CHAPTER F. IMPACT ON THE BIOPHYSICAL ENVIRONMENT

The purpose of this chapter is to focus on aspects of the general environment of estuaries, beyond those fish and invertebrates that are caught as a result of the fishery. It describes the major types and extents of habitats commonly found in NSW estuaries and describes how each of these and the fauna that depend on them, may be affected by the Estuary General Fishery. It assesses the effectiveness of control measures outlined in the draft FMS to minimise these potential impacts, and the effectiveness of the monitoring and research programs proposed in the draft FMS to provide the information required to adequately assess the potential impacts of the Estuary General Fishery. Physical aspects, such as water and air quality, are also discussed both in terms of the impact that fishing has on them, and how they affect the fishery.

1. Biodiversity and Habitat Issues

At least 690 waterbodies join the Tasman Sea along the NSW seaboard, although the vast majority of these are rarely open to the sea (Williams *et al.*, 1998). Approximately 130 have a water area greater than 0.05 km^2, and the Estuary General Fishery is, or has been, conducted to some degree in most of these larger estuaries (Table F1). The estuaries cover a range of shapes, sizes and geological origins (see Appendix F1), and these factors are largely responsible for determining the distribution and abundance of physical habitats and ecological assemblages. Other factors such as the degree and rate of sedimentation and water quality characterisation of an estuary are also important influences on the presence and abundance of the major habitats, particularly seagrasses, mangroves, saltmarsh and intertidal sand and mudflats. These habitats are briefly described below (and detailed in Appendix F2), as well as the potential impacts on them due to the fishery and measures within the draft FMS to mitigate those impacts. Marine protected areas and similar such habitats are also discussed in this section as they form part of the ecosystem and habitat management section of the draft FMS.

There have been some attempts to map the distribution of the major vegetated habitats within estuaries in NSW (West *et al.*, 1985; Bucher and Saenger, 1991), however, they do not include other habitats such as rocky reefs or algal beds. Furthermore, information about the distribution of fishing grounds is not yet available (although the declaration of recognised fishing grounds and designated landing sites is proposed in the draft FMS), nor is information available to determine the importance of the above-mentioned ‘other’ habitats to the assemblages within them or that use them occasionally. Add to that the fact that there is almost no data examining the effects of the methods used in the fishery on habitats and the assemblages within them, and it makes any assessment of the fishery and the draft FMS very limited. As such, commercial fishing data is presented for each estuary in an attempt to determine the degree of pressure that the fishery could exert upon habitats and the fauna that rely upon them. In the absence of data, this assessment uses fishing closures as gazetted by NSW Fisheries, habitat distributions mapped by NSW Fisheries, and principal feeding and roosting grounds for birds as mapped by the Environment Protection Authority (formerly the State Pollution Control Commission) to further examine the degree of protection afforded to habitats and fauna. The limitations of this method are acknowledged, but it is only an indicative, not absolute measure of those estuaries whose biodiversity and habitats are thought to be under the greatest pressure from the fishery.

Table F1 summarises the areal extent of the major vegetated habitats within each estuary, based on a mapping program that was done by NSW Fisheries between 1981 and 1985 (West *et al.*, 1985). It also includes other natural features, such as the existence of nature reserves and National Parks, and use by birds protected under international treaties that could be affected by the fishery. NSW Fisheries is currently reviewing and updating this information, which will also include the distribution of rocky shores. More recent data on the distributions of the major vegetated habitats are also available in numerous Estuary Process Studies done as part of the Department of Land and Water Conservation's Estuary Management Program, and studies done in relation to some large scale developments. The data is of limited use, however, as the process studies only utilised field observations and did not provide any quantitative data, and the other studies only provide information about a very limited number of areas.

a) Major estuarine habitats

i) Seagrasses

Brief description

Seagrasses are flowering plants that live and reproduce completely submerged in seawater (King, 1981a; West, 1989). They are rooted in the sediments, with the leaves appearing above the substratum and produce flowers and seeds, similar to terrestrial grasses (Keough and Jenkins, 1995). Six species of true seagrass are found within NSW and there is a general increase in the number of species from north to south (West, 1989). *Zostera capricorni* is the most widespread species, occurring in most estuaries and for considerable distances upstream. Strapweed (*Posidonia australis*) is the other major species in terms of area but is found in only 16 estuaries and prefers areas where salinity is high and nutrient levels are low (Roy *et al.,* 2001)

Distribution

West *et al.* (1985) mapped the distribution of seagrasses and other aquatic vegetation within NSW and their findings are summarised in Table F1. Almost all estuaries (82%) have some cover of seagrass, although four estuaries account for more than 50% of the total area of seagrass in NSW: Wallis Lake 30%; Clarence River 15%; Lake Macquarie 10%; and Tuggerah Lakes 7%. These and other barrier estuaries contain most of the larger seagrass beds, the exception being Jervis Bay (6%), which is an open ocean embayment. Those estuaries thought to have little or no seagrass are predominantly very small, intermittently open estuaries. Whilst accounting for only a small percentage of the total amount of seagrass for the State, several of these smaller intermittent estuaries have the highest percentage cover of seagrass of all estuaries. In particular, Toubouree Lake, Back Lagoon, Bournda Lagoon, Towradgie Creek and Merimbula Lake have greater than 50% seagrass coverage. On a regional basis, Regions 4 and 6 support the largest extent of seagrass, but when compared to water area, Region 2 has the largest percentage cover (approximately 21%).

Table F1. A list of NSW estuaries and various physical (Roy *et al.*, 2001), biological (West *et al.*, 1985) and fisheries attributes (NSW Fisheries Database; SPCC/EPA, 1984 - 1995) used to assess the potential effects of the Estuary General Fishery on the biophysical environment.

Numbers in parentheses in NP/NR are those with marine protected areas. NB: estuaries without fishing data may have been fished, but their catch included under larger systems.

FISHING REGION	ESTUARY			HABITATS				FISHING METHOD & EFFORT (total days from 1985-2000)						FISHING CLOSURES		
	Name	Type	Water area (km^2)	Mangrove area (km^2)	Seagrass area (km^2)	Saltmarsh area (km^2)	National Parks or Nature Reserves	Hand	Hauling	Meshing	Prawning	Trapping	Total	Type	Preserve wader habitat?	Preserve other habitats?
1	TWEED RIVER	3	17.916	3.091	0.331	0.213	3 (3)	121	11899	6613	170	17549	36352	7	n	n
	CUDGEN LAKE	5	1.427	0.094	0	0.561	1 (1)							7	y	y
	CUDGERA CREEK	4	0.238	0.138	0.016	0.016	1 (1)							6	y	y
	MOOBALL CREEK	3	0.492	0.053	0.013	0	1 (1)							6	y	y
	BRUNSWICK RIVER	3	2.222	0.018	0.816	0.056	2 (2)		61	68		167	296	6	y	y
	BELONGIL CREEK	4	0.126	0.050	0	0.054	1 (1)							6	y	y
	TALLOW CREEK	4	0.082	0	0	0.003								6	y	y
	BROKEN HEAD CREEK	4	0.050	0	0	0.036	1							6	y	y
	RICHMOND RIVER	3	19.071	4.949	0.189	0.099	3 (1)	1159	16212	6693	162	10203	34429	7	n	n
	EVANS RIVER	3	1.787	0.330	0	0.375	1	22	78			20	120	4	y	y
	JERUSALEM CREEK	4	0.214	0	0	0.021	1 (1)							6	y	y
			43.625	8.723	1.365	1.434		1302					71197			
2	CLARENCE RIVER	3	89.243	5.208	19.072	1.954	2 (1)	191	39516	40636	39663	61721	181727	7	n	n
	SANDON RIVER	3	1.414	0.533	0.028	0.258	2 (1)		81	600		2141	2822	4	y	y
	WOOLI WOOLI RIVER	3	1.900	0.493	0.028	0.531	2 (1)	27		14		624	665	7	n	n
			92.557	6.234	19.128	2.743		218					185214			
3	STATION CREEK	4	0.306	0	0	0	2 (1)							6	n	na
	CORINDI RIVER	3	0.873	0.189	0.033	0.293	2 (1)			19		28	47	5	y	y
	ARRAWARRA RIVER	4	0.123	0	0.003	0.008								3	y	y
	DARKUM CREEK	4	0.046	0.001	0	0								6	y	y
	WOOLGOOLGA LAKE	4	0.180	0.002	0	0			17	24	9	53	103	6	y	y
	HEARNS LAKE	4	0.106	0.044	0	0								6	y	y
	MOONEE CREEK	3	0.333	0.036	0.004	0.073	1		30	16	2	151	199	6	y	y
	COFFS HARBOUR CREEK	3	0.308	0.167	0.018	0		24	300	56		746	1126	6	y	y

Table F1 (cont)

FISHING REGION	ESTUARY Name	Type	Water area (km²)	HABITATS Mangrove area (km²)	Seagrass area (km²)	Saltmarsh area (km²)	National Parks or Nature Reserves	FISHING METHOD & EFFORT (total days from 1985-2000) Hand	Hauling	Meshing	Prawning	Trapping	Total	FISHING CLOSURES Type	Preserve wader habitat?	Preserve other habitats?
3	BOAMBEE CREEK	3	0.573	0.066	0.011	0.158		3	13	13		1730	1759	5	y	y
cont	BONVILLE CREEK	3	1.244	0.053	0.008	0.148		13	24	151		1659	1847	5	y	y
	BELLINGER RIVER	3	6.576	0.847	0.059	0.029		48	1202	2179		4590	8019	7	y	y
	DALHOUSIE CREEK	4	0.051	0	0	0								nc	n	na
	OYSTER CREEK	4	0.084	0	0	0								nc	n	na
	DEEP CREEK	4	1.021	0.008	0.007	0.604		4	4	545		2125	2678	7	y	y
	NAMBUCCA RIVER	3	7.738	0.779	0.224	1.034		44	3479	5087	10	17410	26030	7	y	y
	MACLEAY RIVER	3	18.169	5.201	1.097	3.652	1	500	1602	8033	39	25266	35440	7	n	n
	SALTWATER CREEK	4	0.078	0	0	0	1 (1)							nc	n	na
	SOUTH WEST ROCKS CREEK	4	0.118	0.528	0.024	0.141								5	y	y
	KOROGORO CREEK	3	0.221	0.013	0	0.014	1 (1)							4	y	y
	KILLICK CREEK	4	0.198	0	0.011	0.008	1							6	y	y
	HASTINGS RIVER	3	17.287	2.078	1.141	0.804	2 (1)	337	10655	9868	355	17375	38590	7	n	n
	LAKE INNES/LAKE CATHIE	4	5.821	0.001	0.007	5.972	1 (1)		1090	1673	174	2216	5153	6	y	y
	CAMDEN HAVEN RIVER	3	27.833	0.873	6.336	0.780	1 (1)	34	6795	12523	3885	37307	60544	7	n	n
			89.287	10.886	8.983	13.718		983					181535			
4	MANNING RIVER	3	25.348	3.582	0.329	0.721		199	19151	13996	1506	10782	45634	7	y	y
	KHAPPINGHAT CREEK	4	0.960	0	0.019	0.002	1 (1)							4	y	y
	WALLIS LAKE	3	85.559	0.786	30.785	4.005	7	960	41859	35310	19153	74946	172228	7	n	n
	SMITHS LAKE	4	9.371	0	2.080	0.003	1	429	3779	4689	852	913	10662	7	n	n
	MYALL LAKES	5	101.933	0	0.079	0	1 (1)							7	n	n
	KARUAH RIVER	2	3.876	3.479	0.380	4.828								7	n	n
	MYALL RIVER	3	7.541	1.021	2.736	1.784	1 (1)							7	n	n
	PORT STEPHENS*	2	125.970	23.260	7.453	7.719	4 (4)	965	30320	35867	13193	39593	119938	7	n	n
	HUNTER RIVER	3	30.421	15.481	0.153	5.049	2	390	2599	10205	233	15635	29062	7	n	n
	LAKE MACQUARIE	3	115.112	0.998	13.391	0.705		73	30964	21439	1216	468	54160	7	n	n
	TUGGERAH LAKES	3	70.299	0	11.619	0.007	2	143	27783	33772	19438	2456	83592	7	y	y
	WAMBERAL LAGOON	4	0.495	0	0.245	0	1							2	y	y
	TERRIGAL LAGOON	4	0.258	0	0.046	0								2	y	y

Table F1 (cont)

FISHING REGION	ESTUARY			HABITATS				FISHING METHOD & EFFORT (total days from 1985-2000)						FISHING CLOSURES		
	Name	Type	Water area (km^2)	Mangrove area (km^2)	Seagrass area (km^2)	Saltmarsh area (km^2)	National Parks or Nature Reserves	Hand	Hauling	Meshing	Prawning	Trapping	Total	Type	Preserve wader habitat?	Preserve other habitats?
4	AVOCA LAKE	4	0.649	0	0.161	0								2	y	y
cont	COCKRONE LAKE	4	0.320	0	0	0								2	y	na
			578.112	48.607	69.476	24.823		3159					515276			
5	BRISBANE WATERS	3	27.241	1.635	5.490	0.918	3							2	y	y
	HAWKESBURY RIVER	2	100.005	10.654	0.470	1.126	5 (3)	270	13339	17978	361	29305	61253	7	n	n
	PITTWATER	2	17.314	0.180	1.934	0.026	1 (1)							7	y	y
	NARRABEEN LAGOON	4	2.181	0	0.468	0	1		3	15		1	19	2	y	y
	DEE WHY LAGOON	4	0.238	0	0.034	0.044	1							2	y	y
	HARBORD LAGOON	4	0.058	0	0	0								2	y	na
	MANLY LAGOON	4	0.086	0	0.004	0								2	y	y
	PORT JACKSON	2	49.667	0.914	1.286	0.073	4	23	9514	4342	130	4177	18186	7	y	n
	BOTANY BAY	1	49.100	3.996	3.403	1.601	1 (1)	207	18236	12305	244	10556	41548	7	y	y
	GEORGES RIVER	2	12.466	2.038	0.268	0.247								7	n	n
	PORT HACKING	2	11.298	0.328	0.869	0.106	1 (1)	780	96	39	7	65	987	2	y	y
			269.654	19.745	14.226	4.141		1280					121993			
6	TOWRADGIE CREEK	4	0.060	0	0.036	0								1	y	y
	PORT KEMBLA HARBOUR	3	0.098	0	0	0								4	na	na
	LAKE ILLAWARRA	3	36.270	0	6.116	0.203	1	2024	17058	14816	17516	2828	54242	7	n	n
	BENSONS CREEK	4	0.087	0	0.028	0	1					42	42	1	y	y
	MINNAMURRA RIVER	3	0.601	0.484	0.232	0.197	1	27		22		152	201	5	y	y
	WRIGHTS CREEK	4	0.033	0	0.003	0								nc	n	n
	WERRI LAGOON	4	0.113	0	0.017	0								6	y	y
	CROOKED RIVER	3	0.221	0	0.004	0								6	y	y
	SHOALHAVEN RIVER	3	12.889	0.670	0.340	0.146	1	449	15087	10915	541	5545	32537	7	n	n
	CROOKHAVEN RIVER	3	7.883	2.806	0.678	1.396	1							7	n	n
	LAKE WOLLUMBOOLA	4	6.211	0	1.145	0			16	387	354	27	784	7	n	n
	JERVIS BAY	1	102.129	1.250	9.061	2.330	3	51	7794	101	114	249	8309	7	n	n
	ST GEORGES BASIN	3	38.859	0.252	8.538	0.036	1	459	9954	6458	3133	1316	21320	7	n	n
	SWAN LAKE	4	4.082	0	0.587	0			283	275	73	431	1062	7	n	n

Table F1 (cont)

FISHING REGION	ESTUARY			HABITATS				FISHING METHOD & EFFORT (total days from 1985-2000)						FISHING CLOSURES		
	Name	Type	Water area (km²)	Mangrove area (km²)	Seagrass area (km²)	Saltmarsh area (km²)	National Parks or Nature Reserves	Hand	Hauling	Meshing	Prawning	Trapping	Total	Type	Preserve wader habitat?	Preserve other habitats?
6	BERRARA CREEK	4	0.124	0	0.006	0	1							6	y	y
cont	NERRINDILLAH CREEK	4	0.065	0	0.005	0								nc	n	n
	LAKE CONJOLA	3	4.280	0	0.527	0.013		50	889	780	51	347	2117	7	y	y
	NARRAWALLEE INLET	3	0.456	0.378	0.014	0.091	1			39		111	150	nc	n	n
	MOLLYMOOK CREEK	4	0.022	0	0.009	0								1	y	y
			214.483	5.840	27.346	4.412		3060					120764			
7	BURRILL LAKE	3	4.206	0	0.508	0.157		54	751	928	4	476	2213	7	y	y
	TOUBOUREE LAKE	4	1.380	0	1.199	0.010				215		160	375	6	y	y
	TERMEIL LAKE	4	0.445	0	0.070	0			2	242		150	394	nc	n	n
	MEROO LAKE	4	0.635	0	0.115	0			11	79		258	348	nc	n	n
	WILLINGA LAKE	4	0.282	0	0.004	0								5	y	y
	KIOLOA LAGOON	4	0.637	0	0.003	0.006								nc	n	n
	DURRAS LAKE	4	3.214	0	0.509	0.046	1		316	971	200	362	1849	7	y	y
	CLYDE RIVER	2	19.898	2.318	0.092	1.017		71	381	1770	349	1273	3844	nc	n	n
	CULLENDULLA CREEK	3	0.239	0.916	0.064	0.006								nc	n	n
	BATEMANS BAY	1	5.301	0	0.071	0								nc	n	n
	TOMAGA RIVER	3	1.214	0.210	0.046	0.351			1	350	2	101	454	6	y	y
	CANDLAGAN CREEK	3	0.067	0.021	0.016	0.031								4	y	y
	MORUYA RIVER	3	4.222	0.380	0.644	0.674		14	1026	407	247	573	2267	7	y	y
	CONGO CREEK	4	0.128	0	0	0			33	49		174	256	6	y	na
	MERINGO CREEK	4	0.097	0	0	0								nc	n	na
	COILA LAKE	4	6.341	0	1.862	0.317		74	1165	1575	7828	431	11073	7	n	y
	TUROSS LAKE	3	13.299	0.566	0.452	0.401		14	3221	3926	1018	2043	10222	7	n	y
	LAKE BRUNDEREE	5	0.184	0	0.064	0.246				9		40	49	nc	n	n
	LAKE BROU	4	1.663	0	0.078	0.250		2	318	560	2842	139	3861	nc	n	n
	LAKE DALMENY	4	1.393	0	0.294	0.055		1	198	396	136	39	770	2*	y	y
	KIANGA LAKE	4	0.124	0	0.011	0.033			1	6	12	112	131	nc	n	n
	WAGONGA INLET	3	6.276	0.249	1.484	0.056		25	33	4	11	37	110	2	y	y
	NANGUDGA LAKE	4	0.461	0	0.120	0.115			4	155	13	5	177	7	n	n

Table F1 (cont)

FISHING REGION	ESTUARY Name	Type	Water area (km²)	HABITATS Mangrove area (km²)	Seagrass area (km²)	Saltmarsh area (km²)	National Parks or Nature Reserves	FISHING METHOD & EFFORT (total days from 1985-2000) Hand	Hauling	Meshing	Prawning	Trapping	Total	FISHING CLOSURES Type	Preserve wader habitat?	Preserve other habitats?
7	CORUNNA LAKE	4	1.669	0	0.179	0.033			249	762	472	297	1780	nc	n	n
cont	TILBA TILBA LAKE	4	0.640	0	0	0			69	173	1931	141	2314	nc	n	na
	LITTLE LAKE	4	0.100	0	0.003	0.047			8	8	22	6	44	6	y	y
	WALLAGA LAKE	3	7.805	0	1.343	0.295	1	78	1127	3244	747	1594	6790	7	y	y
	BERMAGUI RIVER	3	1.390	0.434	0.338	1.066		0	32	369	48	345	794	7	n	n
	BARRAGOOT LAKE	4	0.377	0	0.049	0.053			7	82	3	50	142	nc	n	n
	CUTTAGEE LAKE	4	1.410	0	0.430	0.076			17	655	47	139	858	no haul	y	y
	MURRAH LAGOON	3	0.816	0	0.016	0.109			21	89		346	456	nc	n	n
	BUNGA LAGOON	4	0.094	0	0	0.018								nc	n	n
	WAPENGO LAGOON	3	3.191	0.409	0.360	0.319	1		3	360		50	413	7	y	y
	MIDDLE LAGOON	4	0.331	0	0.081	0.011	1		16	152	95	19	282	nc	n	n
	NELSON LAGOON	3	0.713	0.271	0.114	0.063	1	10	124	57	8	50	249	nc	n	n
	BEGA RIVER	3	2.657	0	0.304	0.411	1		1463	1444	21	1151	4079	7	n	n
	WALLAGOOT LAKE	4	3.672	0	0.647	0.014	1		21	893		164	1078	6	y	y
	BOURNDA LAGOON	4	0.058	0	0.043	0	1							5	y	y
	BACK LAGOON	4	0.315	0	0.204	0.018	1			11			11	nc	n	n
	MERIMBULA LAKE	3	4.556	0.377	2.297	0.629		90		33		13	136	6	y	y
	PAMBULA LAKE	3	12.949	0.449	0.868	0.188	1	877	53	1194	11	293	2428	7	n	n
	CURALO LAGOON	4	0.708	0	0.058	0.116		1	63	122		58	244	nc	n	n
	TWOFOLD BAY	1	77.049	0	0.026	0.008		9	1383	33	7	141	1573	7	n	n
	NULLICA RIVER	4	0.244	0	0.020	0		390		25		49	464	nc	n	n
	TOWAMBA RIVER	3	1.427	0.900	0.027	0.009		2	53	276		252	583	7	n	n
	FISHERIES CREEK	4	0.024	0	0.046	0.042	1							nc	n	n
	WOMBOYN RIVER	3	3.616	0	0.237	0.483	1	6		4		29	39	6	y	y
	MERRICA LAKE	4	0.106	0	0	0	1							4	y	na
	NADGEE RIVER	4	0.162	0	0	0	1							4	y	na
	NADGEE LAKE	4	0.968	0	0.075	0	1							4	y	y
			198.753	7.500	15.471	7.779		1718					63150			

Table F1 (cont)

Estuary Type (Roy *et al.*, 2001)	**Methods**
1 = oceanic embayment	Hand = handgathering
2 = tide dominated estuary	Hauling = Prawn seine, general purpose, trumpeter whiting, garfish, pilchard, anchovy, bait, prawn haul, and bullringing (garfish) nets
3 = wave dominated estuary	Meshing = Pound (figure six), bottom set, top set, splashing and flathead nets
4 = intermittently closed estuary	Prawning = Set pocket net and running net
5 = freshwater	Trapping = Fish, crab,and eel traps

Closure Types (at July 2001: NB, these are a summary of the true closures and should not be sourced).

