four replicate 5 min timed searches. Full details are contained in Barnes (2010).

3. RESULTS

3. 1 Fish and macroinvertebrate survey data

The fish and macroinvertebrate species in Wallis Lake were consistent with what would be expected from a typical NSW estuarine community assemblage. All the species caught by I&I NSW in the four large sampling projects in Wallis Lake are listed in Tables 2 & 3. Catch per unit effort (CPUE, i.e. total catch divided by the total number of replicate seine and gill nets used in each lake) is presented as an indication of relative abundance among species. Schooling species such as glassfish, striped trumpeter and silver biddy were amongst the most commonly caught, in addition to bottom dwelling gobies and catfish which are typically in large abundances in lakes and estuaries. In the northern sites of Wallis Lake, large numbers of species more suited to brackish conditions such as the large-mouthed goby, *Redigobious macrostoma*, the Swan River goby *Pseudogobius olorum* and the Tamar River goby, *Afurcagobious tamarensis* were caught. The southern region of Wallis Lake tended to have a greater abundance of species such as the half bridled goby, *Arenigobius frenatus*, small mouthed hardyhead, *Atherinosoma microstoma* and the eastern fortescue, *Centropogon australis*, but these species were also caught in the northern sites.

Multivariate analyses indicated that the fish and macroinvertebrate assemblages in seagrass beds (sampled using seine nets) in Wallis Lake were not significantly different from the fish and macroinvertebrate assemblages in seagrass beds in the other five comparable lakes (pseudo-$F_{1,\ 16\ \mathrm{df}} = 1.67$, $P = 0.06$; Fig. 2). There was significant variability in assemblages among sites within all estuaries, as can be seen by the scatter of points in Fig. 2.

Some fish and invertebrate species recorded from Wallis Lake were not sampled from any other comparable NSW estuary as part of the studies used in this report (Table 4).

Most of these species were sampled in very small abundances in Wallis Lake and, although not sampled in the I&I NSW studies analysed here, all have been recorded from other estuaries in NSW. Likewise, there were taxa which were not found in Wallis Lake that were captured in comparable estuaries. These results do not indicate an absence of these species from Wallis Lake or comparable estuaries.

The striped catfish, *Plotosus lineatus*, had the fourth highest CPUE in Wallis Lake and was not recorded in any of the comparable NSW estuaries. *P. lineatus* has an extensive distribution along the entire NSW coast and is commonly found in large schooling balls. The seemingly high abundance of *P. lineatus* is likely explained by one or more of these schools being sampled via seine net, resulting in a high CPUE. The absence of *P. lineatus* from all other estuaries is unusual due to its common status, however, it is likely that this fish does occur in many of the sampled waterways and has evaded capture thus far, perhaps due to its concentrated schooling behaviour.

Notably, one of the fish sampled only in Wallis Lake, the crimson-tipped gudgeon *Butis butis,* was outside its published distributional range. Three individuals were recorded from the Wallamba River in 1996/97. *B. butis* is a tropical freshwater gudgeon with a recorded southernmost distribution on the east coast of the Richmond River, Ballina.

All lakes contained the three most commonly caught macroinvertebrates in Wallis Lake, namely the long armed shrimp, *Macrobrachium intermedium*, the weed shrimp, *Palaemon sp.* and the swarming shrimp *Acetes sibogae australis*. The fourth most commonly caught invertebrate in Wallis Lake, the slender beaked shrimp *Chlorotocella spinicaudus*, was not recorded from the other estuaries in our surveys, although this species is known to occur throughout coastal NSW.

Table 2: Catch per unit effort (CPUE, i.e. catch per replicate seine or gill net) of fish sampled in Wallis Lake by I&I NSW from 1996-2008 (studies and sites used are identified in Table 1 and Fig. 1). CPUE is provided as an indication of relative abundance because each study had a different sampling effort.

Species name	Common Name	CPUE
Ambassis jacksoniensis	Glassfish	82.128
Redigobius macrostoma	Large-mouth goby	78.942
Pseudogobius olorum	Swan River goby	37.298
Plotosus lineatus	Striped catfish	16.539
Gobiopterus semivestita	Glass goby	16.496
Pseudomugil signifer	Southern blue-eye	15.240
Pelates sexlineatus	Eastern striped trumpeter	15.050
Afurcagobius tamarensis	Tamar River goby	11.194
Gerres subfasciatus	Silver biddy	10.465
Liza argentea	Flat-tail mullet	6.295
Arenigobius frenatus	Half-bridled goby	5.612
Atherinosoma microstoma	Small mouthed hardyhead	4.969
Centropogon australis	Eastern fortescue	4.853
Siphamia roseigaster	Silver siphonfish	4.640
Philypnodon grandiceps	Flathead gudgeon	4.302
Favonigobius exquisitus	Exquisite sand goby	3.430
Acanthopagrus australis	Yellow fin bream	2.353
Favonigobius lateralis	Long finned goby	1.446
Rhabdosargus sarba	Tarwhine	1.434
Arenigobius bifrenatus	Bridled goby	1.213
Meuschenia trachylepis	Variable leatherjacket	1.171
Mugil cephalus	Sea mullet	1.101
Myxus elongatus	Sand mullet	1.070
Sillago ciliata	Sand whiting	0.961
Siphamia cephalotes	Little siphonfish	0.950
Urocampus carinirostris	Hairy pipefish	0.860
Girella tricuspidata	Luderick	0.849
Atherinomorus vaigiensis	Ogilbys hardyhead	0.760
Ambassis marianus	Estuary perchlet	0.748
Tetractenos hamiltoni	Common toadfish	0.659
Monodactylus argenteus	Silver batfish	0.616
Hyperlophus vittatus	Sandy sprat	0.585
Bathygobius krefftii	Kreffts goby	0.496
Monacanthus chinensis	Fan-belly Leatherjacket	0.322
Herklotsichthys castelnaui	Southern herring	0.167
Siganus nebulosus	Happy moment	0.124
Petroscirtes lupus	Brown sabretooth blenny	0.109
Pandaka lidwilli	Dwarf goby	0.105
Platycephalus fuscus	Dusky flathead	0.097
Monacanthidae juvenile	Leatherjacket juvenile	0.085
Pseudorhombus arsius	Large toothed flounder	0.078
Synaptura nigra	Black sole	0.066
Cryptocentrus cristatus	Oyster goby	0.062
Torquigener pleurogramma	Weeping toad	0.050
Hyporhamphus regularis	River garfish	0.043
Pseudorhombus jenynsii	Small-toothed flounder	0.039
Sphyraena obtusata	Striped sea pike	0.039

cont.