1 = Closed to commercial fishing

2 = Closed to all nets and traps (* Lake Dalmeny closed to haul nets and all traps)

3 = No nets or traps except for recreational nets

4 = Traps permitted

5 = Traps and dip and scoop nets permitted

6 = Recreational nets and all traps permitted

7 = Mixture of gear, time and place

nc = no closure gazetted, refer to Part 3 of the *Fisheries Management (General) Regulation 1995* , for more detail

* denotes that the figures for Port Stephens include those from Myall Lakes and River and Karuah River

Summary of importance

Seagrass is widely recognised as an important habitat for juvenile fish (e.g. SPCC, 1981a; Pollard, 1984; Bell and Pollard, 1989; Connolly, 1994), but it serves many more roles than the mere provision of food and habitat for species of economic value. They are also reported to:

- prevent erosion by restricting water movement and binding sediment (Fonseca *et al.,* 1982; Scoffin, 1970)
- form the basis of food webs through high productivity and providing detritus (Borowitzka and Lethebridge, 1989; Hillman *et al.,* 1989)
- provide surfaces for colonisation by epiphytes and periphyton (Harlin, 1975; Pollard and Moriarty, 1991)
- restrict water movement which in turn allows for the settlement of plankton (Keough and Jenkins, 1995)
- trap and recycle nutrients (Hemminga *et al.,* 1991)
- provide foraging habitat for many species of birds, particularly cormorants, herons, swans and ducks.

Some studies have also reported the importance of detached seagrass supporting abundant fish communities adjacent to the beaches that it washes up on, forming accumulations known as wrack (Lenanton *et al.,* 1982). In northern Australia, seagrasses form a major component of the diet of dugongs and turtles, but in more temperate environments such as NSW, few animals actually consume seagrass directly (Klumpp *et al.,* 1989). Rather, as stated above, its importance to most fauna and other flora is in the provision of food and habitat.

Potential effects of the fishery

The fishery could have numerous potential effects on seagrass beds and their inhabitants, although as stated above, there is no data to determine the extent or magnitude of these impacts (potential effects of each method are discussed in more detail in Chapter F section 1(c)). Furthermore, many of the effects are likely to be indirect because of the role that seagrass plays in the provision of nutrients for estuarine food webs, stabilising sediments and restricting water movement. Some of the more direct effects could include:

- the removal of epiphytes, periphyton or epifauna from seagrass blades
- removal of or damage to seagrass blades or shoots;
- reducing growing conditions by increasing turbidity or destabilising sediments
- introducing contaminants.

Assessment of management responses proposed in the draft FMS

Table F1 suggests that existing closures offer very little protection to seagrass beds, particularly in the larger estuaries where effort is focussed. To address this, the draft FMS proposes to implement the following management responses:

- prohibit the use of hauling nets over beds of strapweed seagrass (*Posidonia australis*)

- prohibit the use of all prawn hauling and prawn seining methods over seagrass areas
- identify designated landing sites for fish hauling nets in estuaries where seagrass exists around shoreline areas
- reduce the maximum allowable length of fish hauling nets to 500 m and restrict the number of shots per day
- develop a code of conduct with respect to operating on or near river banks, mangroves, seagrasses or saltmarsh habitats
- involve the Estuary General Management Advisory Committee in the development of habitat management policies and habitat rehabilitation works
- modify the use of fishing methods that have detrimental impact on fish habitat.

These measures have adopted a precautionary approach in the absence of any data about the effects of the fishery on seagrass. By restricting the types of techniques that can be used in seagrass beds, and restricting the total area of seagrass available to fishing, overall they should reduce the extent and magnitude of potential impacts. The establishment of designated landing sites and beds closed to prawn hauling and seining provide an opportunity to quantify the proportion of seagrass within each estuary that is fished and by which methods. This could assist in prioritising those beds in which to establish research programs, and/or justify the need or otherwise for those programs. It may also aid the determination of seagrass beds and other habitats that require rehabilitation or warrant inclusion in marine protected areas.

The proposed measures appear to acknowledge that hauling is probably having an impact on seagrass and/or its inhabitants, and the draft FMS proposes to modify methods that have a detrimental impact, yet there are no details of the research programs proposed in the draft FMS. As such, it is not possible to determine their adequacy. When determined, the programs should be independently reviewed at both the planning and reporting stages.

ii) Mangroves

Brief description

Mangroves are trees and shrubs that grow in soft sediments in the intertidal zone of estuaries, generally in sheltered areas where silt can accumulate. They usually form dense forests when conditions are optimal, but can exist as small, scattered trees on rocky areas in extremely sheltered areas (Chapman and Underwood, 1995). Mangroves usually spread their roots out widely in the upper layers of sediment, as opposed to vertically, in order to maximise exposure to oxygen and to enhance stability in otherwise unstable substrata (Chapman and Underwood, 1995). Other adaptations to survive in the intertidal zone include: aerial roots (called pneumatophores) which arise vertically out of the sediment and absorb oxygen and other gases; increasing the numbers of pneumatophores in sub-optimal growing conditions; secreting salt through glands in their leaves; excluding salt via a filtering system; or accumulating salt in old leaves (Hutchings and Saenger, 1987).

Distribution

Mangroves are not as widespread as seagrasses because of their reliance upon more marine conditions. Less than 50% of the larger estuaries support mangroves (Table F1). Of over thirty species known in Australia, five have been recorded in NSW, and there is a decline in the number of species moving from north to south (West *et al.*, 1985). Grey mangroves (*Avicennia marina*) are the most widespread species, found in all but one of the estuaries known to support mangroves, followed by river mangroves (*Aegiceras corniculatum*). Milky mangroves (*Excoecaria agallocha*) are found north of Manning River, spider mangroves (*Rhizophora stylosa*) north of Corindi River and large-leafed mangroves (*Bruguiera gymnorrhiza*) north of Clarence River. They are rarely recorded from estuaries that are intermittently open to the sea, which comprise about 50% of all estuaries (Table F1). Furthermore, six estuaries, Port Stephens (25%), Hunter River (15%) Hawkesbury River (10%), Macleay, Clarence and Richmond Rivers (all 5%) account for 65% of the total area of mangroves recorded in NSW. These estuaries are all located in the central and northern regions of the State, are large in terms of surface area and all are permanently open to the sea.

Summary of importance

Like seagrasses, mangroves have been widely recognised as important ecological communities, and some studies suggest they are the most productive (in terms of organic matter produced per hectare per year) of all estuarine habitats (Larkum, 1981). Mangroves are reported to:

- provide organic materials that form the basis of detrital food chains (West, 1985; Robertson and Alongi, 1995)
- stabilise sediments (West, 1985; Robertson and Alongi, 1995);
- recycle nutrients (Robertson and Alongi, 1995);
- provide feeding and roosting habitat for numerous species of birds, particularly pied cormorants and mangrove honeyeater, a vulnerable species (Chapman and Underwood, 1995)
- provide habitat for a variety of fish and invertebrates (e.g. SPCC, 1981a & b; Pollard and Hannan, 1994; Robertson and Alongi, 1995)
- act as a filter system between the land and aquatic environment (NSW Fisheries, 1999a).

Potential effects of the fishery

Mangroves represent a transitional habitat between the land and the sea, and are less vulnerable to impacts due to the fishery. The shallow waters fronting mangroves and the soft sediments that mangroves grow in prohibit the use of most methods adjacent to mangroves, and that are not used as access points. Hauling is rarely done in front of mangroves because of the limited mobility in front of mangrove forests and the soft sediments prevent effective hauling. When hauling is done in front of mangroves, it usually involves a back net set parallel to the shore in about one metre of water. Nets are retrieved into the back net preventing the need to access the shore. Meshing and trapping are common in the channels and flats adjacent to mangroves, but again do not necessitate entering mangroves. Beyond the immediate activity of the fishery, it is likely that in the past, the establishment of infrastructure for the fishery probably affected some areas of mangroves, for example for boat ramps, jetties and marinas. Such development is now strictly controlled, and also serves more of the community than just fishers. Most of the potential impact associated with mangroves is likely to be on fauna that inhabit the forest, particularly nesting and roosting birds, and infauna and epifauna of the mudflats and channels adjacent to mangroves. The movement of nets across the substratum and the placement and removal of traps could also remove flora and fauna, or prevent their establishment, which may otherwise have enhanced the complexity of the largely unvegetated substratum.

Assessment of management responses proposed in the draft FMS

The management responses to minimise the impacts of the fishery on mangroves are primarily the same as for seagrasses. The techniques, and the way they are used adjacent to mangroves, suggests that the fishery is unlikely to be having an impact on them, although it is possible that the fauna within and adjacent to mangroves may be affected. There are no research programs proposed to determine the effects of the fishery on mangroves or their inhabitants, but given the perceived lack of impacts, the proposed code of conduct for operating in those areas may be sufficient to minimise any potential impacts. The scientific observer program that is proposed in the draft FMS, which should be independent of the fishery, should be used to determine if further studies are warranted. For example, it may reveal that operating in front of and accessing the foreshore of mangroves is far more widespread, and thus potentially causes more damage and disturbance, than perceived in this assessment.

iii) Saltmarsh

Brief description

Saltmarsh refers to a collection of herbaceous plants and low shrubs that can tolerate highly saline soils and at least occasional inundation by seawater (King, 1981b; Morrisey, 1995). Generally, they are found on the high shore between average high water of spring and neap tides and consequently, often remain covered by water for long periods (Morrisey, 1995). They develop on shorelines in estuaries with soft sediments and along sheltered parts of the coast and are more common in barrier and coastal lagoons than other estuaries. Saltmarshes are relatively flat, with shallow pools separated by mounds that are usually vegetated by grasses (Poaceae), saltbushes (Chenopodiaceae), rushes (Juncaceae) and sedges (Cyperaceae), and most assemblages contain only a few species (Morrisey, 1995).

Distribution

Saltmarsh is widely distributed and is reported in 92 estuaries in NSW (Table F1). In, 1985, the total area occupied by saltmarsh within NSW was approximately 57 km^2 (West *et al.*, 1985), and as with other estuarine habitats, only a few estuaries account for more than 50% of the total cover for the State. Port Stephens has the largest area of saltmarsh, 7.7 km^2, and when added to Karuah River (an arm of Port Stephens) with 4.8 km^2, they account for 25%. Lake Innes/Cathie (12%), Hunter River (10%) and Wallis Lake (8%) also have extensive areas of saltmarsh. All of those estuaries except Lake Cathie are in Region 4.

Summary of importance

There has been little work done in Australia on the value of saltmarsh and extrapolations from studies in the Northern Hemisphere are not possible because those relate to fundamentally different marshes. Not only is the species composition different, but the plants are much taller than their analogues in NSW (Adam *et al.*, 1988). Overall, saltmarshes are thought to play a similar role to mangroves in that they are thought to:

- be used by a large variety of migratory and resident birds for feeding, roosting and/or breeding including egrets, sandpipers, curlews, whimbrels, plovers, dotterels and banded stilts (Morrisey, 1995; Zann, 1995; Zann, 1996)

- provide habitat for some terrestrial species of birds, such as chats and parrots, and several birds of prey, such as brahminy kites, whistling kites and harriers
- filter water draining from the land before it enters estuaries (Adam *et al.,* 1985)
- be highly productive (Zann, 1996), although specific information on details such as energy pathways and the export of detritus to adjacent habitats is very limited, and invariably from overseas studies in different types of saltmarsh to those in NSW (Morrisey, 1995; Adam *et al.,* 1985)
- provide habitat for juvenile fish and invertebrates (Thomas and Connolly, 2001; Connolly *et al.,* 1997; Williams *et al.,* 1995; Morton *et al.,* 1987).

Potential effects of the fishery

The extent of fishing adjacent to saltmarsh is unknown. Like mangroves, the main potential effects are likely to arise from hauling, which could involve accessing the foreshore, and general disturbance due to boating or foreshore access. This access would generally be restricted to parking boats on the foreshore to retrieve nets, and could entail trampling the seaward edge of the saltmarsh. Continuous trampling of saltmarsh and the associated compaction of the substratum can cause a decline in the extent of saltmarsh plants because it destroys plants and prevents them from recolonising the area. Compaction makes the soil dense and lowers the height of the ground such that it retains water more often than even saltmarsh plants can tolerate. Crabs, snails and other fauna could also be directly affected, and birds and small mammals could be disturbed during feeding and roosting.

Assessment of management responses proposed in the draft FMS

Given the limited capacity for the fishery to affect saltmarsh and its inhabitants, the responses proposed in the draft FMS, which are generally the same as for seagrass and mangroves, are likely to prove effective in minimising any future potential impacts. As with mangroves and seagrass, the definition of designated landing sites should be used to quantify the areas of saltmarsh that are used on a regular basis, and that information used to determine the need or otherwise for research programs.

iv) Unvegetated soft substrata

Brief description

Unvegetated soft substrata, including intertidal and subtidal mudflats and sandflats, are the most common habitat in estuaries yet are largely ignored because of their lack of physical structure. Unvegetated habitats have not been studied much in Australia (Inglis, 1995), possibly because of their lack of habitat complexity and readily identifiable features. Intertidal shores can comprise both sandflats and mudflats, the major difference being the relative proportions of sand, silt, clay and organic matter in the sediment and deoxygenation of the sediments in mudflats. Sandflats are generally found near the mouths of estuaries, where there are stronger currents and wave action, which deposit marine sands into the lower reaches. Mudflats are located further upstream in more sheltered environments, where silt and clay that has been carried downstream from the upper catchment settles out in response to a reduction in flow and mixing with more saline waters (DPWS, 1992).

Distribution

The distribution of unvegetated habitats has not been included in estuarine inventories done in the past in NSW, rather it has been implied during the mapping of seagrass and algal beds (e.g. Bucher and Saenger, 1991; West *et al*., 1985; Bell and Edwards, 1980). Measures of water area and seagrass in those inventories would suggest there is in excess of 1300 km^2 of bare substratum in NSW estuaries, or approximately eight and a half times the area of seagrass. The distribution of the major intertidal shores, however, has been inferred by a mapping program by the EPA (formerly the SPCC). The EPA mapped the distribution of coastal resources that could be affected by oil spills, and used records of occurrence of wading and threatened birds from the NPWS database and waterway maps to map their occurrence within estuaries (S. Carter, NSW Fisheries, pers. comm.). Most such areas are found in the lower parts of estuaries where sandflats are utilised, and in the upper parts where mudflats dominate.

Summary of importance

Soft substrata are inhabited by a large variety (often hundreds of species) of invertebrates including polychaete worms, crustaceans, molluscs, ascidians and sponges collectively termed benthos (Rainer, 1982; Jones *et al.,* 1986; Morrisey *et al.,* 1992a & b; CSIRO, 1994). Depth, salinity, sediment size characteristics, and the degree of sediment movement are among the physical factors that determine benthic community composition (Jones and Candy, 1981; CSIRO, 1994; Zann, 1996). Irrespective of specific assemblage composition, benthic organisms can be broadly classified according to their method of feeding and include suspension-feeders, deposit-feeders, browsers, predators and scavengers (Morrisey, 1995). Bare substrata are also utilised by a variety of larger invertebrates, such as crabs and prawns, as well as fish and birds. Shallow intertidal sediments are particularly important for wading birds. Despite being broadly referred to as unvegetated sediments, soft substrata can also include microscopic and drifting macroalgae, which provide important food and refuge for fauna.

Potential effects of the fishery

Due to its vast extent, all of the methods used in the fishery could be done in areas of bare substratum, from handgathering in the lower reaches to crab and eel trapping in the upper reaches. The placement, settling, scraping or retrieving of nets across the substratum could result in any combination or all of the following effects:

- damage or remove flora and fauna, thereby reducing habitat complexity
- destabilise sediments, which could increase erosion, decrease water quality and habitat suitability
- resuspend contaminants
- expose infauna to predators
- transfer material, potentially covering or smothering previously exposed sediment.

Assessment of management responses proposed in the draft FMS

There are no management responses in the draft FMS that focus on minimising the potential effects on areas of bare substratum. Most of the previous research into habitats of estuaries has focussed on vegetated habitats, and suggests they are more important than unvegetated areas because they are reported to support more diverse and abundant assemblages. This dearth of information about areas of bare substratum has translated into a lack of specific responses in the draft FMS. The only response that could inadvertently offer some protection to areas of bare substratum is 1.1e, which proposes to minimise the length of general purpose haul nets. Another response that could affect bare substrata is the code of conduct with respect to operating in the vicinity of migratory bird habitat, primarily intertidal areas. Such areas are likely to represent a very small proportion of bare substrata and overall are unlikely to reduce impacts on the substratum. Overall, the draft FMS is considered to offer limited protection to areas of bare substratum, and at this stage proposes very little to improve our understanding of the effects of the fishery on bare substratum and its fauna.

v) Rocky shores and reefs

Brief description

The other key habitat within estuaries is that of intertidal rocky shores and subtidal rocky reefs, although they are far less common than the other habitats. Rocky shores include both natural reef and man-made habitats such as breakwaters and seawalls (SPCC, 1981a; Pollard, 1989). Other man-made structures that provide a source of hard substratum and are abundant within estuaries and include oyster leases, piers, marinas, bridge footings, channel markers and jetties.

Distribution

As with soft substrata, areas of rocky shorelines and reefs have not been mapped in previous inventories. Natural rocky shores are most common in the drowned river valleys such as Port Jackson, Hawkesbury River, Port Stephens and Port Hacking (Morrisey, 1995). Breakwalls are common at the mouths of many barrier estuaries such as Clarence River and Wallis Lake, and the other man-made structures are common in most estuaries.

Summary of importance

Subtidal and intertidal areas of hard substrata enhance habitat complexity by providing a suitable habitat for settlement and recruitment by marine and estuarine species, particularly algae. Diverse assemblages of brown, red and green macroalgae, along with sponges, ascidians and other sessile invertebrates enhance habitat complexity of rocky shores and reefs and provide many opportunities for specialisation (e.g. Jones and Andrew, 1990; Lincoln Smith and Jones, 1995). The large macroalgae (such as kelp) that partially cover most rocky reefs enhance overall species diversity by providing patches of shaded habitat favoured by distinct assemblages of organisms (Kennelly, 1995a). Man-made hard substratum, such as pontoons and piers, also provide alternate types of substratum and are reported to support different assemblages of epibiota compared to adjacent rocky reefs (Glasby, 1999; Connell and Glasby, 1999). The habitat complexity of rocky reefs and other such habitats:

- provide extensive refuge and feeding opportunities for a variety of fish and invertebrates, particularly soft corals, bryozoans, ascidians and sponges (e.g. Butler, 1995; SPCC, 1981b; Jones and Andrew, 1990; Lincoln-Smith *et al.*, 1992; Lincoln-Smith and Jones, 1995)
- may be utilised on a seasonal basis by juveniles of tropical species of fish that are swept southward by the East Australian Current each summer and autumn (Kailola *et al.*, 1993; Kuiter, 1993), but do not usually survive the winter, or if they do, they fail to establish breeding populations (Lincoln Smith and Jones, 1995)

- provide an important part of the lifecycle of many of the protected species of fish in NSW, including grey nurse shark, blue devil fish, elegant wrasse, black cod, estuary cod, blue groper, Australian bass and estuary perch. Rocky reefs would also have provided habitat for the species of algae thought to be extinct, Bennetts seaweed (*Vanvoorstia bennettiana*).

Potential effects of the fishery

Very few of the methods utilised in the fishery could be used on or near rocky reefs or other hard substrata, primarily because of the susceptibility of the gear to damage. Most of the hauling methods are conducted over soft sediments for ease of hauling and to avoid damaging the gear. Garfish hauling and bullringing could be done over and adjacent to reefs, but these methods do not involve contact with the substratum. Handgathering of pipis and beachworms is primarily conducted on ocean beaches, and also targets yabbies on intertidal sandflats and mudflats of estuaries. It also involves a limited amount of diving for cockles and mussels, but given the selectivity and low use of this method, it is unlikely to significantly affect the substratum or its inhabitants. Prawn set-pocket and running nets, and crab and eel traps, are also set over soft sediments of estuaries. Meshing and handlining are the only methods likely to be used in rocky areas, although even these methods would be utilised very little due to the potential for damage to gear. Some of the effects could include damage or removal of flora and fauna causing a reduction in habitat complexity, exposure of previously discrete species, and reducing the abundance of reef species such as some wrasses.

Assessment of management responses proposed in the draft FMS

There are no responses in the draft FMS that relate directly to hard substratum, but this is not surprising given the lack of effort focussed in those habitats and their limited distribution. The potential to encounter some threatened or protected species of fish in estuarine rocky reefs should be accommodated by the observer program, modifications to the catch and effort returns, prohibiting the capture or sale of threatened or protected fish, and the continued prohibition on the use of explosive devices to take fish. These measures should be adequate to minimise potential impacts on rocky reefs and other areas of hard substratum.

vi) Marine protected areas

Marine protected areas are coastal, estuarine or oceanic areas that are managed to conserve marine biodiversity. They range from small, highly protected areas that focus on species or community protection to large multiple use areas that include complex linkages of ecosystems and habitats. Marine protected areas may include reefs, seagrass beds, rocky platforms, mangroves, estuarine waters, mudflats, saltmarshes, shipwrecks, archaeological sites, and coastal and offshore areas of airspace, seabed and water. Internationally, marine protected areas are considered an important tool for achieving conservation objectives in the marine environment. In NSW, marine protected areas consist of Marine Parks, Aquatic Reserves, Intertidal Protected Areas (Table F2), and marine or estuarine extensions of National Parks or Nature Reserves. Coastal parks and reserves often incorporate the beds of adjoining lakes and estuaries, and may include marine extensions to low water and beyond. Other important habitats within estuaries that are protected, although not referred to as marine protected areas because they are protected under International treaties, include Ramsar wetlands and intertidal areas used by migratory waders. These latter areas are generally referred to as JAMBA (Japan-Australia Agreement for the Protection of Migratory Birds, Birds in Danger of Extinction and their Environment) or CAMBA (Agreement between Australia and the People’s Republic of China for the Protection of Migratory Birds and their Environment) habitat.