Table 2 (continued)

Species name	Common Name	CPUE
Arenigobius spp.	Gobys	0.035
Mugilogobius pallidus	Mangrove goby	0.035
Tylosurus gavialoides	Stout longtom	0.035
Cnidoglanis macrocephalus	Estuary catfish	0.031
Meuschenia freycineti	Six-spined leatherjacket	0.031
Paramonacanthus otisensis	Dusky leatherjacket	0.031
Tetractenos glaber	Smooth toadfish	0.031
Glossogobius biocellatus	Goby	0.027
Pomatomus saltatrix	Tailor	0.027
Hippocampus whitei	Whites seahorse	0.023
Marilyna pleurosticta	Banded puffer	0.023
Sillago maculata	Trumpeter whiting	0.023
Lethrinus genivittatus	Lancer	0.019
Scobinichthys granulatus	Rough leatherjacket	0.019
Vanacampus margaritifer	Mother of pearl pipefish	0.019
Engraulis australis	Australian anchovy	0.016
Galaxias maculatus	Common jollytail	0.016
Philypnodon spp.	Dwarf flathead gudgeons	0.016
Tetraodontidae juvenile	Toadfish juvenile	0.016
Batrachomoeus dubius	Frogfish	0.012
Butis butis	Crimson-tipped gudgeon	0.012
Dasyatis fluviorum	Estuary stingray	0.012
Callionymus limiceps	Rough headed dragonet	0.008
Caranx spp.	Trevallys	0.008
Dinolestes lewini	Longfin pike	0.008
Gambusia holbrooki	Gambusia	0.008
Gobiidae species	Gobys	0.008
Mugilogobius spp.	Gobys	0.008
Scatophagus argus	Spotted scat	0.008
Anguilla reinhardtii	Long-finned eel	0.004
Antennarius striatus	Striped anglerfish	0.004
Atypichthys strigatus	Australian mado	0.004
Chelidonichthys kumu	Red gurnard	0.004
Cristiceps australis	Crested weedfish	0.004
Dasyatis spp.	Stingrays	0.004
Dicotylichthys punctulatus	Three-bar porcupinefish	0.004
Enoplosus armatus	Old wife	0.004
Gobiidae juvenile	Goby juvenile	0.004
Leptoscarus vaigiensis	Seagrass parrotfish	0.004
Lutjanus fulviflammus	Black spot snapper	0.004
Notesthes robusta	Bullrout	0.004
Parkraemeria ornata	Ornate goby	0.004
Pegasus volitans	Slender seamoth	0.004
Platycephalus caeruleopunctatus	Blue-spot flathead	0.004
Pseudogobius sp	Blue spot goby	0.004
Repomucenus calcaratus	Spotted stinkfish	0.004
Scomberoides lysan	Queenfish	0.004
Stigmatopora nigra	Wide body pipefish	0.004
Upeneus tragula	Bar-tail goatfish	0.004

Table 3: Catch per unit effort (CPUE) of macroinvertebrates sampled in Wallis Lake by I&I NSW from 1996-2008 (sites sampled are identified in Table 1 and Fig. 1). CPUE is provided as an indication of relative abundance because each study had a different sampling effort.

Species name	Common Name	CPUE
Palaemon sp. (debilis?)	Shrimp	323.378
Macrobrachium intermedium	Long-armed shrimp	194.993
Acetes sibogae australis	Swarming shrimp	70.141
Chlorotocella spinicaudus	Slender beaked shrimp	37.400
Penaeus plebejus	King prawn	16.104
Metapenaeus macleayi	School prawn	6.119
Latreutes pygmaeus	Hump-backed shrimp	4.385
Idiosepius notoides	Southern pygmy squid	2.430
Mysidia spp.	Opossum shrimps	0.644
Penaeus esculentus	Tiger prawn	0.541
Metapenaeus bennettae	Greasyback prawn	0.348
Alpheus richardsoni	Shrimp	0.289
Palaemon spp.	Weed shrimps	0.259
Hymenosoma hodgkini	Spider crab	0.156
Macrobrachium cf novaehollandiae	Long-armed shrimp	0.104
Grapsidae spp.	crabs	0.096
Portunus pelagicus	Blue swimmer crab	0.044
Juvenile squid	Juvenile squid	0.044
Euprymna tasmanica	Dumpling squid	0.030
Thalamita spp.	Sand crabs	0.030
Xanthidae spp.	Stone crabs	0.030
Amarinus spp.	Spider crabs	0.022
Latreutes Type 1	Shrimp	0.016
Cardinia maccullochi	Shrimp	0.015
Hippolytidae	shrimp	0.015
Pandalidae	Shrimp	0.012
Sepiidae spp.	cuttlefishes	0.008
Alpheus spp.	Shrimps	0.004
Loliolus noctiluca	Inshore squid	0.004
Metapenaeus spp.	Penaeid prawns	0.004
Penaeus spp.	Penaeid prawns	0.004

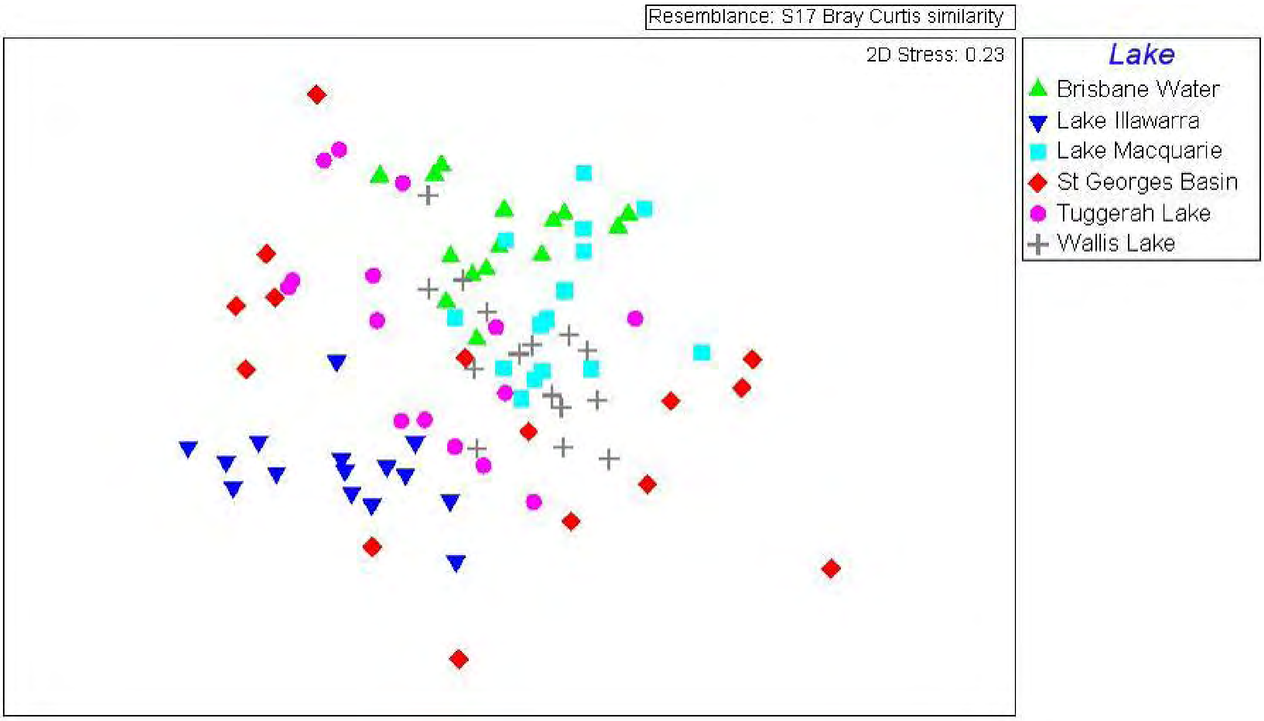

Fig. 2: nMDS plot showing similarity among seagrass sites in terms of the fish and macroinvertebrate assemblages caught in seine nets. The closer together the points, the more similar the assemblages. Each point represents a replicate seine sample; *n* = 5 from each of 3 sites per lake.

Table 4: Fish and macroinvertebrates caught only in Wallis Lake in studies by I&I NSW from 1996-2008 (as listed in Table 1).

Species	Common name
Alpheus richardsoni	Shrimp
Butis butis	Crimson-tipped gudgeon
Callionymus limiceps	Rough headed dragonet
Caridina maccullochi	Shrimp
Chlorotocella spinicaudus	Slender beaked shrimp
Euprymna tasmanica	Dumpling squid
Hymenosoma hodgkini	Spider crab
Loliolus noctiluca	Inshore squid
Metapenaeus spp.	Penaeid prawns
Mugilogobius pallidus	Mangrove goby
Notesthes robusta	Bullrout
Palaemon debilis	Slender beaked shrimp
Pandaka lidwilli	Dwarf goby
Parkraemeria ornata	Ornate goby
Pegasus volitans	Slender seamoth
Penaeus spp.	Penaeid prawns
Plotosus lineatus	Striped catfish
Scomberoides lysan	Queenfish

3.2 Commercial fish catch data

The biomass of commercially caught finfish in Wallis Lake, averaged over the last 6 years, is comparable to the typical catch across other NSW estuaries and lakes (Table 5). Wallis Lake does, however, support more commercial fishing businesses than the average for a NSW estuary; it has the 5th largest number of fishing business of any NSW estuary (Table 5). Wallis Lake has the greatest commercial catch of crustaceans (primarily blue swimmer crabs, mud crabs and prawns) of any NSW estuary, as well as the greatest commercial oyster production in NSW.

Fifty species of fish or invertebrates were caught by commercial fishers in Wallis Lake during the 2008/2009 financial year (Table 6). Sea mullet (*Mugil cephalus*) were the most significant catch (by weight) followed by blue swimmer crabs, flathead and whiting (Table 6). Prawns and mud crabs were also important commercial catches.

Table 5: Commercial fishing catch data (averaged over 2004-2009) and number of fishing businesses in the 2008/2009 financial year. Data from I&I NSW ComCatch database.