Marine Parks, aquatic reserves, and intertidal protected areas

Table F2 describes the locations and features of existing Marine Parks, Aquatic Reserves and Intertidal Protected Areas of estuaries in NSW. It is important to note that many of the existing marine protected areas were chosen opportunistically, with little consideration of biodiversity conservation, however, there had not and still have not been any studies done to determine areas of high marine biodiversity or conservation significance. Furthermore, both commercial and recreational fishing are permitted in most reserves, minimising their effectiveness to conserve biodiversity. In the absence of clear definitions and studies, areas that appeared to be unique in terms of estuarine habitats were chosen. For example, both Shiprock and Fly Point Aquatic Reserve are examples of near-vertical rock faces that descend to about 15 m depth, a habitat more common on exposed coasts. Towra Point Auatic Reserve/Nature Reserve has extensive areas of seagrass, mangroves and saltmarsh and is utilised by numerous species of waders and other seabirds in an otherwise heavily urbanised and industrial estuary.

Table F2. Location and features of existing marine protected areas within NSW estuaries.

Where AR = Aquatic Reserve, MP = Marine Park, IPA = Intertidal Protected Area.

Marine Protected Areas			
Name	**Location**	**Size (ha)**	**Habitats or organisms protected**
Fly Point AR (also on National Estate)	Port Stephens	75	Subtidal invertebrates and vegetation. No commercial fishing, restricted recreational fishing
North Harbour AR	Port Jackson	250	Subtidal invertebrates and vegetation. Restricted commercial fishing
Towra Point AR (also on National Estate)	Botany Bay	333	All flora and fauna under the FM Act. Restricted commercial and recreational fishing
Shiprock AR	Port Hacking	2	Subtidal invertebrates and vegetation. Port Hacking is closed to commercial fishing
Jervis Bay MP (also on National Estate)	Jervis Bay	21450	All flora and fauna. Restricted commercial and recreational fishing
Solitary Islands MP (also on National Estate)	Coffs Harbour	71000	Proposed zoning (open to public consultation at time of this report) could see Sanctuary Zones created in Sandon River, Wooli River and Station Ck; Habitat Protection Zones in Sandon, Wooli Wooli and Corindi Rivers, Station, Darkum, Willis, Moonee, Arrawarra and Coffs Creeks and Woolgoolga and Hearns Lake
Sydney Harbour IPA	Port Jackson		Invertebrates (except for lobster and abalone) out to 10m from low water mark

Future Marine Protected Areas will be selected on the basis of the National Representative System of Marine Protected Areas (NRSMPA), a strategy that has been endorsed by the States and Territories for the conservation of Australia’s marine resources. The Interim Marine and Coastal Regionalisation for Australia report (ANZECC, 1998) provides the general planning framework for developing the NRSMPA. That report identified six discrete regions in NSW, made up of five coastal bioregions and one marine province: the Tweed-Moreton Shelf, Manning Shelf, Hawkesbury Shelf, Batemans Shelf, Twofold Shelf bioregions; and the Lord Howe province. A Marine Park will be established within each bioregion, as well as numerous Aquatic Reserves. The ANZECC (1999) criteria for selection as marine protected areas are outlined below in Table F3, including the definition and measurements applied to those criteria by NSW Fisheries to select candidate sites for estuarine aquatic reserves in NSW.

At the time of writing this report, the assessments for Hawkesbury and Batemans Shelf were complete and had identified 15 rocky shores and seven estuaries (Table F4) as candidate aquatic reserves (NSW Fisheries, 2001b). As these candidates areas are still under investigation, it is not possible to provide details of the levels of protection afforded the various components, assuming they were to be accepted following the public consultation period. It is proposed, however, that like existing reserves, they would give protection to habitats and would comprise a mixture of harvesting, restricted harvesting and no harvesting areas under future management arrangements.

Table F3. Criteria used to select candidate estuarine aquatic reserves.

(Source: Frances, 2001; ANZECC, 1999).

CRITERIA	DEFINITION	MEASUREMENT
Comprehensiveness	First order geomorphological classification	Estuary type
Representativeness	Second order geomorphological classification	Estuary age
Ecological Importance/Uniqueness	Habitat health; Species diversity	Size, health and number of habitats; Species diversity
International/National Importance	Identified species and associated habitats	JAMBA/CAMBA listing; Threatened species sightings
Productivity	Biomass within each habitat type	Size and number of habitats: Commercial fishing statistics
Vulnerability	Degree of urbanisation	CMA maps
Naturalness	Degree of catchment protection	State Forestry maps

It will be important that future reserves implement areas of no harvesting, including recreational, in order to maximise their effectiveness. Furthermore, during the review of the draft FMS, data from the observer or research programs should be collated to define areas of importance in the lifecycle of species targeted in the fishery. An assessment should be made of the need or otherwise to close those areas or to include them into new or existing protected areas, including the establishment of sanctuary zones.

Table F4. Candidate estuarine aquatic reserves.

(Source: NSW Fisheries, 2001b).

Candidate Estuarine Aquatic Reserves (at July 2001)
Fullerton Cove, Hunter River (also on National Estate)
Lake Macquarie (partial, near the town of Swansea)
Wamberal Lagoon
Dee Why Lagoon
Durras Lake
Wallaga Lake
Nelson Lagoon

Estuarine extensions of national parks or nature reserves

Approximately 95 of the larger estuaries have National Parks or Nature Reserves fringing the estuary, and approximately 35 contain marine protected areas and could thus be affected by the fishery (Table F1).

Ramsar wetlands

The Convention on Wetlands of International Importance, signed in the Iranian town of Ramsar in, 1971, aims to halt the loss of wetlands and to conserve the remaining wetlands. Countries that are parties to the Convention nominate wetlands to be listed as Wetlands of International Importance, and following acceptance they become known as Ramsar Wetlands. Countries are expected to manage their Ramsar sites to preserve their unique ecological characteristics, and in Australia are protected under the EPBC Act. Ramsar wetlands within NSW estuaries include

Kooragang Island Nature Reserve (Hunter River), Myall Lakes (Myall River and Myall Lakes) and Towra Point Nature Reserve (Botany Bay).

JAMBA and CAMBA bird habitat

Other applicable international agreements are the Japan-Australia Agreement for the Protection of Migratory Birds, Birds in Danger of Extinction and their Environment (JAMBA), and the Agreement between Australia and the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA). Most of the birds protected under these agreements are migratory waders and seabirds (Appendix F3), and could thus be affected by the fishery. There are approximately 90 species of birds covered under these agreements, but only about 44 of those are likely to occur within and adjacent to estuaries of NSW (Appendix F3). The most numerous are from the families Scolopacidae (curlews, sandpipers and godwits), represented by approximately 23 species, Laridae (terns), five species, and Charadriidae (plovers) with four species. Shearwaters (Procellariidae) and skuas (Stercorariidae) have also been considered even though they are primarily oceanic, because many also utilise coastal waters and large bays. The majority of birds migrate to NSW estuaries during spring and summer and return to the northern hemisphere to breed. The few exceptions are wedge-tailed shearwaters and little terns, which arrive in spring to breed and may remain on our coast all year. Other nomadic species (i.e. occur all year and breed in Australia) include white-breasted sea-eagles, caspian terns, crested terns, painted snipes and white egrets.

Unlike Ramsar, however, there are no listed sites because of the periodic preference for certain areas by such birds. For the purposes of this assessment and to provide some estimate of their occurrence within NSW estuaries, those areas identified by the Environment Protection Authority (EPA) coastal resource atlases were used to determine whether or not existing fishing closures offered protection to those areas (Table F1). These areas are usually located in the lower parts of estuaries in intertidal sandflats and mudflats. It is important to note that the areas defined in the EPA atlases were only for waders that used intertidal areas, and did not consider the species that have much broader feeding ranges, such as sea-eagles or shearwaters. The estuaries thought to be most significant for JAMBA or CAMBA birds are listed below in Table F5.

Potential effects of the fishery on marine protected areas

Despite the name, marine protected areas provide only minimal protection for the flora and fauna within them. Commercial and recreational fishing, albeit slightly restricted in terms of the methods that can be used, is permitted in most of the existing Marine Parks and Aquatic Reserves. It is also permitted in the waters adjacent to and on the foreshores of National Parks, Nature Reserves, all four Ramsar sites and most JAMBA or CAMBA bird habitat. More protection from the fishery is offered to the latter habitats in the form of closures designed to address other issues. As with the other habitats, there is no information about how frequently or intensely these habitats are used, nor of the actual effects that the fishery may have had on them. Potential effects are likely to be similar to those described for the individual habitats.

Assessment of management responses proposed in the draft FMS

There are a limited number of responses in the draft FMS that relate to minimising effects of the fishery on marine protected areas, and probably reflects the limited knowledge about the fishery's interaction with such habitats. The responses include:

- using fishing closures to control the time and area fished to minimise impact on nesting and/or feeding areas of migratory shorebirds and on sensitive shoreline habitat
- using fishing closures to control the time and area fished to protect key fish habitat by defining designated landing sites for fish hauling nets
- developing a code of conduct for the fishery with respect to operating in the vicinity of listed Ramsar wetlands or known JAMBA and CAMBA migratory bird habitat in a manner that minimises disturbance
- participating in the management of marine protected areas in estuarine waters.

These measures should provide adequate protection for these habitats. The most readily implemented response is the establishment of designated landing sites for fish hauling. Whilst designed to minimise effects on seagrass, it should also minimise the amount of foreshore of parks and reserves that can be accessed by fishers, minimising the area of any potential impacts.

The proposal to use closures to minimise effects on migratory shorebirds will significantly improve the existing situation and would be enhanced by the code of conduct during periods, or in areas, without closures. Table F5 presents what are thought to be the most important estuaries for migratory birds, but most of the available information is more than five years old and probably requires a review. It is recommended that NSW Fisheries confirm important sites and times with NPWS during the establishment of closure areas and in formulation of the code of conduct, in a process similar to the Regional Liaison Committees established in the Ocean Hauling Fishery. This would ensure that important areas within estuaries are mapped, that the relevant maps would be made available to fishers within each region, and that they would be reviewed each year during the review of the code of conduct.

Table F5. Estuaries (open to commercial fishing) and coastal areas of international significance because they support more than 1% of the estimated Australian population of a given species protected under international treaties or the TSC Act.

(Source: SPCC/EPA Coastal Resource Atlases, 1984 - 1994).

Location	Important species or population
Hunter River	7000-10000 migratory waders; > 5% of world pop. of eastern curlews and golden plovers
Shoalhaven and Crookhaven system	3000-6000 waders; important for Pacific golden plovers, eastern curlews, Mongolian plovers and ruddy turnstones
Clarence River	3000 waders; important for lesser golden plover, bar-tailed godwit, grey-tailed tattler and curlew sandpiper, red knots, red-necked stints, Terek sandpipers and sharp-tailed sandpipers
Richmond River	1700 waders; important for lesser golden plover, bar-tailed godwit, grey-tailed tattler and curlew sandpiper
Port Stephens	The State's most important site for eastern curlew and whimbrel; also important for lesser golden plover
Lake Macquarie	1000-3000 waders; important for Pacific golden plover and eastern curlew
Botany Bay	> 90 species
Tweed River	750 waders; important for eastern curlew, whimbrel and lesser golden plover
Port Jackson	Grey-tailed tattlers, golden plovers and red-necked stints; little penguin population at North Harbour
Hastings River	Whimbrel
Sussex Inlet	The State's most important site for hooded plovers
Ulladulla coastline	Lake Conjola to Lake Tabourie, sooty oystercatchers and hooded plovers
Sawtell, Harrington, Botany Bay, Lake Wollumboola and Farquhar Inlet	Currently the most important breeding sites for little tern

b) Regional habitat damage due to the Estuary General Fishery

There is no data detailing the modification of habitats in NSW estuaries due to techniques used in the Estuary General Fishery at either the estuary or regional level. Nor is there information available about the extent or frequency of foreshore use by fishers, rather it can only be inferred by the use of particular methods. In the absence of such data, this assessment discusses some of the potential effects due to each of the methods used in the fishery, where possible based on similar techniques that have been studied elsewhere. It considers those potential effects against the intensity (measured as total days of effort over the last 15 years) of each of the techniques to provide some indication of the potential magnitude of impacts. At this stage, it is not possible to relate techniques to particular habitats, but closures are used as a surrogate to assess whether or not the potential impacts are limited in their extent (Table F1), and acknowledges the limitations of this method. It is also impossible to define the potential impacts across fishing regions, as the regions consist of different numbers and types of estuaries, different locations and types of habitats, and different closures.

Table F1 summarises the total fishing effort for each estuary and technique from 1985 - 2000, and indicates if existing closures are likely to protect estuarine habitats. This period represents an upper limit of 3900 calender days, based on only being able to fish during the week, i.e. five days, as a weekend commercial closure is common in almost all estuaries. It is only meant to be a guide and does not include any reductions for public holidays or inclement weather. For ease, Table F6 provides a summary of that information for the top five estuaries for each method that will be referred to in the following passages.

Table F6. The top five estuaries in terms of fishing intensity for each method used in the Estuary General Fishery from 1985 – 2000.

(Source: NSW Fisheries Database).

	Method											
Estuary	**Hauling**		**Meshing**		**Prawning**		**Trapping**		**Hand methods**		**All**	
Clarence River	2	39516	1	40636	1	39663	2	61721			1	181727
Wallis Lake	1	41859	3	35310	3	19153	1	74946	4	960	2	172228
Port Stephens	4	30320	2	35867	5	13193	3	39593	3	965	3	119938
Tuggerah Lakes	5	27783	4	33772	2	19438					4	83592
Hawkesbury R							5	29305			5	61253
Lake Illawarra					4	17516			1	2024		
Richmond River									2	1159		
Pambula Lake									5	877		
Camden Haven R							4	37307				
Lake Macquarie	3	30964	5	21439								

Hand methods = Gathering by hand and handlining
Hauling = Prawn seine (snigging), prawn cloverleafing, general purpose, trumpeter whiting, garfish, pilchard, anchovy, bait, prawn haul, beach haul and bullringing (garfish) nets
Meshing = Pound (figure six), bottom set, top set, splashing and flathead nets
Prawning = Set pocket net and running net
Trapping = Fish, crab, eel and lobster traps

Total effort

Table F6 shows that between 1985 and 2000, the larger systems of the north and central coast were the most intensely fished in terms of total fishing effort. Lake Illawarra (54,242 days) and the Shoalhaven/Crookhaven River system (32,537 days) received the greatest effort on the south coast (Table F1). When fishing effort is compared to water area, however, Coffs Harbour Creek, Tilba Tilba Lake, Nambucca River, Boambee Creek, Deep Creek and Brou Lake appear to be under the greatest pressure. Each of these estuaries, except for Nambucca River, is less than 2 km^2. With the exception of Lake Brou, each of these estuaries has closures that are likely to protect both wader bird habitat and seagrasses. For example, in Nambucca River, the most important wader habitats and numerous seagrass beds are in Warrell Creek and the mouth of Nambucca River, which are closed to commercial nets and traps. These areas are open to handgathering, but 44 days out of a possible 3,900 suggests that this activity is extremely infrequent in Nambucca River (Table F1).

Hauling

The methods used in the Estuary General Fishery could largely be described as passive, or non-destructive to habitats, with the possible exception of hauling, the effects of which are not clearly understood (Otway and Macbeth, 1999). Hauling is generally done on broad, primarily sandy shorelines, and can extend over seagrass and algal beds. There are numerous cases of significant seagrass loss throughout Australia, including NSW, however commercial fishing techniques have not been included as a factor thought to be causing the declines (e.g. Shepherd *et al.*, 1989; Walker and McComb, 1992; Otway and Macbeth, 1999).

Some of the potential impacts that could occur as a result of dragging a haul net across the seafloor include: mechanical damage to sedentary organisms (Lamberth *et al.*, 1995; Reimann and

Hoffmann, 1991); entrapment, transport and removal of organisms, including microalgae (Reimann and Hoffmann, 1991); biofilm re-establishment is delayed in areas of moderate current or wave action, and that repeated hauling in such areas could therefore permanently reduce populations of benthic grazers (Hall, 1999; Kaiser and de Groot, 2000) and resuspension of sediments and contaminants (Dayton *et al.,* 1995; Reimann and Hoffmann, 1991). Some indirect effects that could occur as a result of any or all of these effects include: increased turbidity diminishing the survival of seagrasses and its assemblages; a shift in the composition of benthic communities (Dayton *et al.*, 1995); alteration of sediment type and stability (Churchill *et al.,* 1994); and modifications to microbial activity (Meyer *et al.*, 1981). It is important to recognise that these effects are reported for trawls of various kinds, often on the continental shelf of other countries, and the degree to which they occur during the use of haul nets used in the fishery is unknown.

A recent study of the effects of hauling on *Zostera capricorni*, in nine NSW estuaries, reported that hauling may have caused a reduction in leaf length, but there were also increases in shoot and leaf densities (Otway and Macbeth, 1999). It was concluded that any impact on fish and invertebrate recruitment, whilst not directly tested, was unlikely to be major (Otway and Macbeth, 1999).

A study in South Australia of the effects of hauling on beds of *Posidonia* also reported minimal impacts, as a pressure wave was created in front of the net, which flattened the seagrass and only removed some epiphytes and dead blades (in Cappo *et al.,* 1998). Other studies, however, would suggest that this is not a minimal impact, as epiphytes provide food for fish and invertebrates, and dead leaves provide substantial nutrients for the entire food chain (King, 1981a; West, 1989; Keough and Jenkins, 1995).

A recent study in South Africa of the effects of hauling reported no significant impacts on the benthic flora and invertebrate fauna (Lamberth *et al.,* 1995). A video camera mounted in the net showed that it initially sank to the bottom, whereupon it rose to about 10 - 20 cm from the seafloor at the commencement of hauling. The net was reported to maintain the position throughout the haul, and was not observed to disturb infauna, such as *Callianassa kraussi*. This conclusion should be treated with caution, however, as it was conducted in a bay that was dominated by algae and invertebrates that were probably removed from adjacent rocky shores (e.g. *Ulva* spp. and *Pyura stolonifera*), and thus were not resident species. Furthermore, infauna were not sampled and epifauna were recorded by diver surveys and counts of material retained in the seine nets, which at 44 mm would be too large to retain most invertebrates other than crabs or prawns.

An aspect that such studies have not focussed on is that of the intertidal or foreshore areas, which in estuaries are predominantly used by numerous species of birds, including those of international and national significance. These species utilise intertidal mudflats and sandflats for feeding and/or roosting, so there is potential for them to be driven away due to habitat alteration and general disturbance due to noise or presence. The use of both the low tide (net scour, trampling) and high tide (hauling, trampling, parking boats) areas of the shoreline during fishing could have such an effect. Within the NSW Estuary General Fishery, only two of the top ten estuaries in terms of hauling effort have closures that would probably prevent waders and their habitats from disturbance or modification (Table F1 and F6). These are Tuggerah Lakes and Manning River, neither of which is thought to be particularly important to waders, although they are adjacent to some very important estuaries. In contrast, Clarence and Richmond Rivers and Port Stephens, which contain some of the most important and extensive habitats for waders in the State, have closures that offer little or no protection to such habitat. In the case of Clarence River, on any given weekday over the last 15 years, it is estimated that at least ten fishers would have been hauling in the estuary (Table F6). Many of the preferred hauling grounds in the lower Clarence are in, or adjacent to areas utilised by waders and other threatened birds, and until evidence to the contrary is available, the precautionary principle would suggest it is probably having an impact upon them.

Meshing and trapping

Meshing and trapping could have some similar effects as hauling, but to a much lesser degree. Most mesh nets and traps are negatively buoyant and thus could scrape algae and epifauna from the sediment surface during setting and retrieval, and may alter the habitat of infauna during retrieval. The most likely damage to arise, however, is when anchors or other heavy objects are used to maintain nets or traps in position. The anchors could resuspend sediments and contaminants, bury infauna or expose them to predators, and damage seagrass. Like hauling, these effects have potential flow on effects, although there is no data to suggest the extent to which they could occur within estuaries used in the fishery. The resuspension of sediments could increase the turbidity adjacent to the gear, and the sediment could be transported to adjacent environments, such as seagrass, reducing the light available to it and covering the blades. The transport of any contaminants associated with those sediments could affect water quality and reduce the ability of organisms to survive in the sediment. The degree to which these effects could occur would also be determined by the location within the estuary. The lower reaches are predominantly marine sands and would settle rapidly after disturbance. In the muddy, upper reaches of estuaries where finer sediments dominate, continued resuspension and transport, of sediments and fauna, could occur more frequently. Such areas, however, also support fewer species of fish and invertebrates and lower numbers of organisms, reducing the potential impact. Meshing and trapping are also used in nearly every estuary, so any potential impacts are also likely to be widespread. As with hauling, the top five estuaries in terms of effort account for approximately 50% of the total effort, suggesting that any potential impacts are likely to be more pronounced within these estuaries (Table F6).

Prawning

Prawning, by the methods of set pocket and running netting, can also have some effects and it is probable that they are locally intense, as most of these areas are effectively recognised fishing grounds (albeit undeclared) where the techniques are continually practised. It is probable that if there were any effects on the substratum and adjacent habitats due to these methods, that they may be readily distinguishable from similar adjacent areas that have not been consistently fished by these methods. This may be particularly so for set pocket prawning, which takes place in only 11 estuaries and only two of these, Lake Illawarra and Sussex Inlet, are on the south coast. On a regional level, Regions 3 and 4 have four estuaries, and Regions 2, 6 and 7 all have one estuary where set-pockets are permitted. In contrast, running nets dominate on the far south coast, with Lake Macquarie representing the northernmost estuary for this method. Set pocket netting would normally have very little impact upon habitats, but in the Clarence River it can be done using the assistance of boat propellers to create the necessary current, strengthening or imitating ebb tide. When done this way, it is possible that in shallower areas, sediment could be disturbed and seagrass could be affected both directly and indirectly. The foreshore, including the intertidal area, could also be affected by both of these techniques, as they require access to the shore. This increases the potential extent of any impacts, not only by affecting another type of habitat, but the fauna and flora associated with it, such as infauna, birds and beachplants. The continued trampling of a particular area could also increase the potential for erosion of the shoreline, reducing the habitat quality of both the intertidal and subtidal area. Overall, the limited extent of prawn set-pockets, 11 estuaries and in particular places within each estuary, should minimise the potential extent of any impacts within an estuary and across the State, although there is no data to suggest the type or magnitude of those impacts.

Gathering by hand

Gathering by hand occurs regularly on ocean beaches, targeting pipis and worms, and occasionally within estuaries for species such as yabbies, cockles, mussels, fish and shellfish. Other than removal by hand, yabby pumps and knives are used to collect fauna, and as such effects are fairly restricted, but could include disturbance of birds, trampling, increased exposure to predation or mortality of discards, and sediment modifications. These effects can take place during the collection, but also during access to the foreshores. Even in the most intensely fished area, Lake Illawarra and adjacent beaches (2,024 out of a maximum 3,900 days), such effects are likely to be insignificant due to the selectivity of this method and the popularity of the area for recreation. Regions 4 and 6 (of which Lake Illawarra accounts for 65%) are the most intensely fished regions and account for more than 50% of the effort over the last 15 years for this technique. Within Region 4, Port Stephens and Wallis Lake together account for approximately 65% of the effort in the region, suggesting that if gathering by hand had an impact, it may be detected in those estuaries and Lake Illawarra.

Assessment of management responses proposed in the draft FMS

It is clear that there is no information with which to make an accurate assessment of the degree of habitat damage that may have occurred due to the techniques used in the fishery. The lack of any data, but acceptance that the fishery has probably had some as yet unknown impact on biodiversity and habitats, has meant that the draft FMS has taken a precautionary approach to the ongoing management of the environment. This is reflected in several of the management responses, which are adaptive and include data collection programs, and by adopting this ‘wait and see’ approach whilst data is collected, it allows fishing to continue but sets benchmarks that, if and when reached, may further restrict or modify fishing. It is accepted that there is some uncertainty inherent in such an approach. It is deemed more appropriate, however, to implement those measures while data is being collected, than to either continue fishing in its current pattern suspecting that it may be impacting on the environment, or conversely to terminate fishing on the grounds of that suspicion.

The draft FMS does suggest changes to some methods, which were discussed in Chapter F section 1(a) in relation to each type of habitat. Fish hauling, prawn seining and prawn hauling are generally recognised in the draft FMS as the techniques that need to be either restricted in their area of use, or the gear modified to reduce potential impacts. In the absence of data, it is not unreasonable to assume that by restricting the types and intensity of methods that can be used in the various habitats, that the responses proposed in the draft FMS should minimise, or reduce the extent of, any potential impacts associated with the techniques used in the fishery. That said, alterations to gear and the definition of fished and unfished areas should be capitalised on as opportunities to conduct research that is currently lacking. This should also apply across all methods, not just those generally referred to as hauling. This would serve the dual role of determining the effects of the techniques on different habitats and their fauna, and may define some areas as important in terms of both the fishery and the broader estuarine environment. Such data could be used to base decisions about the need for marine protected areas and the level of protection required within those areas.

c) Level of confidence in achieving predicted outcomes

Section 1(a) of this Chapter outlined the management responses and the confidence levels associated with them for each of the habitats that could be affected by the fishery. The responses are considered in isolation, but they all work towards the primary goal of managing the fishery in a manner that promotes the conservation of biological diversity. Overall, the responses proposed in the draft FMS are deemed to have, at worst, a medium but more likely high probability of achieving its outcomes as they pertain to the management of estuarine biodiversity, and minimising any potential impacts.

This assessment has adopted a precautionary approach in the absence of reliable data about the effects of the fishery on habitats and fauna. Most of the impacts are inferred, based on what are thought to be much more intensive and destructive techniques. Assuming the techniques adopted in the fishery are less destructive than trawling and scallop dredging, for which a lot of research has been done, and pending the results of research programs outlined in the draft FMS, it is probable that any impacts due to the fishery are not long term or permanent. Furthermore, they are likely to be restricted to less than 30 estuaries as they account for 95% of the effort of the fishery. Estuaries are complex environments, with varying salinities, tides, sediments and nutrients. The plants and animals that are adapted to living there have evolved strategies that should allow areas perceived to be adversely affected by fishing, to recover if fishing were to become more restricted in its extent or intensity, as proposed in the draft FMS. Such restrictions need not be permanent, but either way, should ensure that the biodiversity of estuaries utilised by the fishery are maintained and/or improved.

d) Alternate mitigation measures

i) Timing of fishery activities to minimise disturbance

There is yet no data about the effects of the fishery on the biodiversity and habitats of estuaries, so it is difficult if not impossible, to accurately determine how the draft FMS or other proposed measures would affect them. It is the opinion of this assessment, however, that the majority of the responses proposed in the draft FMS should reduce any potential impacts on biodiversity and habitats.

Mitigation measures within the draft FMS include the responses to various management objectives, monitoring programs and the various closures that exist under the FM Act. In particular, the draft FMS aims to minimise the impacts of the fishery on habitats, and hence fauna, and includes responses such as temporary and permanent closures, gear modifications and developing codes of conduct when operating near particular habitats. With respect to timing of activities, the key responses are those that relate to minimising the impact on species during particular periods of their lifecycle. This primarily relates to the disturbance of waders and other birds, usually in spring and summer, and spawning periods for a variety of fish and invertebrates, mostly those targeted in the fishery. Table F1 suggests that more than half of the existing closures currently offers little or no protection to wader bird habitats. There are some closures that cater for seasonal movements of fish and crabs, such as Australian bass, estuary perch and mud crabs, but none related directly to birds. Historically this is understandable, but in light of Ecologically Sustainable Development, the draft FMS should seek to redress this imbalance. The proposed code of conduct for fishers should prove an adequate measure until more information about the distribution of waders is collated and reviewed. Following the review, consideration should be given to the need or otherwise to develop seasonal closures within those estuaries considered to be among the most important for particular species or communities.

ii) Location of fishing activities to minimise impacts

Several estuaries are closed or partially closed to commercial fishing. The draft FMS also proposes to prohibit all hauling over beds of *Posidonia* seagrass, and to prohibit prawn hauling and seining over all seagrass, providing additional protection to a habitat thought to be critical in the lifecycle of numerous fish and invertebrates. Furthermore, several estuaries are currently being considered for inclusion as estuarine protected areas and recreational fishing areas, separately from the draft FMS. The draft FMS adopts a trigger point for such reserves and other closed areas, but considers an overall increase in the number of estuaries open to fishing across the State as the trigger. An additional trigger that should be considered is whether the draft FMS results in an increase in the proportion of the various habitats that are protected in each bioregion. There can be large fluctuations in biodiversity among estuaries and within estuaries through time, and it will be more important to consider closures according to regions, than by the total number of estuaries closed to fishing

On a local level, approximately half (66) of the estuaries have closures in seagrasses and entrance channels that are important for juvenile fish and invertebrate recruitment and migration. Of these, only 12 have a water area greater than 5 km^2, with the majority consisting of smaller estuaries, many of which are open to the sea some of the time and have limited areas of seagrass. It is recommended, as indicated in the responses in the draft FMS, that similar closures be implemented in some of the larger estuaries, including those under the greatest pressure from the fishery. There also needs to be a performance indicator and trigger point established for the area of important habitat that is protected, as discussed above.

Other closures exist that are specific to certain locations to accommodate the seasonal migrations of some freshwater species to estuarine or brackish environments. These are usually in the larger rivers that contain Australian bass and estuary perch in their upper and middle reaches, but which migrate to estuaries in the cooler months to spawn. In these areas, mesh nets must be used by the method of splashing, whereby the net is effectively set near the targeted fish and then retrieved soon afterwards. This ensures that any captured fish can be released quickly and suffer minimal stress or injury. These and the other measures discussed in the draft FMS are considered to be an effective and manageable way of mitigating impacts on the life-cycles of species within the fishery.

iii) Closures in key habitat areas

As discussed above, there are numerous restrictions on fishing activities in key habitat areas for approximately half of the estuaries in the State, and the draft FMS includes strategies to increase these areas. These pertain specifically to using closures to protect key habitats, prohibiting the use of all haul nets over beds of *Posidonia*, temporary closures in areas of high abundance of juvenile fish, and modifying any other techniques that are thought to be having a detrimental impact on habitats. They also include performance indicators to monitor the declaration of protected areas and to monitor interactions with threatened species. As most of the threatened species, and those of international significance, that could be affected by the fishery are birds and as such occupy intertidal habitats, it will be important for future closures to consider those areas as key habitats. These closures, whether gear, time or location specific, need to encompass as many habitats as possible, beyond those historically reserved because they have large areas of aquatic vegetation. The current proposals to declare entire estuaries within the main protected areas framework, whilst not directly part of the draft

FMS, clearly have the potential to strengthen measures in the draft FMS. Extensive closures and/or marine protected areas that include areas of no harvesting, commercial or recreational, are considered to be the most effective, large-scale management tool with which to ensure the fishery has as little impact on biodiversity and habitats as possible.

Following the discovery of the marine algae, *Caulerpa taxifolia*, several estuaries have been closed to some types of commercial and recreational netting. These are summarised below, and their potential impacts and implications are discussed in more detail in section 4 of this Chapter.

Caulerpa is able to regenerate vegetatively, meaning that small pieces that are broken off are able to establish themselves and continue growing, enhancing any infestation that has occurred. Fishing methods, particularly netting, are considered potential vectors for the spread of the algae, within and among estuaries, hence the closures described above. Given the concern over, and the ease with which this algae can spread, it is the opinion of this assessment that marking areas of infestations and closing them to some forms of fishing is inadequate. This does not make sufficient provision for the control of removal and dispersal by users of the estuaries other than commercial fishers. Marking the areas of highest density is appropriate for general awareness, but should not be used as an isolated measure. Furthermore, meshing is allowed in Lake Conjola provided the gear is only used in that estuary, and there are no closures on traps for any estuaries. This places considerable onus on the fishers and assumes that no algae will remain on traps following retrieval.

Table F7. New fishing restrictions in areas affected by the alga *Caulerpa taxifolia*.

Waterway	Commercial Methods	Recreational Methods
Narrawallee Inlet (Ulladulla)	Mesh netting will be banned in the buoyed area	Hand hauled prawn netting will be banned in the buoyed area. Can still line fish and use a landing net
Burrill Lake (Ulladulla)	All netting will be banned in the buoyed area.	Hand hauled prawn and scissor netting will be banned in the buoyed area. Can still line fish and use a landing net.
Lake Conjola (inc. Berringer L) (Ulladulla)	Haul netting will be banned in the whole lake. Can still mesh net with a Lake Conjola specific net only. Commercial fisher's boats and equipment to be quarantined to lake.	Hand hauled prawn and scissor netting will be banned in the buoyed area. Can still line fish and use a landing net.
Careel Bay (Pittwater)	All netting will be banned in the buoyed area.	Hand hauled prawn and scissor netting will be banned in the buoyed area. Can still line fish and use a landing net.
Lake Macquarie	All netting will be banned in the buoyed area	Hand hauled prawn and scissor netting will be banned in the buoyed area Can still line fish and use a landing net
Quibray Bay (near Kurnell, Botany Bay)	No change as all netting is already banned in the buoyed area.	No change as all netting and line fishing is already banned in Quibray Bay.
Port Hacking	No change as all netting is already banned.	No change as all netting is already banned. Can still line fish and use a landing net.

e) Knowledge gaps

It is clear from the assessment that much is known about the biodiversity and habitats within estuaries likely to be affected by the fishery, but there is no data on the magnitude, extent, or even type of effects on those features. The potential effects of the various gear types were based on extrapolations from studies of much larger, more intensive equipment, often from overseas and in marine environments. The few studies of similar gears and habitats, and the study using gear and habitat specific to the fishery, were inconclusive or not readily correlated. As such, there is a fair degree of uncertainty associated with the assessment of impacts of the methods.

Fishing effort and closure information is more readily available, however, and when compared to the distribution of fauna and habitats, has provided an indication of the overall potential impacts of the fishery on biodiversity and habitats. NSW Fisheries is currently mapping the distribution of habitats, fishing closures, marine parks and aquatic reserves within estuaries. This will provide some quantitative data of the proportions of each habitat type that are fished, adding considerable confidence to an assessment of the potential impacts on those habitats. Such a qualitative approach is far from definitive, however, and there is an obvious need for the collection of targeted, quantitative data, and for it to be fed back into the draft FMS for future reviews. The establishment of research or scoping programs, other than the observer program, should also be included as trigger points in the draft FMS.

At this stage, the draft FMS does not propose any research programs examining the effects of methods on habitats and/or biodiversity. The draft FMS is unable to determine, prioritise or fund those projects because they will be determined by the observer survey, which is supposed to identify problems of physical damage on habitats. The proposed observer survey may well be adequate for recording the numbers of directly or indirectly affected threatened or protected species, but will offer little information to prioritise areas of habitat that are damaged. Subjective observation should not be the basis for determining which habitats and techniques warrant manipulative field experiments as proposed in the draft FMS. It is recommended that during the establishment of preferred landing and hauling sites and recognised fishing grounds, impact (fished) and control (non-fished) sites be selected from numerous estuaries for a research program into the effects of the fishery on habitats and biodiversity. As a minimum, and priority, the selection of sites should seek to partition habitats by technique, with the overall aim of determining the proportion of habitats within each estuary that is affected by each of the techniques. This would also allow a regional assessment of potential pressure on seagrass, assist in determining the need and timetable for research, and where justified, provide the scope required of any research.

It is recommended that the draft FMS be modified to include specific details of research programs to investigate the effects of the methods used in the fishery on the habitats in which fishing occurs. As a minimum, any proposed programs should be run over at least a few years, include multiple control locations and an impact location within impacted estuaries, and also include the same number of locations in control estuaries. This will provide an estimate of the spatial extent of the impact of the method. If the impact is restricted to the impact location, then the control locations within the same estuary will be different. If they are not different from the impact location, but are different to the other control locations in adjacent estuaries, then the impact affects other areas within the estuary, not just the location in which fishing was done.

The establishment of aquatic reserves also presents an opportunity to monitor a planned environmental disturbance (in this case a supposedly positive disturbance). By monitoring in a similar way to that described above, but on numerous occasions before and after the reserve was declared, it should be possible to detect any changes attributable to the reserve. This in itself is important, as it has other implications. This also has the advantage of providing an estimate of the resilience of habitats to fishing methods, and may provide information about sizes or features of reserves that are important for maximising diversity. This information could then be used as smaller scale closures in other estuaries that are not aquatic reserves, somewhat similar to crop rotation in terrestrial environments. For example, it may be decided that an area in the lower estuary has been under substantial fishing pressure, but information from the reserve program suggests that closing that area to a particular method for 12 months should be enough for habitats and assemblages to recover to a certain point. This situation, whilst purely hypothetical, indicates the opportunities that readily exist to fill some of the more important gaps in the knowledge that are required to assess the impacts of the fishery.

2. Threatened and Protected Species

a) Threatened species that may be affected by the Estuary General Fishery

Owing to its widespread use and variety of techniques, the Estuary General Fishery has the potential to affect a variety of non-target species, including those broadly described as threatened. As mentioned in previous sections, however, there is a paucity of information about the existence or degree of these effects on any species, let alone threatened species. Furthermore, this does not allow the assessment to focus on particular methods that are thought to be responsible for a decline in any species, as is the case in many oceanic fisheries (e.g. otter trawling and turtles, longline fishing and albatross). To enable as wide a scope as possible, for threatened species of fish, the methods will be presented that could impact on the various species, based on habitat use at particular life stages. For threatened birds, which are largely migratory waders and shorebirds, it will initially be assumed that all methods have an equal impact, as impact is likely to be due to disturbance as opposed to direct capture. An attempt will be made, however, to isolate those methods, such as hauling and bait collecting, which could have a more direct impact as they are more likely to utilise habitats of both waders and shorebirds.

For the purposes of this assessment, threatened species refers to any estuarine or coastal species, populations or ecological communities and their habitats as defined and listed under Schedules 4 or 5 of the *Fisheries Management Act 1994,* Schedules 1 or 2 of the *Threatened Species Conservation Act 1995*, or Subdivisions C or D of the *Environment Protection and Biodiversity Conservation Act 1999*. This assessment also includes any species of fish listed as protected under Sections 19 (totally protected - not to be taken) or 20 (not to be taken by commercial fishers) of the FM Act.

The species considered in the following general assessment under the FM Act, and the TSC Act and EPBC Act, are summarised in Tables F8 and F9, respectively. Detailed species profiles are provided in Appendix F4, and the complete eight-part test referred to below is in Appendix F5.

Based on the various relevant pieces of legislation protecting threatened species and an analysis of their distribution and ecology, it would appear that the Estuary General Fishery has the potential to impact approximately 42 species, one population and one community. Of those species, very few are truly estuarine species and many only inhabit estuaries for a limited period either annually or throughout their life. The species listed have been included because some of their preferred habitat occurs within estuaries and so they could be affected in some manner by the fishery.

Table F8. List of species protected under the *Fisheries Management Act 1994* that could be affected by the Estuary General Fishery.

* denotes species also considered vulnerable under the EPBC Act.

Species/ group	**Types of habitat where most likely to be caught or affected**	**Methods**	**Main age groups liable to be affected**
Endangered Species			
green sawfish*	lower reaches, particularly mouths of estuaries on far north coast	meshing, hauling	all
grey nurse shark*	lower reaches of larger estuaries and bays	meshing and hand-lining	all
Vulnerable Species			
black cod	rocky reef, particularly where caves and/or large drop-offs are present, especially lower estuarine areas	meshing, fish trapping and hand-lining	all, especially juveniles
great white shark*	lower reaches of larger estuaries and bays	meshing and hand-lining	all
Protected Species (Section 19)			
Australian grayling*	brackish to freshwater areas of the south coast	fish hauling	juveniles
eastern blue-devil	rocky reef near estuary entrance, particularly in the south	fish trapping and hand-lining	adults
elegant wrasse	algal beds and reefs in lower estuarine areas	fish hauling, fish trapping, hand-lining and meshing	all
estuary cod	as above, but more prevalent in north of state	fish trapping and hand-lining	all
Queensland groper	rocky reef near estuary entrances, but more prevalent in north of state	fish trapping and hand-lining	all
weedy seadragon	rocky reef and kelp beds near estuary entrance in areas subject to strong marine influence	fish hauling	all
Protected Species (Section 20)			
Australian bass	brackish to freshwater areas; during winter further downstream in estuary proper, particularly after heavy rain	fish and prawn hauling, meshing and eel trapping	all
blue groper	seagrass and rocky reef near estuary entrance	fish hauling, prawn hauling, meshing, fish trapping and hand-lining	juveniles
estuary perch	upper estuaries, sometimes in lower freshwater reaches; during winter may be found well downstream towards estuary mouth	fish hauling, fish trapping, hand-lining and meshing	all

Most of the fish are marine species that inhabit rocky reefs, but have been included because such habitat could be utilised by the fishery, and although it may not cause direct impact through capture, it could compete for similar target species and thus reduce the food available to the threatened species. Australian grayling are a freshwater fish restricted to several coastal drainages of the far south coast, some of which are not open to commercial fishing. They spawn in freshwater and the eggs are carried out to sea or to the lower reaches of estuaries. Maturing juveniles then return to, or swim back up the estuary to freshwater, during which time they could be caught in haul nets or prawn nets.

Of the plants, two occur within saltmarshes in a limited number of coastal lakes of the south coast. It is possible that the plants could be trampled during access to the shoreline or during hauling or prawning operations. The other plant is a fresh to brackish water species of which very little is known, but it is thought possible that it could occur in the upper reaches of Lake Macquarie, near Belmont.

Approximately half of the species of birds are migratory. Most breed in the Northern Hemisphere and arrive in spring and summer to feed on sandflats and mudflats of estuaries and adjacent coastal beaches. Some remain over winter, but do not breed. The others are permanent residents. Some feed and breed exclusively in estuarine and/or adjacent coastal environments, such as oystercatchers, whereas others may breed further inland when conditions are suitable. It is extremely unlikely that any of the threatened species would be caught by any of the methods of the fishery, and most of the potential impact would be indirect. Disturbance during feeding or roosting could affect all species, and disturbance during nesting could affect the resident species. Some species, such as little terns, little penguins, ospreys and oystercatchers could also be affected by reduced food sources through competition with the fishery.

Table F9. List of species protected under the *Threatened Species Conservation Act 1995* or *Environment Protection and Biodiversity Conservation Act 1999* that could be affected by the Estuary General Fishery.

Species/group	Types of habitat where most likely to be affected	Most likely effects	Protective treaties or legislation
Endangered Species			
Wilsonia rotundifolia	Saltmarsh of Lake Wollumboola, Swan Lake, Meringo Lagoon and Lake Coila	trampling	TSC
beach stone-curlew	North of Nambucca River; open beaches, sandflats and mudflats	disturbance - feeding	TSC
bush stone-curlew	Central coast; saltmarsh, mangroves	disturbance	TSC
hooded plover	South of Jervis Bay on long sandy beaches backed by vegetated dunes	disturbance - feeding disturbance - nesting	TSC
little tern	Sand-spits, islands and beaches or feeding at estuary mouths	disturbance - feeding disturbance - nesting	TSC, EPBC, J and C
Zannichellia palustris	Tributaries of Hunter River (Lake Macquarie?)	could be hauled over	TSC
Endangered Populations			
little penguins (population)	North Harbour Aquatic Reserve, entrance to Port Jackson	disturbance - feeding disturbance - nesting	TSC
Endangered Communities			
Taren Point Shorebird Community	Taren Point	disturbance - feeding	TSC
Vulnerable Species			
Plants			
Wilsonia backhousei	Saltmarsh, esp. in Jervis Bay, and north to Wamberal Lagoon	trampling	TSC
Reptiles			
green turtle	Seagrass beds of northern and central NSW	disturbance - feeding	TSC and EPBC
leatherback turtle	Mouths of major rivers - primarily oceanic	disturbance - nesting	TSC and EPBC
loggerhead turtles	Seagrass beds, estuarine and coastal reefs	disturbance - feeding	TSC - vulnerable EPBC - endangered

Table F9 (cont).