Estuary	Average #days fished 2004-09	Average kg/day 2004-09	# registered fishing businesses in 2008-09
Wallis Lake	114.0	64.2	51
Tweed Cobaki Broadwater Terranora	113.4	44.8	22
Richmond River North Creek R Ck	64.3	100.9	28
Clarence R Iluka Maclean Yamba Wooloweyah	109.5	66.2	101
Lake Wooloweyah	55.9	59.7	56
Macleay River, Spencers Creek, Trial Bay	93.1	37.5	20
Lake Innes, Lake Cathie	75.4	36.1	9
Camden Haven R, Queens Lake, Watson Taylors Lake, Nth Haven, Laurieton	151.1	33.2	21
Manning River, Crowdy Heads	76.1	72.5	16
Smiths Lake	51.9	67.7	12
Port Stephens/ Myall Lakes, Myall River, Tea Gardens	97.9	77.0	60
Hunter River	59.2	69.6	34
Tuggerah Lakes, Munmorah, Budgewoi	123.3	68.8	45
Hawkesbury River, Broken Bay, Brisbane Water, Pittwater, Patonga	105.0	77.1	56
Lake Illawarra, Wollongong	88.9	93.1	18
Shoalhaven River, Crookhaven River	95.7	78.1	17
Lake Wollumboola	19.9	68.7	7
Coila Lake	30.8	69.8	7
Corunna Lake	30.5	54.8	9
Wallaga Lake	53.4	94.3	13
Average of all NSW estuaries	80.5	66.7	30

Table 6: Biomass of finfish and invertebrates caught commercially in Wallis Lake during the 2008/2009 financial year. Data from I&I NSW ComCatch database.

Species	Weight (kg)
Sea mullet	102,718
Blue swimmer crab	57,254
Luderick	32,964
Dusky flathead	27,457
Sand whiting	22,722
Yellowfin bream	19,441
School prawn	18,550
Giant mud crab	13,004
Greentail prawn	11,698
Eastern king prawn	10,960
River garfish	5,278
Goldspot mullet	3,461
Sand mullet	2,766
Common silverbiddy	2,359
Tailor	1,889
Catfish	1,373
Trumpeter whiting	1,339
Brown tiger prawn	1,196
River eels	782
Cockles	730
Tarwhine	553
Octopus	526
Leatherjackets	445
Bonito	381
Diamondfish	335
Eastern sea garfish	333
Shovelnose rays	326
Southern calamari	162
Estuary squid	153
Mulloway	135
Cuttlefish	115
Bluespotted flathead	115
Mackerel tuna	83
Flounders	72
Striped grunters	51
Wobbegong sharks	28
Silver trevally	27
Yellowfin tuna	25
Hammerhead sharks	24
Australian sardine	18
School shark	12
Whaler shark	12
Yellowtail kingfish	8
Dart	8
Snapper	5
Yellowtail scad	4
Australian salmon	2
Soles	1
Goatfish	1

3.3 Macrophyte mapping

In general, boundaries of charophytes (primarily *Lamprothamnium* sp.) could not be mapped because (a) they were not distinguishable in aerial photos and (b) charophytes were very sparsely distributed over large areas. It is also important to note that the distribution and abundance of charophytes is known to vary greatly over relatively short periods of time (months), so any map of their distribution is unlikely to be accurate for long. We did, however, identify two large patches of dense charophytes in the south-east section of Wallis Lake which seemed to be relatively consistent over time (Fig. 4). Other small areas of dense charophytes were found during surveys for sponges and these have also been identified, but their precise boundaries have not been delineated (Fig. 4). In general, charophytes were most abundant around the edges of the southern basin of Wallis Lake, but were found in small densities intermingled with seagrasses across much of the lake to the south of Booti Island.

Narrow bands of *Ruppia megacarpa* were found in shallow water along the south-eastern shoreline. By far the most dominant seagrass in the southern basin was *Zostera capricorni* which occurred as either monospecific beds or mixed with species such as *Halophila* spp., *R. megacarpa* or *Posidonia australis*. Monospecific beds of *Halophila* were sparse and not mapped because they could not be distinguished in aerial photos.

Within the central-southern basin of Wallis Lake, a total of 1643.20 hectares of seagrasses (i.e. excluding charophytes) were mapped in 2010 compared to 1573.95 hectares in the same area in 2002 (based on imagery from 1997). Of the total seagrass area in 2010, 3.98 hectares were mapped as monospecific beds of *P. australis*. The *Posidonia* beds were mostly small and patchy and occurred only north of 32°18'S (around the town of Whoota on the western shore; Fig. 4). Notably, the total area of monospecific *Posidonia* in this central-southern basin appears to have increased considerably since 2002 when just 0.64 hectares were mapped in the same area. This apparent increase has been due to increases in the size of *Posidonia* beds along the western shoreline and increased numbers of small patches in the central region (Fig. 4). Comparisons of *Zostera* over time are difficult to make because in 2010 *Zostera* occurred as either monospecific beds, or mixed with other species, while in 2002 it was mapped only as monospecific beds. Moreover, the 2002 map did not identify any *Ruppia,* which could indicate that *Zostera* was confused with *Ruppia*.

It is noteworthy that the area of saltmarsh in the southern basin of Wallis Lake was estimated at 69.1 ha in 2002, but just 43.8 ha in 2010. Again, differences might be due in part to differences in mapping techniques and the quality of aerial images, but such a large difference in a habitat that is known to be vulnerable to human disturbances is a concern.

One of the most interesting findings during the macrophyte mapping of 2010 was the discovery of the seagrass *Halodule tridentata* (Steinheil) F. von Muell, which has not been recorded in NSW previously. *H. tridentata* (family Cymodoceacea) was found growing sparsely amongst *Z. capricorni* across much of the southern basin of Wallis Lake (Fig. 5). The species was identified by Professor John Kuo (University of Western Australia), who confirmed that this was the first record of the species in NSW and the southernmost distribution of the species on the east Australian coast. It was not possible to map the distribution of this species in this project because the species was extremely scattered and could not be distinguished from *Z. capricorni* in aerial photos.