Species/group	**Types of habitat where most likely to be affected**	**Most likely effects**	**Protective treaties or legislation**
Vulnerable Species (cont)			
Birds			
Australasian bittern	Saltmarsh	disturbance - feeding disturbance - nesting	TSC
black bittern	Northern half of coast, wetlands and mangroves	disturbance - feeding disturbance - nesting	TSC
black-tailed godwit	Sp. and Su; sandspits and mudflats, esp. Hunter R.	disturbance - feeding	TSC, J and C
broad-billed sandpiper	Sp. and Su; Hunter to Shoalhaven Rivers, sand and mudflats adjacent to mangroves	disturbance - feeding	TSC, J and C
collared kingfisher	Tweed to Ballina, mangroves and creeks	disturbance	TSC
comb-crested jacana	Tweed to Bermagui, upper reaches	disturbance	TSC
freckled duck	Coastal brackish lakes	disturbance - feeding	TSC
great knot	Sp. and Su; sandflats, mudflats, sandy beaches	disturbance - feeding	TSC, J and C
greater sand plover	Su; sandflats and mudflats	disturbance - feedin	TSC, J and C
lesser sand plover	Su; beaches, sandflats, mudflats and mangroves south to Shoalhaven R.	disturbance - feedin	TSC, J and C
mangrove honeyeater	Mangroves from Tweed to Macksville	disturbance - feeding disturbance - nesting	TSC
osprey	Areas of extensive open water	disturbance	TSC
pied oystercatcher	Sandflats, mudflats, beaches	disturbance	TSC
sanderling	Su; mudflats, sandspits, coastal lagoons	disturbance - feeding	TSC, J and C
sooty oystercatcher	Rocky shores, beaches	disturbance	TSC
Terek sandpiper	Sp & Su; mudflats near mangroves, lakes and creeks	disturbance - feeding	TSC, J and C
Marine Mammals			
Humpback whale	Entrance of larger bays and harbours	disturbance	TSC and EPBC
Indo-Pacific humpbacked dolphin	Far North Coast, mouths of larger rivers.	disturbance - feeding capture	TSC - vulnerable; EPBC - insufficiently known
Southern right whale	Entrance of larger bays and harbours	disturbance	TSC and EPBC

Where: Sp = spring
Su = summer
J and C = Threatened species that are also protected under JAMBA and CAMBA (see Appendix F4).

There is much less scope for the fishery to impact marine mammals or reptiles, as they are largely only occasional visitors to coastal waters, and even fewer actually frequent estuaries. Southern right whales and humpback whales are seen off our coastline from about July to October as they migrate to and from breeding grounds. They are not believed to feed off NSW waters, but often enter the larger embayments such as Jervis Bay, Twofold Bay and Sydney Harbour, presumably to rest. Thus there is potential, albeit very limited, for general disturbance and boat strikes, particularly as numbers of the animals increase. There is very little known about the occurrence of Indo-Pacific humpbacked dolphins or any of the turtles in NSW waters, but in other areas they are known to regularly enter estuaries, and their range of distribution includes several north coast estuaries. They could be affected by direct capture, disturbance during feeding, and/or competition for food resources.

The following sections will aim to more precisely define this level of impact, to isolate measures from within the draft FMS designed to mitigate potential impacts, and to determine the effectiveness of those measures.

b) Potential impact due to direct capture or disturbance

As discussed in previous sections, the Estuary General Fishery uses a variety of techniques across all types of habitats, ranging from seagrass and algae to bare substrata and sandy shores. This section will focus on how these techniques may impact on threatened species through either capture or disturbance, or by altering the habitats of the various threatened species. For brevity, generalised statements will be used for species that utilise similar habitats, except where it is apparent that a method or its timing may adversely impact upon a particular species. The conclusion from the eight-part test is included in this section (complete test in Appendix F5), as it must be taken into account in deciding whether there is likely to be a significant effect on threatened species or their habitats.

i) Capture rates and mortality

There are no data about the capture and/or potential mortality associated with it for threatened species within the Estuary General Fishery. Historically, information about capture rates and/or mortality due to fishing of such species has not been recorded as part of the monthly catch returns for estuarine fishers. The concept and legal application of threatened species legislation in itself is still only a relatively recent phenomenon. In 1987, the Commonwealth government protected seals and sea snakes under the *National Parks and Wildlife Conservation Act*, following on from the ban on driftnet fishing in 1986, which was causing a high incidental mortality of dolphins (Eisenbud, 1985; Northridge, 1991; Miller, 1995). Oceanic longlining vessels targeting tuna in the Southern Ocean and waters of the southwestern Pacific were also capturing large numbers of seabirds, particularly albatross and petrels (Environment Australia, undated; Murray *et al*., 1993; Brothers, 1991). The NSW NPWS introduced the concept in 1991 through the Endangered Fauna (Interim Protection) Act, which became the TSC Act 1995, and in 1997, NSW Fisheries included similar amendments to the FM Act 1994. Furthermore, and largely because it is a recent concept, many species that are considered threatened do not have recovery plans, which are a requirement of all threatened species legislation and would detail threatening processes and management measures to mitigate those processes. An example of an existing threat abatement plan is longline fishing and albatross in Australian waters (Environment Australia, undated).

Within the fishery, the closest parallel occurs with hauling in Spring Cove near the little penguin colony. Discussions with staff of the NPWS suggest that although there is a fair degree of community opposition to commercial fishing due to the perceived conflict, there is in fact no evidence of capture by, or mortality directly attributable to, commercial fishing (B. Humphries, NPWS, pers. comm.). The mortality database maintained by NPWS lists numerous other factors, such as gunshot wounds, foxes and dogs that are largely responsible for the 84 deaths that have been recorded since the database was established in 1994.

The draft FMS acknowledges that of the protected species of fish, the fishery occasionally captures Australian bass, estuary perch and estuary cod, although there are no data about where or how frequently these captures occur. Australian bass and estuary perch would most likely be caught in the mid to upper reaches of the larger estuaries with fresh to brackish tributaries. Estuary cod, and several of the other threatened species of fish for that matter, could be caught in the lower reaches where there is rocky reef or other suitable hard substrata. Whilst the methods that can be used in such habitat are limited in terms of type and extent, there is potential for the fishery to capture more species than those mentioned in the draft FMS.

The recovery plan for marine turtles in Australia did not include any commercial fishery of NSW in its list of Australian fisheries known or thought to have a potential impact on marine turtles (Environment Australia, 1998). The plan identified fisheries from Queensland, Northern Territory, Western Australia and Tasmania, and detailed programs to resolve uncertainties about bycatch and mortality of marine turtles in those fisheries.

ii) Habitat disturbance or loss

As previously discussed in Chapter F of section 1, there is little quantitative or qualitative data on the effects of the techniques used in the fishery on aquatic habitats. The fishery has existed for over a hundred years, and it is probable that any changes that might have occurred due to fishing would have taken place early on and any subsequent changes would probably be less visible or dramatic. Furthermore, they may no longer be readily identifiable due to the variety and extent of other factors affecting habitats, e.g. sand and gravel extraction, dredging, urbanisation and industry.

Habitat disturbance, in its various forms, is amongst the processes threatening the survival or viability of many species or communities, particularly threatened birds. For example, commercial fishermen working adjacent to some islands off the coast of Wollongong were reputedly responsible for preventing adult little penguins (not part of the threatened population at Manly) from returning to their nests (NPWS, 2000a). Whilst not intentional, nor part of the Estuary General Fishery, it provides some indication of the sensitivity of certain animals to disturbance and provides some insight as to what may occur elsewhere and for other species or populations. Until more research is done, particularly during the formulation of management and recovery plans for such species, the extent of this impact remains unclear.

iii) Indirect impacts

Whilst not readily quantifiable, indirect impacts such as noise, collision with vessels and alteration of food webs could affect some threatened species during feeding and/or roosting. There are over 180 000 vessels registered by the Waterways Authority in NSW, of which commercial fishing vessels used in the fishery, mainly runabouts of generally between 3 - 6 m in length, account for less than 0.5%. Recreational vessels comprise approximately 96% and other commercial vessels 3.5%. This suggests that the potential impact of estuary general fishing vessels would be much less than that of recreational vessels, especially considering that recreational vessels can generally access all areas, yet closures exist for commercial fishers. Within the smaller estuaries, these closures are often extensive in terms of gear and area, effectively precluding the use of boats from estuaries that could be perceived as more natural and thus more vulnerable to impact. Examination of the effort associated with the fishery also suggests that the majority of it is focussed in 24 estuaries, and that these are predominantly the larger estuaries of the central and north coasts, which are also popular tourist destinations. Furthermore, during setting and retrieval of nets, fishers usually use a smaller motor operated at low speed. This is likely to minimise potential effects due to disturbance or boat strikes, even at night when other boating activities are likely to be minimal.

The Estuary General Fishery catches a combination of predator, prey and scavenger organisms from within the estuarine food web. This can have a myriad of subsequent effects, both favourable and detrimental to all trophic levels (see Chapter F section 3). Such effects are widely speculated, but poorly documented, in the scientific literature. Dayton *et al.* (1995), reported the proliferation of squid populations in the tropics as a result of heavy fishing pressure, and a study in Port Phillip Bay, Victoria, suggested that adult little penguins had died from starvation because fishing had depleted stocks of anchovies and pilchards (Harrigan, 1992). It was later reported that weather patterns, particularly related to the El Nino-Southern Oscillation phenomenon, caused dramatic shifts in baitfish recruitment, schooling behaviour, abundances and distributions, such that penguins were probably unable to catch sufficient food, irrespective of fishing practices (Hoedt *et al.*, 1995; Dayton *et al.*, 1995), also highlighted the problem of catching aggregated prey such as baitfish and were concerned that it could be a significant, but unstudied problem in Australia.

Many of the indirect impacts associated with commercial fishing, particularly the harvest of baitfish adjacent to the little penguin colony at Manly, have been implicated as processes threatening the species (NPWS, 2000a). However, no data to substantiate the claims exists, and fishing is not listed as a Key Threatening Process under the TSC Act. Conversely, some species may benefit by becoming adapted to fishing activities, behaviour common among many species of dolphins, sharks and birds feeding on discards from prawn trawls (Wassenburg and Hill, 1990; Broadhurst, 1998; Blaber *et al.,* 1995).

iv) Summary of the eight-part test

This assessment has considered the eight factors under the relevant sections of the FM Act, TSC Act and the EP&A Act in deciding whether there is likely to be a significant effect on threatened species, populations or ecological communities or their habitats (Appendix F5). The assessment was based on a review of biological information derived from the various agencies responsible for those species, from published literature and from personal communications. The assessment has found that the proposal will not have a significant effect on any threatened species, populations or ecological communities or their habitats, and as such a Species Impact Statement is not required for the draft FMS.

v) Assessment of impact on threatened species

Whilst hardly definitive or based on an abundance of scientific data, the factors listed above would suggest that the Estuary General Fishery is not having a direct and/or adverse impact on any threatened species. The lifecycles, preferred habitats of many threatened species and techniques used in the fishery suggest that there is limited scope for the fishery to have a significant impact on them. There is, however, a high degree of uncertainty associated with this assessment due to the paucity of quantitative data, and reliance upon anecdotal or speculative information. Until data are collected that detail interactions between fishers and threatened species, there will always be a risk that species are being negatively impacted upon without management actions being enacted. Such an approach is also largely reactive, and in order to avoid negative impacts on threatened species, pro-active measures need to be defined in species recovery plans and effectively implemented. At this stage, there are no recovery plans for any marine or estuarine species under the FM Act considered in this assessment, although the NSW NPWS has finalised a recovery plan for the little penguin colony at Manly, and drafted a recovery plan for little terns. Environment Australia has also drafted recovery plans for grey nurse sharks and great white sharks.

The little penguin population is located within and close to North Harbour Aquatic Reserve administered by NSW Fisheries. Despite being listed in the threat abatement plan as a threatening process for the little penguin population, some commercial fishing is allowed in the reserve. Lobster pots and fish hauling are allowed between Manly Point and Cannae Point, the stronghold for the species, and lobster pots are permitted throughout the rest of the reserve. The apparently contradictory status of a potential threatening process being allowed to continue suggests recognition of a lack of data implicating fishing, and an adaptive management regime. Furthermore, the area is not defined as critical habitat. Hauling, in particular, is scrutinised as it can obstruct adult birds from returning to their burrows and may be amplified in the breeding season when adults are forced to remain in the water longer and consume fish that they would otherwise have fed to their chicks. Part of the overall monitoring program of the population is a threat abatement program, which includes the establishment of a mortality register by NPWS and for NSW Fisheries to monitor fishing effort and catches of baitfish in Sydney Harbour, and to record any incidental catches of little penguins. Since the establishment of the register, there have not been any reported deaths associated with commercial fishing. Effort data also suggest that there is minimal potential for an impact on the penguins. There are only two crews that regularly use the area and both concentrate their activities in winter and autumn, which is when mullet and bream make spawning migrations. One of the crews works twice a month at this time, and the other works 2-3 times a week during those periods, which are largely out of the main breeding time for the little penguin. At this stage, it would appear that the fishery is not having an adverse impact upon this little penguin population.

The draft recovery plan for little terns does not specifically mention commercial fishing, but it would be included as a form of human disturbance, for which management actions are listed in the plan. Four breeding sites, at Harrington, Farquhar Inlet, Botany Bay and Lake Wollumboola, were identified as requiring intensive management during the breeding season. The nesting sites at Harrington and Botany Bay were also identified as worthy of inclusion into Crowdy Bay National Park and Towra Point Nature Reserve, respectively. Intensive management would involve signposting the areas and boatramps, a public education campaign, preventing access by humans and animals through fencing, prohibiting off-road vehicles from the vicinity of nesting sites, control of encroaching vegetation and using wardens to patrol the busiest sites. The nesting site at Towra Point is also within the sanctuary zone of Towra Point Aquatic Reserve, administered by NSW Fisheries, which means that fishing is not permitted. The combination of these measures should continue to ensure that commercial fishing has little or no impact on little terns.

The draft recovery plan for grey nurse sharks in Australia did not include any of the techniques used in the Ocean Hauling Fishery in its list of fisheries known or thought to have a potential impact on grey nurse sharks (Environment Australia, 2000a). The plan identified demersal gillnetting, setlining, droplining and fish and prawn trawling as probably being responsible for the incidental catch of grey nurse sharks, but noted that the degree of this impact was unknown. Some of the measures the report recommended were consistent with those proposed in the draft FMS and included:

- assessing commercial data to determine current level of grey nurse bycatch
- modifying fisheries logbooks to record grey nurse catch and biological data
- ensuring existing fishery observer programs record interactions with grey nurse sharks
- developing appropriate mechanisms to protect key sites.

The draft recovery plan for great white sharks in Australia did not include any commercial fishery of NSW, nor any of the techniques used in the Ocean Hauling Fishery, in its list of Australian fisheries known or thought to have a potential impact on white sharks (Environment Australia, 2000b). The plan identified the southern shark fishery, the snapper fisheries in Victoria, the Gulf of St Vincent and the Spencer Gulf, the tuna farming industry and the WA shark fishery as taking or killing significant numbers of sharks as bycatch. The plan detailed programs to resolve uncertainties about bycatch and mortality of white sharks in those fisheries.

Overall, the draft FMS is consistent with the limited number of recovery plans that have been implemented or drafted to date. This should minimise any potential impacts on the threatened species or populations and provide data that can be fed into the recovery plans. Assuming recovery plans are effective and numbers of threatened species increase, there will be an associated increased likelihood of occurrence and interaction within the fishery. It will be important that observer surveys are scheduled every few years to make provision for this, and not as a one-off when the likelihood of occurrence or interaction is very low.

c) Management uncertainty

As discussed in section 2(b) of this chapter, most of the uncertainty related to threatened and protected species lies not with the management of those features, but of the past impacts of the fishery upon them. The lack of any data, but acceptance that the fishery has probably had some as yet unknown impact on them, has meant that the draft FMS has taken a precautionary approach to the ongoing management of those species. This is reflected in several of the management responses, which are adaptive and include data collection programs, and by adopting this 'wait and see' approach whilst data is being collected, it allows fishing to continue but sets benchmarks that, if and when reached, may further restrict or modify fishing activities. It is accepted that there is some uncertainty inherent in such an approach. It is deemed more appropriate, however, to implement those measures while data is being collected, than to either continue fishing in its current pattern suspecting that it may be impacting on threatened species, or conversely to terminate fishing on the grounds of that suspicion. This approach should minimise any potential impacts on threatened species and provide data with which to more accurately determine what, if any, those impacts are.

d) Precautionary management measures

Table F10 which follows summarises the significance and acceptability of the potential impacts that the fishery could have on threatened and protected species. It identifies the management measures presented in the draft FMS designed to mitigate/rehabilitate those impacts, defines the level of confidence that this assessment has in the effectiveness of those measures, and details why those levels were assigned to each measure.

Despite the uncertainty about the impacts that the fishery may have had on threatened species in the past, it is clear that the draft FMS attempts to understand these impacts better and minimise them if and where they do occur. Most of the responses are reliant on data collection from observer programs and studies of the biology and ecology of certain species. Failing to adequately fund those programs, and/or failing to have some done by organisations independent of the fishery, would reduce the confidence associated with achieving their aims.

The proposal to use closures to minimise effects on migratory shorebirds will significantly improve the existing situation and would be enhanced by the code of conduct during periods, or in areas, without closures. As stated previously in Chapter F section 1(iv), it is recommended that NSW Fisheries confirm important sites and times with NPWS during the establishment of closure areas and in formulation of the code of conduct. That information should also be used when determining which regions or estuaries will be the focus of observer surveys. Such a coordinated approach should ensure that the surveys are as comprehensive and effective as possible.

It could be argued that the level of acceptability of any impacts on threatened species should be low. Generally, that would be correct if the fishery was the only source of impact, that the impact was clearly defined, and of such intensity and magnitude as to drive a species to extinction. That is not likely to be the case in the estuarine environment in which the fishery operates. There are multiple user groups, each of which has some unknown degree of impact upon species, and there are many external factors over which NSW Fisheries, through the draft FMS, has limited control. Establishing research programs aims to provide a more accurate assessment of the level of impact that the fishery is having on threatened species, and where appropriate, implement measures to reduce or eliminate that source of pressure on the species.

Table F10. Potential impacts of the fishery on threatened species and the relevant management responses in the draft FMS.

Potential impacts	Significance of impact	Level of acceptance	Management response	Confidence levels	Note
Capture - fish, turtles, mammals, penguins	Medium	Low-medium	1.1 all	High	Prevent and/or minimise direct and indirect effects
			1.2a & b	High	Closures and gear restrictions to avoid interactions
			1.2c	Medium	Code of Conduct
			1.3d	Medium	May increase areas closed to fishing
			3.1a	Medium	Catch & effort return forms
			3.1b	High	Considers threat abatement plans
			3.1c	High	Regulates species
			Goal 6	Med-High	Effective compliance
			Goal 7	Med-High	Community education
Habitat modification	Medium - high	Low	1.1g & h	High	Regulates gear
			1.2 all	High	Increases areas closed to fishing
			1.3d	High	May increase areas closed to fishing
			1.5 all	High	Habitat mapping, rehabilitation and management
			2.4	Medium	Manages externalities
			3.1b	High	Considers threat abatement plans
			7.1, 7.2, 7.3	Med-High	Community education
Disturbance	Medium	Medium	1.1f	Med-High	Data collection - some needs to be fishery independent
			1.2	Med-High	Closures and research programs
					Defines designated landing sites
			1.5 all	High	Habitat mapping, rehabilitation and management
			2.2c	Medium	Licensing arrangements
			3.1	High	Considers threat abatement plans
			Goal 6	Med-High	Effective compliance
Trophic effects	Unknown	Probably low	1.1b	Med-High	Minimises bycatch
			1.3a - c	Low-medium	Likely to be very difficult and expensive to discern

e) Level of confidence in achieving predicted outcomes

Table F10 outlined the management responses to issues concerned with threatened species and the confidence levels associated with them. The responses are considered in isolation, but they all work towards the primary goal of minimising the impact of the fishery on threatened species. Overall, the responses appear to have a high probability of achieving their aims. Those with a low to moderate probability are influenced by multiple external factors and/or will take a long time to elucidate, if at all. Species and population numbers can vary significantly through time and space, and research programs may not be able to detect the degree to which the draft FMS affects species, owing to both the variability and external factors. Importantly, for those aspects where the draft FMS has the greatest control, e.g. closures and bycatch programs, there is a high probability that the draft FMS will have a positive impact upon threatened species. It does this by using closures to protect areas utilised by threatened species, collecting data about direct and indirect effects, and minimising disturbance during fishing operations. These aspects should remove a large proportion of the uncertainty associated with the potential impacts of the fishery on threatened species.

f) Effectiveness of mitigation measures

The content of each of the responses and the monitoring programs designed to test their effectiveness should be able to adequately address the issues as they pertain to threatened species. The underlying assumption is that in the absence of data to the contrary, the fishery in its existing form is thought to be having minimal impact on threatened species, and that the draft FMS will both elucidate those effects and minimise them where they do occur. Despite this, some of the associated trigger points require some refinement.

As discussed in section 1(d)(ii) of this chapter, there should be either an alternative or additional trigger point for the number of estuaries closed to fishing (Goal 1, Trigger 1), which should measure an increase in the proportion of the various habitats that are protected in each bioregion. This would allow closures to be more specific, capitalising on information obtained by recovery teams and observer programs and apportioned in relation to the existing extent of, and habitat types represented in, Marine Protected Areas. This is likely to result in a more efficient and equitable allocation of the resource between user groups, including the environment.

Goal 3, Triggers 1 and 2 of the draft FMS pertain directly to threatened species. Trigger 1 is likely to require some modification. First, the trigger point of 25% or more is to be based on data from the observer program and catch return records, and those data are to be reviewed annually. Initially, such a review is unlikely to be sensitive enough. For example, the available data suggest that there is currently minimal fishing effort adjacent to the penguin colony at Manly, and that the effort is focussed in winter. Subtle shifts in effort and catch could affect the population and it is recommended that catch and effort data receive quarterly analysis in consultation with the Little Penguin recovery team. There needs to be only an annual report each June, and it should incorporate flexibility so that if it were found that in the first year no penguins were caught, the report could recommend biannual or annual reviews thereafter.

Second, it is proposed that fishery participants should fund the observer program. As numerous aspects, stakeholders and much of the confidence in the draft FMS relies on the observer program, there should be more than one source of funding and should include other stakeholders, which will also make the program more equitable and readily accepted by fishers. Some of the data collection should also be done by organisations independent of the fishery.

Third, it is currently proposed to consider only monitoring capture rates. Given that there are very few threatened species that could actually be captured by the fishery, and of those, many are highly improbable based on their habitat requirements, this appears to be a disproportionate distribution of effort. The program should include the capacity to record and document effects on all threatened species due to disturbance and habitat modification.

Summary

The proposal has the potential to affect more than 40 threatened species under the FM Act, TSC Act and the EPBC Act. At this stage, however, there appears to be little or no hard data implicating the fishery in having an adverse impact on any of those species, their habitats or accentuating other circumstances that may be having an adverse impact upon them. It will be important for the observer program discussed within the draft FMS to obtain information about effects due to disturbance, not just direct capture, as this appears to be the most likely form of impact on the majority of threatened species and species of international significance. Half of the estuaries in NSW have existing closures that probably protect many areas of habitat for these species. The draft FMS includes several measures to further mitigate any impact, including complementarity with departmental initiatives to expand the range of marine protected areas, closures and research programs, in addition to concurrent proposals to create recreational fishing areas. These strategies have been considered adequate to mitigate any future potential impacts due to the fishery and should remove a large degree of the uncertainty associated with existing data.

3. Trophic Structure

Very little is known about trophic interactions in relation to the methods used in the Estuary General Fishery. Most of the references cited in this section relate to work on prawn trawling, with the assumption that many of the interactions are likely to be similar, though probably on a smaller scale for most methods used in the Estuary General Fishery.

The magnitude of any trophic structure effects is likely to vary considerably among methods used in the Estuary General Fishery, essentially in accordance with the likely amounts of bycatch involved (Chapter E section 2). Hauling, meshing and some types of gathering by hand are much more likely to cause trophic effects than are trapping or hand-lining. In the case of gathering by hand, any effects would be extremely localised, essentially relating to small organisms killed or displaced by trampling or use of implements.

a) Species likely to be affected by the fishing activity

NSW estuaries are host to a large number of bird, fish and invertebrate species and most of these are potentially affected by trophic interactions arising from fishing activities (Cappo *et al.*, 1998; Jennings and Kaiser, 1998; Hall, 1999). The species most likely to be significantly affected (because of discard provisioning) include various seabirds and benthic scavengers/ omnivores (Jennings and Kaiser, 1998; see also sub-section (c) following). Within NSW estuaries, the latter include crabs as well as finfish such as yellowfin bream (Table F11).

Trophic structure effects may be direct (i.e. discard provisioning) or indirect (arising from the removal or attraction of particular species). These effects are discussed in the following sections.

b) Likely productivity/flows and associated impacts of removing predators, prey or competitors

These are flow-on or indirect consequences of a fishing gear's use. Estuarine communities are structured by complex arrays of interspecific factors such as competition and predation (Cappo *et al.*, 1998; Hall, 1999; Kaiser and de Groot, 2000) and changes to any one component (say through a reduction in the abundance of a particular species or size class) may have a range of consequences for other components, whether they are competitors, predators or prey. Plausible food web/community effects (see also Kennelly, 1995b; Cappo *et al.*, 1998; Hall, 1999) arising from estuary general fishing methods include:

- a local decline in the abundance of an apex predator (e.g. tailor, dusky flathead or even seabirds) caused by the selective removal of prawns or baitfish (Dayton *et al.*, 1995; Cappo *et al.*, 1998)
- increased survival (and therefore abundance) of some prey species (e.g. small fish, squid and shrimps), particularly those eaten by target species such as flathead or bream (e.g. Dayton *et al.*, 1995; Engel and Kvitek, 1998)
- the favouring of mobile opportunists, better able to 'follow' food supplies created by hauling operations, at the expense of less mobile or less aggressive species (Dayton *et al.*, 1995)

- less efficient predator foraging due to the dispersal of prey aggregations, resulting in lower reproductive success and/or reduced populations among predator species (Dayton *et al.*, 1995)
- changes to the condition of seagrasses or other marine vegetation through the removal of species (e.g. luderick and leatherjackets) that are likely to graze on epiphytic growth
- changes to benthic invertebrate communities through the removal of fish such as sand whiting that eat benthic invertebrates
- changes to benthic communities arising from removal of sea mullet, a species that ingests (and turns over) the substratum to feed on micro-algae and detritus
- short-term increases in the abundances of scavenger or predator species (fish, crabs or birds) as a result of large numbers of dead or injured fish being made available as food during or after a fishing operation (Table F11)
- longer term increases in the abundances of scavenger or predator species (fish, crabs or birds) as a result of large numbers of trapped, dead or injured animals being made available in regularly fished areas (e.g. Blaber and Wassenberg, 1989; Wassenberg and Hill, 1990).

From these examples it is apparent that food web and community effects are complex and far reaching, and that their prediction in any given case would be very difficult (Cappo *et al.*, 1998; Jennings and Kaiser, 1998; Hall, 1999). Also, a further 'generation' of flow-on or cascading effects through the food web would be possible in each case (e.g. Kennelly, 1995b in relation to prawn trawling), although such affects have proven very difficult to demonstrate conclusively, particularly in species-rich communities (Jennings and Kaiser, 1998; Hall, 1999).

Scavengers or predators initially concentrated in an area as a result of a fishing operations could end up being caught (e.g. Jennings and Kaiser, 1998) but, in any case, would have to rely on other food sources once the initial supply of dead fish etc. was consumed. This may adversely affect other species in the area, as might a sudden increase in a particular prey species (second point above) which may even alter habitat conditions. Also, whilst the availability of discards could cause nesting populations of some seabird species to increase, it may (in turn) caused the depletion of other bird species (Cappo *et al.*, 1998), possibly through competition for nesting sites (Ross, 1996). It has even been suggested that larger predators that were initially attracted by discards (Cappo *et al.*, 1998; Blaber *et al*., 1990) could eat smaller target species. In the case of the Estuary General Fishery, the target species that could conceivably be affected this way include prawns and garfish. On the other hand, the incidental capture and subsequent mortality of small fish as a result of hauling may reduce significant rates of predation by small fishes on prawns (Salini *et al*., 1990; Brewer *et al*., 1991).

Despite the possibility that virtually all elements of the state's estuarine biota may be affected in some way, extensive evidence from overseas studies (Jennings and Kaiser, 1998; Hall, 1999) suggests that indirect trophic effects of the sort discussed above are unlikely to have significant impacts on diverse communities, such as those occuring in NSW estuaries. This is because predator-prey relationships within such communities are often relatively weak and, in response to natural population changes, quite variable. Jennings and Kaiser (1998) emphasises the importance of natural environmental factors (albeit in conjunction with fishery-related factors) in causing population changes amongst marine species.

c) Likely food provisioning from discards

Under 'natural' (unfished) conditions within NSW estuaries, there are likely to be relatively weak trophic links between surface/ pelagic species and benthic/demersal species. Food provisioning is likely to strengthen these links, particularly in an 'upward' direction, with a whole range of new food sources becoming available to certain seabirds (Table F11). Benthic scavengers and/or omnivores are also likely to benefit, though not to the same degree (Jennings and Kaiser, 1998; sub-section (b) above).

The effects of discard provisioning would depend on whether the discards floated or sank upon return to the water (Harris and Poiner, 1990; Hill and Wassenberg, 1990; Wassenberg and Hill, 1990). Floating discards would be readily available to birds, whilst sinking animals could be taken in mid-water by fish or squid, or by fish and a variety of invertebrates (particularly crabs) on the seafloor.

In the context of the Estuary General Fishery, the major beneficiaries of discard provisioning are likely to be pelicans, seagulls and both blue-swimmer and mud crabs (Table F11). Marine mammals and reptiles are relatively rare within most of the state's estuaries, as are fairy penguins: these groups are unlikely to benefit greatly. Diving birds such as cormorants would benefit to a fair degree (Table F11), but would not be able to exploit the full size range of discarded material. Pelicans would possibly benefit the most because they can eat larger discards than other species, and could supplement their normal feeding behaviour, which restricts them to small prey items and the shallow margins of estuaries.

Large gatherings of pelicans around commercial fishers are a common sight. Whilst no data are available for NSW, the blue swimmer crab has been shown to be readily attracted to trawl discards in Moreton Bay: these discards apparently contribute to the success of the local blue swimmer crab fishery, and are probably important in maintaining populations of the major scavengers present (Wassenberg and Hill, 1987, 1990).

Table F11. Summary of discard provisioning (by trophic level/feeding group) that may arise from fishing operations (particularly hauling and meshing) within sub-tidal estuarine waters in NSW.

'Discards' may be live or dead and may result from either capture or contact with fishing gear.

Trophic level/ feeding group	Representative species/types	Normal prey/food source	Additional food sources facilitated by fishery operations	Likely overall effect on food availability/feeding options
diving birds	cormorants, fairy penguins, terns	surface swimming baitfish	small/juvenile fish associated with benthic habitat/marine vegetation	slight increase
other seabirds	pelicans, seagulls	'external items' from terrestrial habitats and/or near water's edge	fish from all trophic levels/feeding groups	large increase
pelagic predators (fish)	tailor	surface swimming baitfish	small/juvenile fish associated with benthic habitat/marine vegetation	slight increase
'surface swimming' baitfish	garfish, whitebait	plankton	none	no change
plankton	zooplanktion (including fish and invertebrate larvae), phytoplankton	NA	NA	NA
benthic omnivores/scavengers	yellowfin bream, trumpeter whiting, blue swimmer crab	benthos	fish from all trophic levels/feeding groups	large increase
herbivorous/detritivorous fish	sea mullet, luderick	algal slime and detritus	none	no change
benthic predators (fish)	dusky flathead	benthos, particularly larger mobile forms	'surface swimming' baitfish	slight increase
small/ juvenile fish associated with benthic habitat/ marine vegetation	juvenile bream, luderick & leatherjackets; gobies, pipefishes	plankton, epiphytes & small invertebrates associated with seagrass	none	no change
benthos	worms, marine snails, bivalves,	algal 'slime' mud and detritus	none	no change
seagrass/other marine	seagras, macroalgae	NA	NA	NA
algal 'slime' mud and detritus	various small algae, including microscopic forms	NA	NA	NA

d) Risk and uncertainty of the fishery disrupting trophic structure and the necessary management measures to address this risk

It is possible that disruptions to trophic structure within the area of the fishery's operation could cause long-term changes in community structure (e.g the loss/replacement of particular species). Changes to fishing practices aimed at reducing bycatch could even adversely affect certain bird species (e.g. pelicans) that may have come to depend on the associated provisioning (Jennings and Kaiser, 1998). Long term community shifts may also result from differing abilities to survive the rigours of being caught, sorted and discarded. For example, Greenstreet and Hall (1996) found that dogfish and skates, being relatively resilient to fishing pressure, have replaced gadoid finfish on the Georges Bank trawl ground in the North Atlantic. Further impacts may also be introduced by the fact that fishing effort is directed at the predators themselves (Cappo *et al.;* 1998, Kaiser and de Groot, 2000). Unfortunately the level of competition between predators and commercial fisheries for baitfish has not been studied, although it may be of concern (Dayton *et al.;* 1995, Hall, 1999). NSW estuaries are inhabited by a variety of predatory fish and seabirds that mostly feed on bait fish (e.g. SPCC, 1981b). The dispersal of baitfish schools, particularly as a result of purse seining or bull-ringing, may cause these predators to move elsewhere or to have difficulty in finding sufficient food (Cappo *et al.*, 1998). Furthermore, it is not known whether increased food supplies associated with certain fishing operations actually result in increased populations of the attracted species, or just locally increased abundances. It is conceivable, for example, that fishing operations may result in populations of such species being reduced, due to their being concentrated in areas where they are more liable to capture (NSW Fisheries, 1999b). A similar question has been widely asked in relation to fish attracted to artificial reefs (Pickering and Whitmarsh, 1997).

Unfortunately, there remains a great deal of uncertainty in relation to trophic impacts associated with fishing (Cappo *et al.*, 1998; Jennings and Kaiser, 1998; Hall, 1999). Despite specific evidence in a few cases (e.g. on temperate rocky reefs), Jennings and Kaiser (1998) argue that it is wrong to assume that most predator-prey relationships are so tightly coupled that the removal or proliferation of one species would result in detectable changes in ecological processes. They state that "simplistic models of predator-prey interactions often take no account of prey switching, ontogenic shifts in diet, cannibalism or the diversity of species in marine ecosystems and thus often fail to provide valid predictions of changes in abundance".

It appears that the risks of significant or irreversible trophic effects is low for most elements of the estuarine biota, the most likely exceptions being some of the sea birds. Even where localised effects do occur, the dispersed nature of fishing effort within the Estuary General Fishery needs to be considered from which we might conclude wide scale impacts are very unlikely. Jennings and Kaiser (1998) conclude that most marine trophic relationships are weak, and that environmental influences are normally paramount.

The range of management measures contained within the draft FMS aimed at reducing bycatch and controlling overall exploitation levels should be sufficient to safeguard community integrity.

4. Translocation of Organisms and Stock Enhancement

a) Background

Translocation of an aquatic organism can be generally defined as "the movement of live aquatic material (including any stages of the organisms' lifecycle and any derived, viable genetic material) beyond its accepted distribution, or to areas which contain genetically distinct populations, or to areas with superior disease or parasite status." (MCFFA, 1999).

The introduction of exotic species into new environments can pose a major threat to the integrity of natural communities, the existence of rare and endangered species, the viability of living resource-based industries and pose risks to human health. Marine pests can be as damaging as polution events but their effects are much more persistent (CRIMP, 2000a).

The risks associated with the translocation of any organism include the potential for the establishment of feral populations, environmental impacts and genetic shifts in wild populations. There is a wide range of species that have been introduced into Australia (Pollard and Hutchings, 1990a&b). Some of the more notable marine translocations which have occurred in Australia include Northern Pacific Seastars (*Asterias* sp.) and the Japanese seaweed (*Undaria* sp.).

Translocated species, if introduced to a new water body under the right conditions, may grow or breed prolifically and adversely affect other species or habitats; for example an introduced marine snail may compete with local snails, whilst a macroalgae (such as *Caulerpa taxifolia*) may smother seagrasses.

i) Possible mechanisms of translocation

Live aquatic organisms may be transported either deliberately through the trade in live product or the use of live bait, or inadvertently, through the movement of water or through the movement of vessels (hull fouling, ballast water and/or internal waters) and gear. Some invertebrates and macroalgae readily survive transport if lodged amongst damp equipment, and in some cases only a small fragment of macroalgae is necessary for propagation.

ii) Deliberate translocation

Currently there is no trade in live organisms derived from this fishery. Given the species concerned, it is considered unlikely that this will develop in the future unless there is a significant increase in market value or demand for live products.

The fishery does not routinely use live bait species, and it is not anticipated that this practice would be introduced into the fishery. With the limited amount of handlining undertaken, the risk of effective translocations through this process is extremely small.

iii) Inadvertent translocation

Movement of water

There is a risk that some vessels will retain water in their bilges, which could be transferred between locations, but routine practice is to drain trailered vessels each time they are removed from the water.

The target species are not normally part of the live fish trade in NSW and the use of live bait is very minimal and consequently the inadvertent translocation of species, from carrying live fish for sale or for bait, is highly unlikely.

Should live product trade or live bait practices be introduced on a significant scale, the fate of the transport medium is of some concern as undesirable organisms may be transported with it. This is of particular concern if the stock is being sourced from an area where pests, red tides, algal blooms or disease outbreaks are current and or common, and there is a possibility of subsequent release into natural waterbodies.

The risk may be minimised through appropriate treatment and disposal of transport medium, including the appropriate treatment (cleaning etc.) of equipment. The risk can be further minimised through obtaining material (catches and or bait) from areas where there have been no associated pest species or disease outbreaks.

Movement of fishing vessels

As the vessels used in this fishery are predominantly trailer boats, there is little risk of transmission of organisms through the fouling of hulls or their internal water supply systems as the vessels are removed from the water when fishing has been completed and stored out of the water until the next fishing operation.

Movement of fishing equipment

Some of the commercial fishing methods used in estuaries such as hauling, meshing and trapping, are very likely to involve the transport of equipment between estuaries within different areas of the state and may therefore result in the translocation of organisms beyond their current ranges. The relatively small boats used for handling, meshing and trapping are easily trailered between estuaries, so it is likely that the gear may be transported in damp or wet conditions inside the hull.

The movement of haul nets and mesh nets between fishing grounds is a significant vector for the movement of some hardy species, particularly if the net is not thoroughly cleaned after each fishing operation, and it is rolled or bundled so it remains damp until the next operation. A number of species, of algae and molluscs for example, can remain alive in damp conditions for several days and could be routinely and inadvertently translocated by this means.

b) Species likely to be translocated by fishing equipment

For an organism to be successfully translocated as a result of fishing activities it will need to survive collection, transportation and release.

Species that are most likely to be translocated by fishing equipment are those that are vulnerable to capture by, or attachment to, the gears used, and not susceptible to mortality as a consequence of the collection, transport or release. These will include species that are found on the fishing grounds and in association with target species or their habitat, are hardy, and can survive out of water for reasonable periods.

Organisms that may be subject to translocation can include species native to NSW that are moved between existing populations; native species that are moved to new locations (range extensions); or exotic species which having been established in one location (in NSW or possibly another state) could be spread further by their movement by fishing equipment or vessels.

While some organisms that are translocated do not establish feral populations, they could still pose a risk of introducing disease and or parasites from their original environment by direct impact such as predation or competition with species in the new environment. However, the primary threat of translocation comes from those species, which are able to adapt and survive and form viable populations in the new environment.

The species most likely to be translocated successfully through operations of the NSW Estuary General Fishery include any number of native species of aquatic plants and animals, but those more likely are molluscs, echinoderms and algae.

In addition, there is an increasing number of introduced species which are in NSW or neighbouring states, or could become established in NSW waters, which may be subject to translocation by fishing activities in the future. These include species that have been listed as ‘trigger’ species for national emergency response procedures, including:

Caulerpa taxifolia* (Vahl.) C. Agardh (1822)

An invasive strain of this macroalgae has become established in a number of locations in NSW water including Port Hacking, Lake Conjola, Careel Bay (Pitt Water), Lake Macquarie, Botany Bay, Burrill Lake and Narrawallee Inlet. In the northern hemisphere the species is known to compete with seagrass populations and colonise a wide range of habitats, reducing biodiversity and possibly fisheries productivity. It is very difficult to eradicate and can be spread readily through fishing gear, anchor chains and boating activities (CRIMP, 2000b; Grey, 2001). Fishing gear has been identified as a possible vector for the movement of the species.

Mytilopsis sallei

This species (known as the black striped mussel) is similar to the zebra mussel which has invaded the Great Lakes in North America and resulted in annual control costs of over US$30 million. It forms massive monocultures of up to 24000/m^2, out-competing native species and threatening maritime industries through fouling. Although it was eradicated following a $2 million emergency response program, the introduction of the species into Darwin in 1999 threatened the pearl culture industry and could have spread to northern Australian coastal waters between Sydney and Perth (CRIMP, 2001a).

***Undaria pinnatifida* (Harvey) Suringer**

This Japanese seaweed is extensively cultivated as a food plant in Japan, and was introduced to New Zealand and Australia most likely as a result of hull fouling or ballast water. The species is highly invasive, grows rapidly and has the potential to overgrow and exclude native marine vegetation. It also has the potential capacity to create major fouling problem for marine farmers. (CRIMP, 2000c). It is present in Tasmania and Victoria.

***Maoricolpus roseus* (Quoy and Gaimard, 1834)**

Although a native to the South Island of New Zealand, the NZ screw shell has been reported from waters of NSW since having spread from populations established as the result of translocations into Victoria and Tasmania. The species is known to establish extremely dense populations and compete with native mollusc species. Its superabundance on some fishing grounds is likely to result in economic losses and the high possibility of further translocation. It is present in NSW waters.

***Asterias amurensis* (Lutken, 1871)**

The northern pacific seastar is arguably the most significant marine pest established in Australian waters. In 1998 some 50 juveniles were found in Port Phillip Bay (www.brs.gov.au, 2000) and in June 2001 that population has grown to an estimated 130 million (Rod Gowans, pers. comm.). The species is a significant predator and a threat to native marine communities and commercial shellfish farming operations. Although its translocation is most likely in the larval form in ballast water, an individual has been found in the water intakes of a coastal vessel, and movement of adults in fishing gear is possible (CRIMP, 2000d). It is present in Tasmania and Victoria.

***Codium fragile tomentosoides* (Sur.) Hariot subsp. (Van Goor) Silva**

This species is regarded as a pest because of its invasive capabilities and reported impacts on shellfish farms in the United States of America. It is also reported to settle on native algae and to foul commercial fishing nets. Its habitats include intertidal and subtidal estuaries and ocean sites on hard substrata. (CRIMP, 2001b). It is present in NSW waters.

c) Risks/implications likely to be associated with translocations

The translocation of aquatic organisms raises many issues relating to the maintenance of local biodiversity including genetic shift in wild populations; establishment of feral populations; environmental impacts from the release of the species, and translocation of associated species (MCFFA1999). The social and economic impacts of established feral populations resulting from translocations can be very significant, as evidenced by the financial and amenity costs associated with management of the introduced zebra mussel in the Great Lakes of North America.

The introduction of parasites and diseases as a consequence of translocations can also have implications for both biodiversity and social and economic values.

Genetic shift in wild populations

Genetic diversity is recognised as one of the three levels of biodiversity which should be preserved to ensure the conservation of biological diversity. Genetic shift is a change in the composition of a population which results in a loss of biodiversity. Translocated individuals may interbreed with distinct resident populations of the same species, and this may result in the genetic shift in the local population through the introduction of foreign genetic material.

Although there is evidence that translocations have resulted in genetic shifts in native populations (Sheridan, 1995), there are little data available on the genetic composition of populations of aquatic organisms in NSW and no evidence of any such changes in NSW to date.

Establishment of feral populations

Feral populations are defined as populations that successfully establish as a result of the escape or release of organisms. Translocated organisms may establish feral populations and these can have a range of negative environmental effects including competition, predation and environmental modification.

There are a number of feral populations of marine organisms already established in coastal waters of NSW, including fish, sea squirts, bryozoans, gastropd and bivalve molluscs, isopods, crabs, barnacles and annelids (Furlani, 1996).

Environmental impacts from escaped organisms

Regardless of their ability to establish self sustaining populations in receiving waters, if translocated organisms are able to survive long enough in natural waterways they may have other impacts including competition, displacement, predation and habitat alteration.

Translocated organisms may compete with and displace local species, potentially causing long lasting changes to the community structure. Additionally, translocated organisms may eat endemic species. In many cases endemic species will be at greater risk to the translocated predator than to local predators because there would have been no similar predator-prey co-evolution. This may be particularly devastating if the local species are not normally eaten, and consequently have not developed defence mechanisms or appropriate defensive behaviours.

Translocated organisms may alter the habitats of natural waterways, for example the case of the marine alga *Caulerpa taxifolia.* This species has established marine vegetation communities at the expense of native seagrasses but these are not able to be consumed by native species, and do not provide a suitable environment for epiphytic organisms which are important in the food chain.