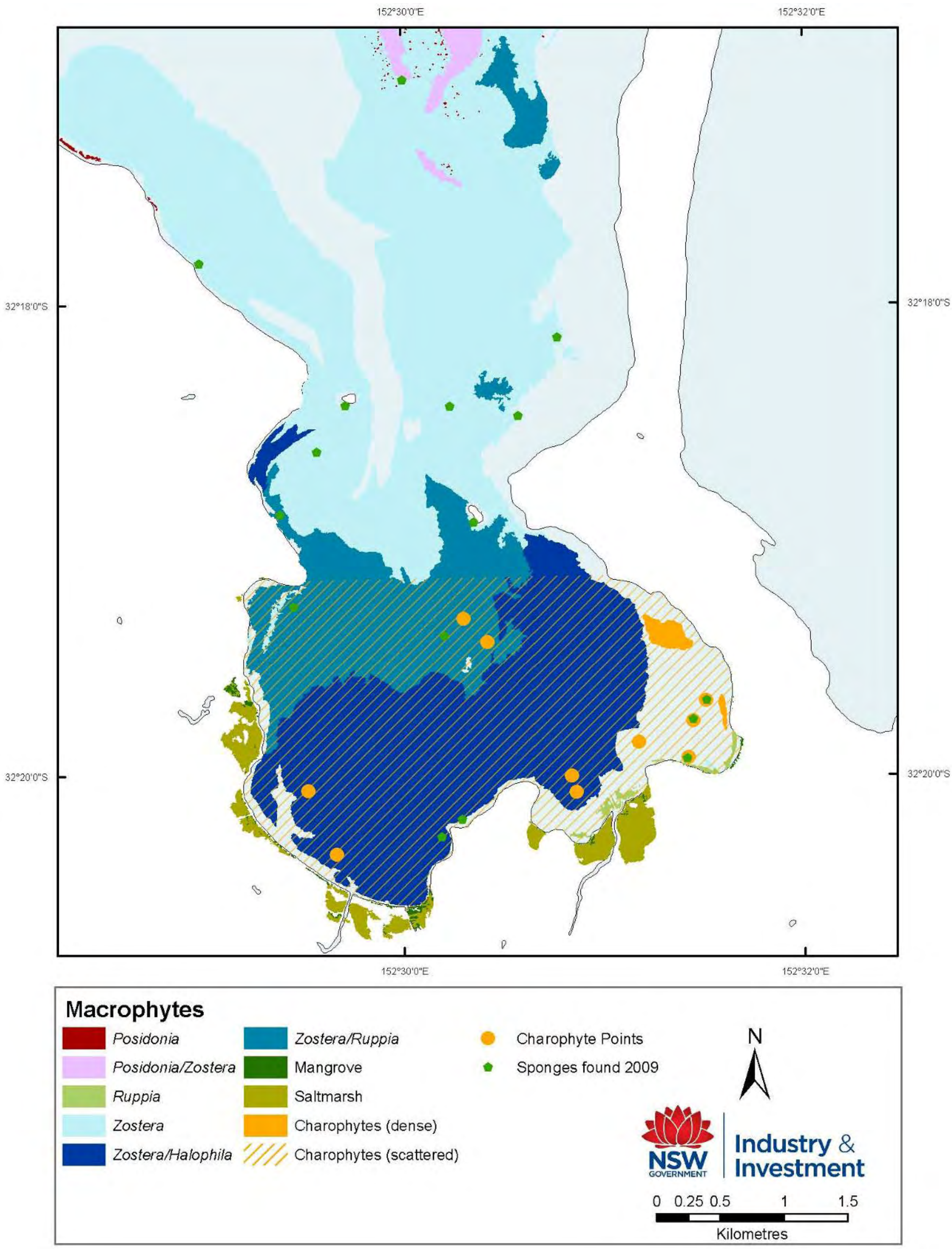

Fig. 4: Macrophytes in the central-southern basin of Wallis Lake, based on an aerial image taken in 2005 and field validation in May 2010. Boundaries of small beds of dense charophytes were not mapped, but points are provided to indicate their locations. Sites where sponges were found in the December 2009 are also marked.

Fig. 5: The seagrass *Halodule tridentata* (centre, light green) growing amongst *Zostera capricorni* (dark brown) in Wallis Lake, May 2010. Note the growth form with rhizomes exposed and growing over *Z. capricorni*. This is the first record of this species in NSW.

3.4 Sponge and invertebrate surveys (summary of Barnes 2010)

3.4.1 November 2007

Four species of sponge (*Aplysilla* c.f. *sulphurea, Chondrilla* c.f. *australiensis, Mycale* sp., *Suberites* sp.), two species of solitary ascidian (*Styela plicata, Eudostoma laysani*), one species of sea hare (*Aplysia* sp.) and one species of nudibranch (*Hypselodoris obscura*) were recorded in the southern basin of Wallis Lake (Barnes 2010). *Styela plicata* is an introduced ascidian which is widespread throughout Australia and much of the world but is not classified as a pest.

Three general regions were able to be categorised based on the type and density of seagrasses and macroalgae present. These were:

1. Habitat dominated by the charophyte, *Lamprothamnium* sp. in the southernmost portion of the Lake, including Pacific Palms, Charlotte Bay and the southern portion of the bay west of Deepwater Point (sites 1,2,3,7,12, 13,14 in Barnes (2010)). Typically sites were no deeper than 1.5 metres. The sponges, *Suberites* sp., *Aplysylla* c.f. *sulphurea* and *Mycale* sp., and the ascidians, *Styela plicata* and *Eudostoma laysani* were found in this region. Previous studies from 2001-2004 (Barnes, unpublished data), found these areas and the charophyte meadows had a consistently large diversity and abundances of sponges.
2. A central region which generally consisted of a mosaic of patches of *Zostera capricorni*, with large areas of bare sediment in the middle of the lake. No sponges or ascidians were found in this region. Typically the water was murkier with less visibility than other in other habitats.
3. The northern portion to Earps Island was dominated by meadows of *Zostera capricorni* which were tall, dense and healthy in appearance, interspersed with patches of *Ruppia* and filamentous algae. The sponges, *Mycale* sp. and *Aplysilla* cf. *sulphurea* were very abundant in some of the sites, typically found attached to the leaves of the seagrasses (sites 6, 18 and 19 in Barnes (2010)).