Implications for aquaculture

Some introduced species such as the northern Pacific seastar, could prey on aquaculture species such as mussels and oysters. Other species such as marine algae could overgrow equipment and sites causing economic losses, and control measures such as obligatory cleaning of mussel ropes, washing or sterilisation of gear etc could impose additional operational and financial burdens on farmers.

As a result of the establishment of the populations of *Caulerpa taxifolia* in Lake Conjola, the oyster farmer who holds leases in the area has been obliged (under the conditions of his permit) to ensure that his dinghy and gear is clean, and inspected, before he moves it between the Lake and other sites. Furthermore, the depuration water from Lake Conjola oysters must not be released into waterways.

Implications for other water users

Introduced species can have a direct impact not only on aquatic biodiversity and fisheries production, but also on other water users.

Feral populations of pest fouling organisms such as mussels and algae could result in loss of amenity and additional costs to all water users, and tourism and the community in general. The introduction of the invasive zebra mussel into the Great Lakes has resulted in fouling of fishing vessels, pleasure craft, stormwater outlets, marinas and moorings, boat ramps and beach amenities.

Implications for the environment

The establishment of introduced species breaks down the isolation of communities of co-evolving species of plants and animals. Such isolation is essential for the evolution and maintenance of biodiversity. Disturbance of this isolation by alien species can interfere with the dynamics of natural systems and cause shifts in predator/prey relationships, and ultimately, premature extinction of species (www.iucn.org, 1995, see Sheridan (1995) for a review).

Diseases and parasites

As a consequence of translocations, there is the risk of introduction of an exotic disease or parasite (bacteria, virus, protozoan or other organisms eg. worms, nematodes) into natural water bodies and subsequent infection of fish stocks or aquatic vegetation. The translocation of endemic diseases and parasites to new areas is also a major concern.

Parasites and disease are an integral part of any natural system. However, the introduction of disease or parasites (not necessarily exotic) into a natural water body could change the existing "parasite and disease status" of the waters. This introduction may perpetuate or aggravate existing diseases by increasing their incidence, virulence, potency and frequency. This impact may apply to parasites such as ecto-parasites on fish, fungal flora and gut parasites.

i) Proposed mitigation measures

As translocation requires the movement of an organism from one water body to another where it is not normally found, the more mobile the fishery and the greater degree of flexibility of operators to move around the state, the greater is the risk of translocation regardless of the means.

In the case of the Estuary General Fishery, fishing activities are now restricted to specific zones and fishers can generally not operate outside these zones.

As the geographic range of each zone is limited (the maximum is less than 200 km of coastline), the risk of fishers translocating organisms into areas that they do not normally exist is small.

Marine pests

There are currently no formal processes in place for the management of introduced marine pests in NSW, although the state is committed to the development of such processes in the short term.

The NSW Government has endorsed the recommendations of the National Taskforce on the Prevention and Management of Marine Pest Incursions. These recommendations included the requirement for all states and territories to provide resources for the interim and/or long term for:

- effective and timely implementation of interim arrangements for managing marine pest incursions pending the development of a National System for the Prevention and Management of Marine Pests;
- the development and implementation of a NSW Emergency Marine Pest Management Plan (EMPMP)
- data collection and dissemination on pests and response processes
- a review of legislative powers to act in the event of an emergency
- communication and information programs
- the development of the National System for the Prevention and Management of Introduced Marine Pests
- plans for the mitigation of impacts of established marine pests
- the inclusion of marine pests provisions in port environment management plans

- investigating the issue of liabilities for persons involved in dealing with emergency responses
- agreement to contribute to interim national cost sharing arrangements for emergency responses comprising a 50:50 share between the States and the Commonwealth, with the States' contribution calculated on a simple per capita basis
- agreement to contribute to a national funding base for the support of the National System in the long term including port baseline surveys, community preparedness, education and training, research and development and monitoring (AFFA, 2000).

The NSW EMPMP will include details of the mitigation methods proposed and these will be in accordance with the guidelines laid down in the Taskforce Report (AFFA, 2000). These will include general protocols for the transport and handling of equipment being moved between estuaries in the event of an outbreak of marine pests in any region.

ii) Contingency plan for pest species management in NSW

In the event of an outbreak of marine pests in the intervening period, NSW will adopt the draft Australian Emergency Marine Pest Plan as detailed in the report of the Taskforce on the Prevention and Management of Marine Pest Incursions.

Education programs are required to make boat operators and owners aware of the potential for their vessels to transport exotic fouling organisms and the steps they should take to minimise the risk of this occurring.

Codes of practice are required to ensure that fishing operations do not facilitate the spread of exotic organisms through the movement of equipment between areas. This will involve industry awareness programs and the development of treatment (‘sterilisation’) protocols for gear and equipment. In Victoria for example, research is currently underway to develop ways of treating mussel grow-out lines to kill exotic species before lines are moved between coastal waters (CRIMP, 2000a). Similar protocols are imposed in NSW for the management of *Caulerpa taxifolia*.

Current situation: Caulerpa taxifolia

Following the identification of invasive populations of the marine algae *Caulerpa taxifolia*, in NSW the Minister for Fisheries announced a series of restrictions, including prohibition on the removal of equipment from already affected estuaries, area specific fishing nets and boats, and the closure of certain waterways to netting activities. These actions complement an intensive public education and awareness campaign on the nature and impact of the species, and the declaration of the species as noxious marine vegetation.

Small Ports Project

NSW Fisheries is working in association with the Victorian Department of Natural Resources and Environment, local Port Managers, the Centre for Research on Introduced Marine Pests and other agencies to develop practical ways to assist fishers, vessel operators and port managers to reduce the risk of spreading marine pests. The key focus is on ways to reduce the spread of marine pests through gear and hull fouling and will take the form of a series of guidelines (DNRE, 2000).

Diseases and parasites.

The *Fisheries Management Act 1994* contains provisions for response to disease of fish or marine vegetation. These include the powers to declare a disease, establish quarantine areas, prohibit the sale or movement of diseased fish or marine vegetation and control the release or transmission of the disease. In addition, plant diseases can also be declared and subsequently managed in a similar manner under the provisions of the *NSW Plant Diseases Act 1924*.

Following its endorsement by the Commonwealth Ministerial Council on Forestry Fisheries and Aquaculture, NSW (along with all States and Territories) is committed to the management of aquatic animal health through AQUAPLAN. This plan is a broad, comprehensive strategy that outlines objectives and projects to develop a national approach to emergency preparedness and response to the overall management of aquatic animal health in Australia (AFFA, 1999). Within AQUAPLAN there are a series of programs, including quarantine, surveillance, monitoring and reporting, preparedness and response, and awareness, that will address aquatic disease management issues.

In a manner similar to that for marine pests, it will be important to ensure that fishing operations do not facilitate the spread of disease through the movement of equipment between areas. Depending on the nature of the disease this may include industry awareness programs and/or the development of treatment (‘sterilisation’) protocols for gear and equipment. Alternatively, the closure of areas to fishing can be ordered by the Minister under the provisions of Section 8 of the *Fisheries Management Act 1994*.

Stock enhancement

There are currently no proposals for the artificial enhancement of populations of species which are the target for this fishery and none are anticipated in the immediate future.

All such proposals would be subject to separate environmental impact assessment processes in accordance with the provisions of the *Fisheries Management and Environmental Assessment Legislation Amendment Act 2000*.

5. Fish Health and Disease

a) Impacts of gear types and fishing methods

It is considered that the gear used in the Estuary General Fishery is unlikely to have a significant impact on the health of the target or non-target organisms. While it is possible that some individuals will be physically injured or damaged by the direct effect of fishing gears, there is no evidence to suggest that fishing activities are having any impact on the health of the individuals in the ecosystem, or are promoting increased disease risks.

There is no information available on the levels of stress, injury or susceptibility to disease that might be imposed as a consequence of the activities of the fishery.

b) Use of bait

The Estuary General Fishery includes a small component of handlining, including the use of aquatic species as bait. In the large majority of cases, the fishers would routinely collect their own bait from the immediate vicinity of the area in which they are fishing (Stewart *et al.*, 1998). It is unlikely that there is any additional risk of transmission of diseases using bait under these circumstances.

Imported bait

Imported seafood products are regularly used in Australia as bait, and have been associated with a number of fish disease incidents in recent years. There is some concern that the use of imported bait presents a significant disease risk (Fletcher *et al.*, 1997; Gaughan *et al.*, 2000; and Whittington *et al.*, 1997).

The use of imported raw prawns as bait in Australia has recently been identified as a matter of concern, with the knowledge that some imported species carry white spot syndrome virus (WSSV). Although there are restrictions in place for the use of these imported prawns as bait as opposed to human consumption, their use is likely to continue at least on a small scale (www.affa.gov.au, 2001). While it is possible that some imported prawns destined for human consumption do find their way to the bait trade and could be purchased by estuary general fishers, it is much less likely than the fishers collecting their own prawns for bait.

Notwithstanding the limited amount of bait use that takes place, and the ready availability of local species, it is considered that the extent of use of imported bait presents a small risk of disease introduction.

Minimising impacts on health of wild fish resources

Although the use of imported bait is limited, there is nonetheless a requirement for the use of pilchards and these have been traditionally obtained from overseas. Although there is no evidence to suggest that the use of imported species by the Estuary General Fishery has resulted in the introduction of disease to NSW to date, there is still a risk that this could occur.

While ever the imported bait can not be assured to be disease free, the use of imported bait will present a risk. The Commonwealth Government through the Australian Quarantine and Inspection Service (AQIS) is currently developing import risk analyses on imported fish products for use as feed or bait, and this is likely to result in the development of new import protocols which should reduce the risks of diseased product being imported (www.brs.gov.au*;* 80/fish/status99, 2001). However, to minimise the risk it would be appropriate to avoid the use of imported bait and promote the use of alternative products derived from local species.

c) Stock enhancement

The deliberate translocation of any target species resulting from stock enhancement would present a risk of disease and parasites although this can be mitigated by the use of fingerlings/fry which had been raised in accordance with appropriate health protocols.

However, as previously noted, there are currently no proposals for the artificial enhancement of populations of species which are the target for this fishery and none are anticipated in the immediate future.

All such proposals would be subject to separate environmental impact assessment processes in accordance with the *Fisheries Management Act 1994*.

6. Water Quality Issues

a) Potential sources of pollutants related to the proposal

Table F12 summarises the characteristics, likely magnitude, and probable frequency of pollutant related events that may impact on the operation of the fishery.

Table F12. Characteristics, likely magnitude and probable frequency of pollutant related events derived from operations associated with the Estuary General Fishery.

Magnitudes and frequencies are given in relative terms, bearing in mind that the (invariably small) vessels used in the fishery account for less than 0.5% of the vessels registered in NSW. In terms of magnitude, "Low" means no measurable effect likely from an individual incident; "Moderate" means localised and/or short term effects likely; and "High" means widespread and/or long term effects likely.

Source	Characteristics/ issue	Magnitude	Frequency
Antifouling treatments	Toxic chemicals leached into water, more toxic forms particularly harmful to sessile invertebrates	**Low** - less harmful compounds now in use; slow rate of release into environment	**Low** - possibly one treatment per vessel per year among less than 0.5% registered vessels
Chemicals, fuels etc.	Toxic chemicals discharged into water; variable effects depending on compound	**Low** to **Moderate,** depending on actual incident	Fuels and chemicals: **Low** except for extremely minor incidents; Bilge water: **Moderate**
Debris	Solid material, generally non-toxic; but may injure or interfere with marine life	**Low** - minor accidental dumping only likely; most fishers increasingly conscious of gross pollution	**Low**
On-board processing waste	Organic material likely to be consumed by marine life; can have undesirable trophic effects, and is a source of (usually undesirable) nutrients.	**Low** - vessels used in fishery too small to facilitate substantial on-board processing	**Moderate** in relation to small amounts of waste (e.g. less than a fish box); **Low** otherwise

i) Antifouling agents

Antifouling agents are painted on boat hulls to reduce marine growth and the consequent loss of performance. In recent years, much concern was raised about the environmental affects of tributyl-tin based compounds. However, these have now been banned on all vessels less than 25 metres in length, and are no longer allowed to be used on boats in the Estuary General Fishery. Substitute treatments are far less damaging to the environment. Many vessels used in the Estuary General Fishery are regularly moved between brackish and high salinity areas, reducing the need for regular antifouling.

ii) Discharge of chemicals, fuel or bilge water

Accidental or (very rarely) deliberate discharges of chemicals, fuel or bilge water are likely to occur in relation to vessels used in the Estuary General Fishery. However, serious discharges would be very rare. Modern engines and fuel systems are compact and easily managed (particularly on the small vessels used), meaning that individual spills of fuel and/or oil are likely to be extremely minor. Also, the size of the vessels used means that larger than usual catches often have to be temporarily held on board in open boxes or even directly in the hull; this means that fishers have a strong incentive to keep their boats as clean as possible. 'Bilge water' would be the most likely discharge from these small vessels. However, bilge water, as its name suggests, is mostly water, with variable amounts of organic matter (from having fish aboard etc.) and small amounts of fuel and/or oil mixed in: such discharge would be only mildly toxic and unlikely to have any major effects considering the volumes involved.

iii) Discharge / dumping of debris

A variety of debris may potentially be dumped or lost from fishing vessels. Examples include plastic, paper and pieces of fishing gear. Such materials are mostly non-toxic, but may injure or interfere with marine life. Such interference or injury would be rare, simply because most debris would not be of a shape and/or material likely to trap or ensnare birds or other animals. Also, species likely to ingest items such as plastic bags (e.g. turtles) are relatively uncommon in NSW estuaries. Members of the public are now very conscious of gross litter (Zann, 1995) and commercial fishers in particular are becoming increasingly conscious of any obvious pollution within their working environment. It is therefore likely that most incidents would be very minor.

iv) Discharge / dumping of on-board processing waste

On board processing waste is likely to consist of liquid ‘slurry’ containing body juices, scales etc. All of this material would be readily decomposed or eaten, although not without possible trophic effects (see Chapter F section 3) and/or impacts associated with nutrient enhancement (see Chapter F section 10). It is likely, due to the small sizes of vessels used in the fishery, that most on-board processing would be restricted to small amounts of catch. Substantial amounts are most likely to be processed at shore-based facilities (particularly at ‘fisherman’s co-ops’).

b) Associated risks to water quality

The sources of pollution associated with fishing operations are likely to be of low magnitude and of low to moderate frequency (Table F12 and discussion above). The number of vessels used in the Estuary General Fishery represent less than 0.5% of the more than 180,000 vessels registered by the Waterways Authority in NSW, and the vessels used in the fishery are almost invariably small, at between three and six metres: the collective potential for pollution from these vessels is likely to be only a tiny fraction of that associated with boating generally. Furthermore, these fishing vessels are widely dispersed between and within estuaries. Unlike some other fisheries, there are no major ‘home ports’ containing large numbers of vessels in one location. Fishing effort (i.e. operations) are also similarly dispersed: problems caused by the cumulative impact of many small sources in one area are unlikely to occur, even within those estuaries (e.g. coastal lagoons) where water circulation is poor. Even under abnormal conditions, such as during stratification after heavy rain, or during prolonged periods of entrance closure associated with drought, pollution arising from fishing operations is unlikely to have any significant effects in the context of other vessels, and the wide range of land-based sources of pollution (Chapter F section 10).

On the basis of the above, it is assumed that the risk to water quality associated with fishing operations in the Estuary General Fishery is very small, and does not require any further management given existing controls as administered by the Waterways Authority and the Environment Protection Authority.

There is however, some potential for localised impacts from on-shore facilities associated with the fishery. Whilst any effects related to vessel maintenance are likely to be insignificant in relation to the number and sizes of vessels maintained within NSW generally, significant (though highly localised) effects from on-shore fish processing facilities (i.e. ‘fishermans co-ops) are possible.

Discharge from such facilities would primarily consist of non-toxic organic waste derived from cleaning fish. This would be expected to have some localised trophic effects (e.g. attract scavengers) and would contribute nutrients to receiving waters. However, in the context of the plethora of major land-based sources of nutrients (Chapter F section 10), any such effects are likely to be minor.

c) Baseline studies in areas of significant impact

There are unlikely to be any areas of significant impact, and no baseline studies are therefore necessary. Existing controls (administered by the Environment Protection Authority) on shore-based activities liable to cause pollution are sufficient to effectively manage activities such as on-shore processing and vessel maintenance.

7. Noise and Light Impact Assessment

The following summary is based on the detailed consultants report prepared by SMEC Australia Pty Ltd and presented in Volume 4 Appendix CF1.

a) Noise impact on residents adjoining estuaries

Noise from estuary general fishing may cause adverse effects to residents where houses are close enough to the estuary for the fishing activity to cause disturbance. Given the type of activity and likely low sound power level of the potential noise sources, it is probable that there is only a potential for disturbance during night-time operations and complaints related to fishing activity are minimal. The potential for disturbance would be determined by the following factors, the:

- size of the boat motor and whether it is an outboard or in-board motor
- duration and type of fishing activity
- number of other boats operating in the same area
- position of the house, both its distance from the activity and intervening topography
- land-based activity in the vicinity of the house.

A house in a coastal town or close to a main road could be expected to have a higher background noise level to an isolated farm house.

b) Noise impact on wildlife

Noise from estuary general fishing activities would only affect wildlife when:

- fishing is undertaken in areas where wildlife that is sensitive to noise is present; and/or
- noise from fishing activities disturbs wildlife either due to the volume or type of noise generated.

Noise impacts could result from fisherman's voices, the sound of equipment contacting boats, motors and the splashing of water. Wildlife that could be affected may include birds, terrestrial and arboreal mammals, aquatic mammals and non-target fish. Any such wildlife that is disturbed may:

- remain in the area but become inactive (i.e. hide)
- temporarily move away from the area to return when the disturbance has ceased
- may permanently move away from the area (this is more likely if the disturbance is prolonged or occurs frequently).

The significance of the disturbance to wildlife would vary depending on the species and on the timing of the disturbance. The greatest impacts could be expected during the nesting or breeding season. At these times, any disturbance could impact upon the reproduction of a species and may endanger the viability of local populations. This would be particularly be the case if the disturbance were a frequent, regular or ongoing activity.

Species most likely to be impacted by commercial fishing during the nesting or breading season would include birds that nest in aquatic or riparian vegetation or in vegetation near the water's edge. Non-target fish could similarly be impacted if fishing is undertaken near nurseries or breeding habitat such as mangroves and areas of seagrass.

c) Noise mitigation measures

A potential for some adverse effects caused by noise from estuary general fishing on people and wildlife has been identified. This is not a new phenomenon as commercial estuary fishing has been a continuing industry for more than 100 years. There are existing controls on the Estuary General Fishery including:

- A **code of conduct** in the Clarence River administered by the Waterways Authority that establishes maximum acceptable noise levels for prawn set pocket net fishing operations
- **Location controls:** Refers to restrictions on the parts of the estuary where commercial fishing can be done, and where certain types of equipment may or may not be used
- **Time controls:** Refers to daily time restrictions on when commercial fishing may be done, and at what times of day certain equipment can be used
- **Weekend/public holiday/school holiday closures:** Refers to a total closure or closures to netting on commercial fishing activity during the specified times
- **Seasonal controls:** Refers to restrictions on what periods of the year certain commercial fishing activities may be done
- **Total closure:** Means that the estuary is closed to commercial estuary general fishing.

These controls were instigated for a number of reasons including wildlife conservation and to prevent disturbance to people living close to the estuaries.

It is proposed to monitor the levels of complaints received concerning noise levels from the commercial Estuary General Fishery. Two authorities currently receive complaints, local councils (who tend to refer these to NSW Fisheries) and regional offices of NSW Fisheries. The number and type of complaints will be used as input into future reviews of the draft FMS.

d) Light impact on residents

The only potential for adverse effects from lights used in the fishery would be from spotlights used as part of the fishing activity. Navigation lights or deck lighting would not have a potential for significant adverse effects. Spotlights would only cause an adverse effect where these were shone into houses adjoining the estuary. The activities of the estuary general fishers generally do not require intensive use of spotlights nor high strength lights. It is not anticipated that this type of lighting would have a potential for significant adverse impacts.

e) Light impact on wildlife

Impacts from light upon wildlife are unlikely to be significant unless light beams repeatedly or continuously affect the same individuals. The severity of this impact would increase with the intensity of the light.

Wildlife most susceptible to impacts from light would be those occurring in the water, on aquatic vegetation or near the water edge. Species would include aquatic mammals, non-target fish, arboreal and terrestrial mammals and birds. Nocturnal species would be most likely to be impacted. However, diurnal species disturbed from their sleep could also be impacted.

f) Light mitigation measures

Mitigation measures outlined for noise impacts are generally applicable for reducing the potential for adverse effects from lighting. In summary these were:

- existing controls to limit the location and hours of fishing
- monitoring of levels of complaint.

8. Air Quality

The following summary is based on the detailed Consultants report prepared by SMEC Australia Pty Ltd and presented in Volume 4 Appendix CF1.

The identified sources of air emissions from the Estuary General Fishery are emissions from boat engines. These emissions do not have a potential to significantly affect air quality. They:

- do not represent a concentrated source of inputs as they occur along the NSW coast
- vary according to both season and time of day
- are from relatively small engines.

Mitigation measures to reduce air quality emissions are the same as those proposed to reduce energy and greenhouse inputs. These are discussed in the following section.

9. Energy and Greenhouse Issues

The following summary is based on the detailed Consultants report prepared by SMEC Australia Pty Ltd and presented in Volume 4 Appendix CF1.

a) Description of fishing fleet

Boats used in the Estuary General Fishery are generally small ‘run-about’ or ‘punt’ style vessels generally of aluminium, wood or fibreglass construction using petrol or marine engines/motors.

Table F13 contains a summary of the characteristics of the estuary general fishing fleet.

No data were available for the typical use of boats in terms of hours used. This would vary according to the fishing business, the estuaries operated in and the time of year. Similarly, there is no quantitative information on the catch/effort characteristics of the different methods of fishing.

Table F13. Fishing fleet characteristics.

Characteristic	Sample size	Median	80% Range	Range
Motor (kilowatt)	457	18.6	7.4 to 44.7	3.4 to 150
Boat Length (metres)	562	5.1	4.0 to 5.9	2.5 to 9.0

Source: Data supplied to SMEC by NSW Fisheries

Petrol and diesel fuels have similar CO_2 emission factors as shown in Table F14. On that basis, the fuels are not dissimilar in their potential greenhouse impact although this would depend on other factors such as comparative efficiency between diesel and petrol motors and motor size availability.