With the exception of small rocky regions around the Earps and Booti Islands, the substratum at all sites consisted of soft sandy or muddy sediment.

3.4.2 December 2009

Survey effort was more intensive in 2009, and an additional seven species of sponge (*Aplysilla* c.f. *sulphurea*, *Chondrilla* c.f. *australiensis, Dysidea* sp., *Mycale* sp., *Raspaillia* sp., *Suberites* sp., Calcareous sponge), one species of ascidian (*Styela plicata*), one species of sea hare (*Aplysia* sp.) and one species of nudibranch (*Chromodoris daphne*) were recorded in the southern basin of Wallis Lake. Sites where any sponge was found have been identified in Fig. 4.

Similar to the survey in 2007, the southernmost portion of the Lake, including Pacific Palms, Charlotte Bay and the southern portion of the bay west of Deepwater Point (sites 22, 23, 24, 25, 41, 44 in Barnes (2010)), was characterised by beds of the charophyte, *Lamprothamnium* with patches of seagrass and other macroalgae. Typically sites were no deeper than 1.5 metres. On the days of sampling, water clarity was poor in this region and there appeared to be a heavy sediment/microalgal cover on the aquatic vegetation. The water clarity on these days was the worst that had been observed during sponge surveys since 2001 (P. Barnes, pers. com.).

The sponge, *Suberites* sp., (Fig. 6) was found at a number of sites along the southern shoreline where *Lamprothamnium* was present, but in very small abundances, with most individuals relatively small (less than the volume of a golf ball) and showing signs of necrosis. An opportunistic investigation of the small jetty adjacent to Pacific Palms Recreation Club found six relatively larger individual *Suberites* sp. which were healthy in appearance showing no signs of necrosis. These individuals were attached to the pylons in the top 50 cm of the water column. *Suberites* sp. was not found on the rocky reefs near Earps and Booti Islands. Previous studies from 2001-2004 (Barnes, unpublished data), have found these rocky areas and *Lamprothamnium* meadows have consistently contained the largest diversity and abundances of sponges in Wallis Lake.

The remainder of the sites were not easily categorised based on habitats, as was done for the 2007 survey. Rather, the sites contained varying covers of the seagrasses, *Zostera capricorni, Halodule tridentata, Posidonia australis, Halophila spp., Ruppia megacarpa*, in addition to red and green algae, but generally did not contain *Lamprothamnium*. With the exception of small rocky regions around the Earps and Booti Islands, the substrata at all sites consisted of sandy or muddy sediments.

There has been a clear decline in the abundances of sponges in the southern basin of Wallis Lake. Most notably, the most obvious and largest sponge, the bright blue *Suberites* sp., was not found in transects in December 2009 (although some individuals were seen during timed searches), whereas 1 – 4 individuals tended to be found in transects from 2002 – 2007 (Fig. 7). As part of the macrophyte surveys in May 2010, searches for sponges were done at the southernmost sites (where sponges had been most abundant in previous years). Only one dead *Suberties* sp. was found. Moreover, no *Suberites* sp. were found on the jetty adjacent to Pacific Palms Recreation Club where six healthy individuals were seen in December 2009.

3.4.3 Invertebrates in Wallis Lake compare to other NSW lakes

In terms of diversity of ascidians, Wallis Lake cannot be considered unique. Of the two species found, *Styela plicata* is an introduced and widespread species in Australian waters and *Eudistoma laysani* is a cosmopolitan species. Additional species (*Pyura stolonifera*, *Micocosmus squamiger*) have been found in previous studies (Barnes 2009), but again these are cosmopolitan species with broad distributions.

It is difficult to provide a quantitative assessment of the uniqueness of Wallis Lake in terms of its molluscan fauna (nudibranchs, sea hares, octopuses), because there appears to be no information on the distribution of these animals in other NSW lakes and lagoons. It would appear, however, that nudibranchs and sea hares are typically rare or in most cases absent from other lakes and lagoons, while not uncommon in Wallis Lake (P. Barnes, pers. obs).

The uniqueness of Wallis Lake in terms of diversity of invertebrates lies with its sponge fauna. In a survey of 10 coastal lakes in 2002 (Barnes 2009), Wallis Lake with ten species had almost twice as many species as any other lake. Sponges and ascidians are absent from the majority of lakes and lagoons in NSW. Most species appear restricted in distribution to only one or a few lakes. For example, *Dysidea* sp., *Raspaillia* sp., a species of *Haliclona* and a species of *Halichondria* have only been recorded in Wallis Lake (Barnes 2009). Of the twelve species so far reported from the southern basin of

Wallis Lake only, *Chondrilla* c.f. *australiensis* and *Aplysilla* c.f. *sulphurea* could be tentatively identified to species. The remainder are likely to be undescribed and new to science.

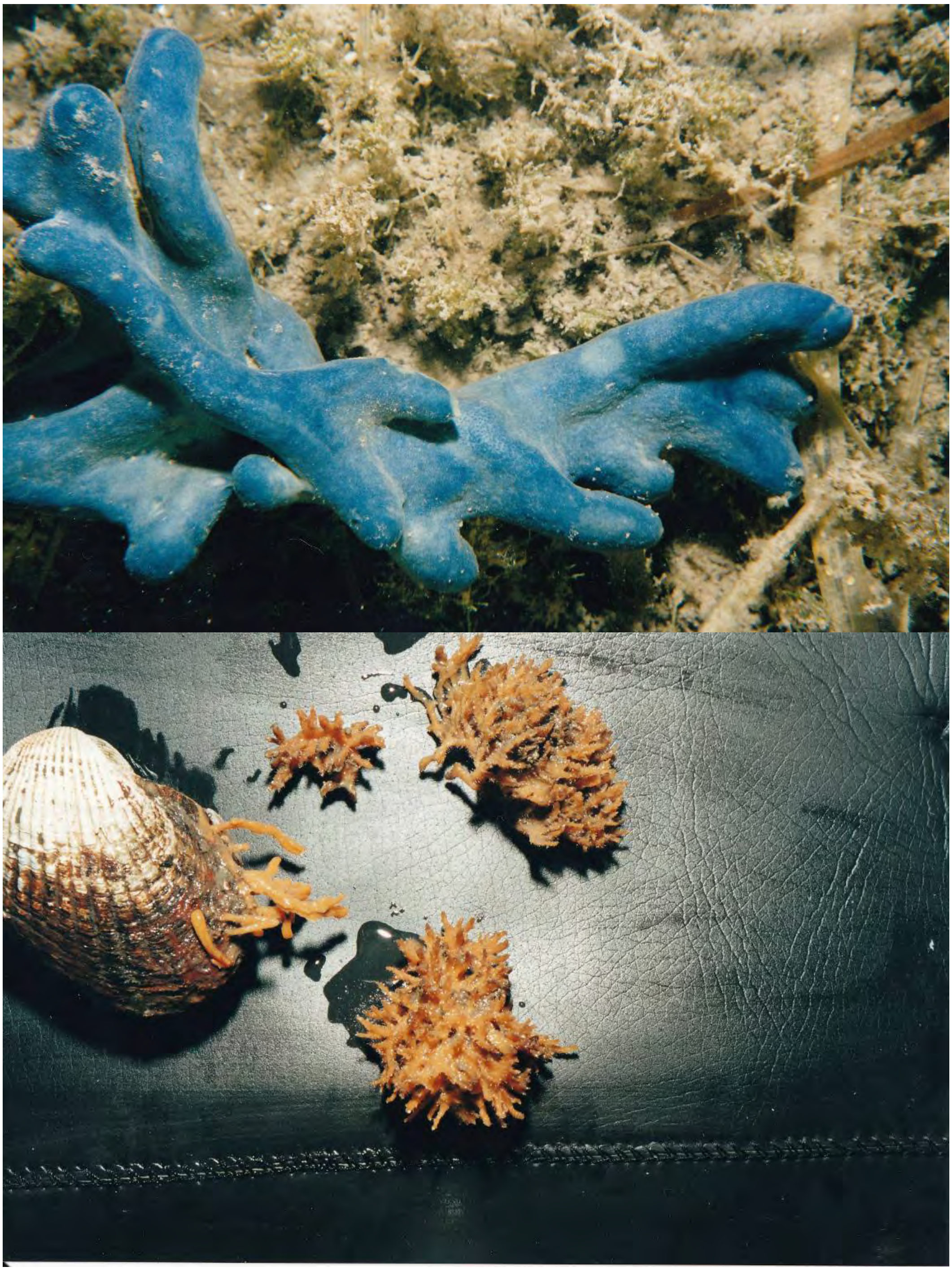

Fig. 6: Examples of sponges found in Wallis Lake, December 2009. Top, *Suberites* sp., bottom, *Raspaillia* sp. Photos courtesy of Peter Barnes.

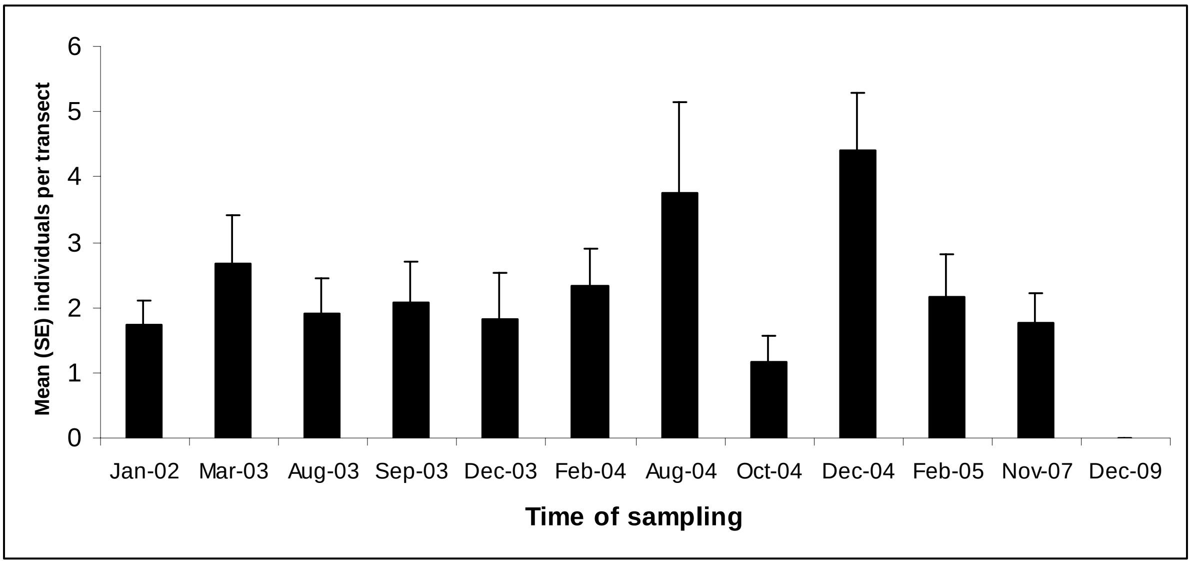

Fig. 7: Mean (+SE) number of *Suberites* sp. in charophyte meadows in the southern basin of Wallis Lake (*n* =12 transects). All data collected by Peter Barnes (Barnes 2010) and are included here with his permission.

4. Discussion and Conclusions (including text from Barnes 2010)

The data analysed here indicate that Wallis Lake is similar to other NSW lakes in terms of fish and macroinvertebrate fauna (sampled using seine and gill nets). Gibbs (1985) formed a similar conclusion after a qualitative review of studies on fishes and invertebrates done in estuaries throughout NSW. It is, however, noteworthy that Gibbs (1985) suggested that the macrobenthic fauna in Wallis Lake seemed to be amongst the more diverse of NSW barrier lagoons (which includes estuaries not classified as lakes according to the definition used here), together with Lake Macquarie, Crookhaven River, Tuross River, Wagonga Inlet and Merimbula Lake.

In the present review, some species were sampled in Wallis Lake but not sampled by I&I NSW in other NSW lakes. These species are not, however, unique to Wallis Lake, nor necessarily rare in other lakes. All species have been recorded in numerous NSW lakes and most are known to have a wide distribution within NSW. The one exception to this was the crimson-tipped gudgeon *Butis butis* which was recorded from the Wallamba River in 1996/97. This species is a tropical brackish water gudgeon with a previously recorded southernmost distribution in the Richmond River, Ballina.

There is a moderate commercial catch of finfish in Wallis Lake relative to other NSW estuaries, and the lake supports more commercial fishing businesses than most other NSW estuaries. Wallis Lake has the greatest commercial catch of crustaceans (primarily blue swimmer crabs, mud crabs and prawns) of any NSW estuary, as well as the greatest commercial oyster production in NSW.

The overall diversity and distribution of sponges and ascidians in Wallis Lake in 2007 and 2009 were similar to previous years. In 2009, however, the abundances, sizes and apparent health of the sponges were reduced compared to previous years. Most notably, the most obvious and largest sponge, the bright blue *Suberites* sp., was less abundant in 2009 than during any survey from 2002 – 2007, and was not seen during macrophyte surveys in May 2010. It is possible that this decline is related to an apparent increase in turbidity in the southern basin of Wallis Lake, but there may be numerous other possible causes. In coastal environments, the distribution of sponges and ascidians may be affected by a variety of human impacts (Carballo *et al.* 1996; Carballo & Naranjo 2002) including sewage and silt deposition (Roberts *et al.* 1998; Roberts *et al.* 2006). While little is known of the tolerances of the sponges in Wallis Lake to impacts such as silt deposition, it is likely that increased sediment loads would adversely affect their physiology and feeding efficiency.

The sponge fauna of Wallis Lake appears to be different from other similar NSW lakes. In a survey of 10 coastal lakes in 2002 (Barnes 2009), Wallis Lake with ten species had almost twice as many species as any other lake. Sponges are absent from the majority of lakes and lagoons in NSW, and many species appear to be restricted to only one or a few lakes. For example, *Dysidea* sp., *Raspaillia* sp., a species of *Haliclona* and a species of *Halichondria* have been recorded only in Wallis Lake. Moreover, Hutchings et al. (1978) found fewer than 10 sponges (not identified to species) in over 200 grab samples taken at 9 sites in Wallis Lake. Of the 12 species so far reported from the southern basin of Wallis Lake, only *Chondrilla* c.f. *australiensis* and *Aplysilla* c.f. *sulphurea* have been tentatively identified to species. The remainder are likely to be undescribed and new to science.

The main vegetated marine habitats in Wallis Lake are seagrasses, mangroves and saltmarshes (Adam 1985). Mangroves are found primarily around the northern shoreline of the lake (Adam 1985) and as such only small areas were mapped in the current study which focussed on the southern basin. Wallis Lake contains the largest area of seagrasses of any NSW estuary (the most recent estimate being 3190 hectares (31.9 km^2)) and it represents the most northerly extent of *Posidonia australis* in NSW (Creese *et al.* 2009). Wallis Lake contains the second largest area of saltmarsh in any NSW estuary after Port Stephens (Creese *et al.* 2009). It is notable that the area of saltmarsh mapped in the southern basin during this project was less than had been mapped in the same area in 2002. During the 2010 macrophyte mapping, I&I NSW staff found a species of seagrass (*Halodule tridentata*) that had not been recorded previously from NSW. The species is ostensibly similar to *Zostera capricorni*, in that it has narrow green/brown leaves.

Of the features examined here, the three that set Wallis Lake apart from most other saltwater lakes in NSW are:

- A large abundance of sponges has been recorded in Wallis Lake.
- A species of seagrass, *Halodule tridentata*, which is relatively widespread (although patchy) in the central-southern basin of Wallis Lake has not been recorded from any other NSW lake or estuary. Wallis Lake is currently the southernmost known distribution of this species along the east Australian coast.
- More area of seagrass than any other NSW estuary or lake and the second largest area of saltmarshes.
- The most northerly extent of *P. australis* in NSW.

The notable findings of this study that may warrant further investigation are:

- The apparent large decline in the numbers of sponges in the southern basin of Wallis Lake, concomitant with an apparent increase in turbidity. Even if this decline is a natural occurrence, small numbers of individuals may render populations more susceptible to extinction from unforeseen or planned human disturbances (e.g. increased nutrient loads leading to loss of aquatic vegetation; large inputs of sediment from construction, road works, land-clearing, etc.).

- The apparent decline in the amount of saltmarsh in the southern basin of Wallis Lake. This possible decline will be further investigated when macrophytes in all of Wallis Lake are mapped by I&I NSW in late 2010 using high resolution digital imagery captured in mid 2010. At this stage it is not possible to determine whether the estimated decline may actually be a consequence of different mapping techniques used in 2002 and 2010.

5. ACKNOWLEDGEMENTS

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