Table F14. CO_2 emission factors.

Fuel	CO2 Emission Factor
	(kg CO2/GJ)
Petrol	65.3
Diesel	69

Source: *Factors and Methodologies* (Greenhouse Challenge, AGO, 2001)

b) Energy and greenhouse assessment

Energy and greenhouse effects are considered together because the only potential for greenhouse gas inputs is from the energy consumed in the boat motors. Overall, the numerical size of the fleet and the size of the boats and motors used means that the overall consumption of energy resources and subsequent greenhouse gas emissions are not significant. The Estuary General Fishery consists of many small businesses operating in a low technology environment. Potential measures to reduce energy and greenhouse emissions may not be practicable for many of these ventures due to their initial cost.

Renewable energy sources for fishing vessel operation could include solar and wind energy. However utilisation of these energy alternatives is not currently considered economically viable for general estuarine commercial fishing vessels.

10. External Impacts on the Fishery

The purpose of this section is to outline the sources of external impacts that could occur on the Estuary General Fishery, a discussion of their effects and magnitude on the fishery and any mitigative management responses to combat these impacts.

a) Land based activities likely to affect the environment on which the fishery relies

i) Urban foreshore development

Urban foreshore development includes the construction of marinas, the clearing of foreshore vegetation, drainage of wetlands and reclamation. The environmental effects associated with these developments are discussed in NSW Fisheries (1999a) and are outlined in the following paragraphs.

Marinas, jetties and similar structures may have a variety of effects on nearby fish habitats (NSW Fisheries, 1999a; Hannan, In prep.). They may cause direct damage to sensitive habitats during construction: for example, seagrasses may be destroyed by piles, and mangroves may be cut to make way for walkways or ramps. These structures may also cause overshadowing of marine vegetation, with seagrasses (especially strapweed, *Posidonia australis*) being particularly sensitive (Fitzpatrick and Kirkman, 1995; Glasby, 1999a and b; Shafer and Lundin, 1999). Also, interference with waves and/or currents may result from the physical bulk of the underwater portion of a structure. Such interference (say from a large pylon) may cause localised scouring of the seabed and destruction of any seagrass in the affected area. Depending on prevailing wave and current conditions, initial damage to seagrass may progressively expand through continued undermining of the exposed seagrass edges. Although the loss of habitat associated with any individual structure may be small, cumulative impacts and fragmentation (especially with respect to sensitive habitat such as seagrass) may be significant along highly developed shorelines (Shafer and Lundin, 1999).

The clearing of foreshore vegetation, say to make way for buildings or recreational facilities, can also have a range of detrimental effects on fish habitats (Hannan, 1997; NSW Fisheries, 1999a). Intertidal vegetation such as mangroves or reeds may form habitat corridors for species such as Australian bass and bully mullet, whose juveniles migrate from estuaries to freshwater at a young age: breaks in such corridors may hinder such migration by making the juveniles more prone to predation, by reducing food availability, and/or by altering their behaviour. Foreshore vegetation is the ultimate source of snag material, which in turn provides favoured habitat for a variety of fish and invertebrates; by providing shelter (from predators and/or strong currents) and food supply. Also, the overhanging branches provide terrestrial food such as insects. Loss of snag material and/or overhanging vegetation is likely to significantly alter fish community structure in the effected area (Gehrke *et al.*, 1996; Growns *et al.*, 1996). Foreshore vegetation can also help to absorb and slow runoff, thereby trapping sediments and nutrients before they reach the waterway. Loss of foreshore (riparian) vegetation exacerbates the pollution related problems (see sub-sections ii and iv which follow) associated with land clearing and urban development.

Wetlands include mangrove forests, saltmarshes and brackish/ freshwater swamps. They provide habitat for a wide variety of fish and invertebrates. They also tend to trap/absorb in-flowing pollutants and therefore contribute to better downstream water quality. Major wetland loss within a particular catchment is likely to impact on fish communities and exacerbate problems relating to nutrient or sediment inputs. For example, a perceived decline in fish populations within the lower Clarence River over recent decades has been blamed on the widespread drainage of associated swamps, these having provided important nursery and feeding habitats for local estuarine fishes (Pollard and Hannan, 1994). A lack of wetlands (whether natural or artificial) within most urban areas contributes to problems associated with storm water runoff (see sub-sections (ii and (iv) which follow). Furthermore, the drainage and/or excavation of wetlands is also a common cause of acid runoff, which may result in massive fish kills under certain conditions (see sub-section iii which follows).

Reclamation is often the most damaging type of activity associated with foreshore development, as it usually causes the total destruction (as opposed to modification) of aquatic habitat. Reclamation can also interfere with water circulation, and possibly result in a range of indirect effects beyond the actual works area. These may include increased siltation, reduced water quality and habitat (e.g. seagrass) loss. Major reclamation works, such as those for the runways and port works in Botany Bay (Sydney) can result in the loss of large areas of seagrass and other shallow habitat. Apart from reducing the area available to fishing, such works may have major impacts on an estuary's productivity. In the case of Botany Bay, it is known that reclamation for the third runway resulted in the loss of a particularly productive juvenile habitat, where consistently outstanding recruitment of juvenile tarwhine, luderick and yellowfin leatherjacket had been previously noted by McNeill *et al.* (1992).

ii) Stormwater and sewage outfalls

Stormwater and sewage carry a wide range of pollutants, the most notable being pathogens, nutrients and sediment. The nature and impacts of the various other pollutants are discussed under "Pollution from point and diffuse sources" (sub-section (iv)).

Excessive pathogen concentrations, whilst of primary concern to swimmers, are also likely to affect fish and other aquatic life. Many types of pathogens (particularly bacteria) are not host-specific, and are capable of infecting aquatic animals, particularly when such animals have already been injured in some way. Fish that have suffered damage to their skin or gills are particularly susceptible. Also, many types of mollusc (including oysters and mussels) are filter-feeders and tend to concentrate pathogens in their gut, thereby posing a risk to human consumers. In regularly affected areas, the resultant marketing problems (discussed below) tend to include all types of seafood (including finfish).

High nutrient concentrations can, under the right conditions, promote excessive growths of microscopic algae (such as cyanobacteria and dinoflagellates) in the water. Such 'algal blooms' can become toxic, to the point that other aquatic life are harmed. Also, humans can become ill from consuming affected seafood (especially filter feeding molluscs), leading to marketing problems as discussed below (See also Chapter H section 2.1).

Suspended sediments can clog fish gills and block the filter-feeding systems of invertebrates. In reducing underwater visibility, they can also reduce the feeding ability of sight based predators, including many types of carnivorous fish.

Impacts on habitat

Seagrass habitats are particularly vulnerable to the effects of pollution. Urban runoff (stormwater), sewage overflows and septic seepage threaten seagrass habitat through the continuing addition of suspended sediments and nutrients. These inputs cause greater than natural turbidity, both directly and from excessive phytoplankton growth. Such turbidity is most evident where flushing is poor and inputs are great. Increased turbidity reduces the light available to seagrass, with the deeper parts of a bed being particularly vulnerable to consequent damage (Shepherd *et al.,* 1989; Fitzpatrick and Kirkman, 1995). Whilst extra nutrients can actually enhance seagrass growth, very high levels are likely to cause heavy epiphytic growth that can smother and shade seagrass, and eventually lead to its decline (Shepherd *et al.*, 1989). Nutrient enrichment may also promote the competitive replacement of seagrass by *Caulerpa* spp., which are green macroalgae morphologically similar to seagrass.

Also, sedimentation gradually makes areas too shallow for seagrass, particularly in bays receiving urban stormwater runoff. Heavy loads of fine sediment washed down after heavy rain can coat seagrass leaves, reducing photosynthetic efficiency and therefore vigour (Poiner and Peterken, 1995). As a result seagrass is especially vulnerable to being coated in sheltered bays where waves and currents are slight. Where sediment inputs are particularly great, seagrasses can be completely buried. Sedimentation also alters the nature (particularly with respect to parent material and grain size composition) of substrata supporting seagrass which can cause both changes in the seagrass itself, and in the invertebrate community associated with the substrata.

Other habitats can also be seriously effected by sediment-laden runoff. Macroalgae (an important component of rocky reefs) are liable to be affected in the same ways as seagrasses. Macroalgal assemblages on rocky reefs are complex (Kennelly, 1995; Kennelly and Underwood, 1992) and their recover after smothering could take years because some species of algae will recolonise faster (such as green turfing algae) than other species (such as kelp). In fact Kennelly (1987) found that early colonisers of turfing algae can inhibit the later colonisation of kelp species. Sessile invertebrates (another major component of rocky reef habitat; Chapter F section 1) are vulnerable to suspended sediments, which can interfere with their feeding and respiration. Rocky reef itself is vulnerable to being buried by sediment derived from new urban developments and rural erosion; for example within many of the sheltered bays and inlets in and around Sydney, depositions of sand or mud are slowly encroaching on adjacent rock habitat.

Impacts on seafood marketability

Filter feeding bivalve molluscs (such as oysters, mussels and pipis) are very efficient at concentrating within their guts any bacteria, viruses or toxic algae that might be present in seawater. Whilst these organisms might not harm the mollusc, they can cause serious illness in human consumers, particularly when the mollusc is eaten raw (See also Chapter H section 2.1). The risk of human illness is greatly increased when the water from which the mollusc is harvested has been recently contaminated with sewage effluent, stormwater or an algal bloom. Such contamination has the potential to cause many cases of illness, as illustrated in the recent cases of hepatitis attributed to Wallis Lake oysters (NSW Fisheries, Internal Report). These cases were believed to have resulted from poorly treated sewage effluent (NSW Fisheries, Internal Report).

Areas that have been associated with multiple cases of seafood-borne illnesses are likely to acquire a reputation of being ‘polluted’ and treated with extra caution by members of the public, leading to on-going marketing problems. Furthermore, any negative perceptions (whether based on reality or not) are likely to extend to other types of seafood, such as finfish.

iii) Disturbance/drainage of acid sulphate soils

Floodplain drainage, excavation or dredging associated with the installation of floodgates or other in-stream works (and in some circumstances the works described in sections 10(a)(i) and 10(b)(ii) can expose acid sulfate soils to air.

Impacts of acid water

The effects of acid sulphate soil drainage on aquatic biota can be described at the ecosystem, population and species level. In general the effects can be categorized as mortality of fish and invertebrates; increased susceptibility to disease especially epiozotic ulcerative syndrome (EUS); physiological effects (related to reduced growth, visual and olfactory impairment, bone disorders); and avoidance responses (Sammut *et al.,* 1993; Sammut *et al.,* 1995). The cause of the observed effects is not fully understood but the interrelation of pH and its effect on the chemistry of iron and aluminum and their respective toxicity are the key contributors to the impacts on biota.

The physiological effects of low pH and its association with aluminum and iron is well studied for northern hemisphere freshwater fish and other aquatic organisms (Erichsen Jones, 1969; Lloyd, 1992; Howells, 1994). However, data for Australia are limited to the work by Wilson and Hyne (1997) and Hyne and Wilson (1997) on Sydney rock oyster embryos and larvae of Australian Bass and the Richmond River study on estuarine fish and benthic communities (Roach, 1997).

The associations between acid drainage, *Aphanomyces* fungal infection and "red-spot" ulcer disease or EUS and fish kills have been reviewed by Callinan *et al.* (1989, 1993, 1995a, b).

Hydrology and rainfall in the catchments govern acid production in a sequence of events that have the following major features and impacts (adapted from the reviews of Alabaster and Lloyd, 1980; Cappo *et al.*, 1997; Howells, 1994; Sammut *et al.*, 1993, 1995, 1996; Willet *et al.*, 1993). After rainfall events and a rise in the water table, aluminium, iron, manganese and other ions are stripped out of the soil by sulphuric acid originating from the oxidation of pyritic sediments. The significant quantities of aluminium and iron derive from aluminosilicate clays commonly associated with coastal estuaries. The lower the pH, the greater the amount of aluminium and other ions that are mobilised. In addition, low dissolved oxygen in water bodies has also been linked to the suspension of iron monosulfides in drains.

Floods and other high flow events drain large "slugs" of this low pH water through floodgates to meet higher pH bicarbonate rich estuarine water. This can produce aluminium hydroxide and iron hydroxide flocs in massive amounts. About one tonne of iron floc is produced for every tonne of pyrite oxidised. The aluminium and iron flocs disperse through the estuary producing a bluey-green stain. The flocs then bind to clay particles and settle out to produce clear estuarine waters. Smothering of the substratum with flocs of iron hydroxide (up to one metre deep) can result in the death of most gilled, benthic life. During this time fish and invertebrate kills occur for a variety of reasons that depend on the prevailing pH.

- acid kills most fish and invertebrates at approximately pH 3 - 3.5
- aluminium hydroxide flocs bind to clays and attach to skin and block gills at higher pH
- above pH 4, iron oxyhydroxides are precipitated and may cause suffocation
- inorganic monomeric aluminium [$AlOH_2^{++}$] toxicity kills most fish at pH 5

- lack of dissolved oxygen can occur when oxidation of iron occurs from the ferrous iron to ferrihydrate

Fish with epithelial defenses weakened by metal flocs and acid suffer from *Aphanomyces* fungal infections. These infections produce extensive ulcers (red-spot, EUS, Bundaberg Disease) on fish that often are so deep that the caudal rays or neural spines of the backbone are visible. Survivors of these attacks invest so much energy in healing that there is no reproduction until condition is regained in subsequent years.

Fish with ulcers or healed ulcer scars are unmarketable and have, at times, comprised up to 30% of some catches of whiting, bream, mullet and flathead. Lower growth rates of prawns in pond aquaculture occurs because less bicarbonate is available to them in the low pH water and they will not molt. In the Tweed and Hastings Rivers, the role of acid drainage in oyster mass mortality, disease, shell erosion and low growth performance has been apparent.

The impacts of acid water on non aquatic fauna includes poor crop and pasture growth in acidified parts of the floodplains, lower dairy and beef animal production, corrosion of pipes and cement structures and acidification of aquifers and potential human health problems from groundwater consumption (high aluminium, acidity) (Anon, 2000).

Impacts of floods

The impact of major flooding due to climatic events can adversely affect fish resources and result in significant fish kills. The February/March 2001 floods and resultant fish kills in the Richmond River and Macleay River are examples. The floods initially resulted in minor fish kills, but within a week had escalated to become unprecedented relative to available records. Surveys revealed tonnes of dead and dying fish and invertebrates from juveniles to adults, throughout the river.

These were sudden floods, the water level peaked quickly and dropped very fast with large volumes of water inundating the floodplain. Then, the weather cleared with high daytime temperatures. Much of the decaying organic material on the floodplain drained into the river over a few days, reducing oxygen levels. Sampling of the water on the floodplain and in the rivers showed acceptable acidity, but the dissolved oxygen levels were below one part per million.

The relationship between the floodplain and the fishery is not fully understood and more investigation is needed to identify specific problem areas. However, the changed nature, management and use of the floodplain has altered natural drainage patterns. Flood waters used to take 100 days or more to drain back into the river, now they take about five to seven days and this has significant impact on water quality.

iv) Pollution from point and diffuse sources

Unpolluted water is the most critical component of fish habitat, with few fish species being able to survive in badly polluted water. Pollutants affect fish and other aquatic animals in a variety of ways, including direct toxicity, interference with feeding and respiration, altered behaviour, increased susceptibility to disease and reduced reproductive success. Even if pollution does not directly kill affected animals, a variety of chronic or sub-lethal effects can occur.

A wide variety of pollutants enter estuaries and associated rivers and streams. Common pollutants include pathogens, nutrients, sediments and a wide range of toxic chemicals such as heavy metals, oil and pesticides (Table F15).

Table F15. Types and sources of pollutants affecting estuaries.

Further information provided in Birch *et al.* (1996), NSW Fisheries (2000), and Irvine and Birch (in press). Those pollutants strongly associated with stormwater and sewage outfalls (pathogens, nutrients and sediment) have been discussed above under Section (ii); the remainder are discussed in the following paragraphs.

Type of pollutant	Specific examples	Main sources
pathogens	bacteria and viruses	discharges from sewage treatment works; sewerage overflows; stormwater runoff from urban areas
nutrients	nitrogen and phosphorus	discharges from sewage treatment plants; sewerage overflows; stormwater runoff from urban areas; agricultural runoff from fertilised areas
sediment	silt, mud, sand; coal wash and clay	land clearing; erosion; building sites; dredging; mining; stormwater runoff
heavy metals	copper, mercury and zinc	current and former industrial sites; refuelling and boating facilities; airborne dust; sewage overflows; waste dumps; stormwater runoff from urban areas
oil	crude oil, diesel and petrol	accidental spillage during transport (e.g. ship or road tanker); refineries and associated berthing facilities
pesticides	various organo-chlorine compounds; dieldrin, heptachlor	agricultural runoff; aerial spraying
acid	sulphuric acid, hydrochloric acid	runoff from acid sulfate soils that have been exposed to air; accidental spillage/discharge during transport or industrial process
other toxic chemicals	dioxin, alkalis,	current and former industrial sites; accidental spillage/discharge during transport or industrial process
thermal	excessively hot or cold water	power stations (hot water); discharges from large reservoirs (cold water)

The sources of pollution as listed in Table F15 fall into two categories: point sources and diffuse sources. Point source pollution originates from a specific identifiable site, such as a discharge point from a sewage treatment plant or industrial site, an accidental spillage or a particular activity (such as dredging or mining). Diffuse source pollution arises from a large area and/or a collection of unidentifiable sites, such as is the case with urban or agricultural runoff. Following is a discussion of the nature and impact of the main types of point source and diffuse source pollutants not already dealt with under section (ii) of this chapter “Stormwater and sewage outfalls”.

Heavy metals and organo-chlorine compounds, if present in unnaturally high concentrations, tend to accumulate within fish tissue in a process termed bio-accumulation (e.g. Scanes and Scanes, 1995; Birch *et al.*, in press), in some cases leading to ‘biomagnification’, whereby top predators may have very large concentrations of contaminants even without being exposed to the original source (Scanes and Scanes, 1995). Biomagnification occurs because such metals are not easily excreted and because, at each level in the food chain, a particular fish (or other animal) must consume, in the course of its life, many times its own weight in prey (whether that prey be another smaller animal or plant matter). Consequently, tissue concentrations of such substances progressively increase as one goes up the food chain, resulting in particularly high concentrations in long-lived, top predators. Such concentrations, whilst unlikely to kill these predators outright, are likely to have a range of (unknown) chronic effects on growth and reproduction. Affected seafood may, in severe cases, pose risks to human consumer, and associated marketing problems are likely in relation to areas perceived to be polluted by heavy metals or organo-chlorines. Sediments subjected to runoff from urban/industrial areas progressively accumulate heavy metals and other toxic chemicals (Shotter *et al.*, 1995; Birch, 1996; Birch *et al.*, 1996, 1997; Irvine and Birch in press). Of particular concern is the fact that previously contaminated sediments continue to affect associated biota (particularly benthic, but also the fish that feed on it), even though waste disposal practises have since improved (Scanes and Scanes, 1995).

Oil and related products can harm fish and other aquatic organisms in several ways. Not only do oil spills release off toxins, but they can also cover intertidal invertebrates, resulting in suffocation and disruption of feeding mechanisms. In severe cases whole intertidal communities can be affected, denying dependent fish species an important food resource. The short-term effects of an oil spill depend greatly on weather and sea conditions, as well as the clean up method(s) used. Ultimate recovery depends on the recruitment of organisms from other unaffected areas. Mangroves and saltmarsh are most vulnerable to water pollution during high tides, at which time they can be affected by events such as oil spills (Allen *et al.*, 1992a,b), acid soil leachate or toxic spills.

Most aquatic organisms can only tolerate a relatively narrow range of pH values; for example most estuarine fish prefer pH values between 6.5 and 8.5 (Howells, 1994). Values outside of this range (whether caused by acid or alkali) cause irritation and injury to skin, gills and other membranes. This damage subsequently leaves fish more vulnerable to disease. For example, acidic water derived from the disturbance of acid sulfate soils has been shown to cause ‘red-spot disease’ in fish (NSW Fisheries, 2000). Extreme pH values, such as these might be caused by concentrated runoff or spillage in a confined area, quickly kill fish and other aquatic organisms. Furthermore, the activity of other chemicals present in a water body is strongly influenced by its pH value: for example the bio-availability of nutrients, heavy metals and organo chlorines may be increased under low pH conditions.

Thermal pollution, whether caused by unnaturally hot or cold water, will kill or repel less tolerant aquatic organisms from the affected area (Hannan, 1985 and 1989). Those species remaining will often experience altered growth, feeding and/or reproduction. Within NSW estuaries, the main cause of thermal pollution is the discharge of heated cooling water from facilities such as power stations and refineries. In the case of the power stations on the central coast (in Lake Macquarie and Tuggerah Lakes), discharge temperatures may exceed 35°C in summer and are commonly around 20-22°C in winter. The associated plumes may cover many hectares and have been shown to have a range of effects on local fish and invertebrate communities (Friedlander, 1980; Virgona, 1983; King, 1986; Hannan, 1989). These effects include:

- year-round reduction in the abundance of certain species, particularly those closely associated with seagrass (e.g. leatherjackets and pipefishes)
- increased abundances of many species during winter, including most commercially important species
- reduced abundances of most species during summer (but through emigration to other areas rather than through mortality)
- presumed possible increases in overall growth rates
- a range of possible effects relating to increased predation and/or exploitation of fish concentrated as a result of warm waters during winter
- locally altered benthic communities, including the occurrence of tropical species not normally found in central NSW
- habitat alteration, particularly in relation to seagrasses (see discussion below).

Whilst the central coast power stations may be providing a net benefit to fisheries production within the affected estuaries, it is difficult to determine whether the warm water is actually causing an overall improvement, or whether it is merely concentrating fish from other areas and at the same time making them more vulnerable to exploitation (Hair and Bell, 1992).

A database of fish kills in NSW is maintained by NSW Fisheries. Of the more than 400 kills reported from estuarine areas since the early 1970s (Allan Lugg, NSW Fisheries, pers. comm.), approximately 53 % were attributable to a particular cause (Figure F1). 'Pollution' in the simplest sense (i.e. toxic chemicals, pesticides and sewage) was blamed for nearly 18% of those kills, while runoff from acid sulfate soils is considered to have caused nearly 16%. Whilst nearly half of the kills able to be attributed to a particular cause were linked to potentially natural processes such as de-oxygenation or algal growth, many of these processes would have been the result of human-related factors such as nutrient enrichment and/or the alteration of natural water circulation.

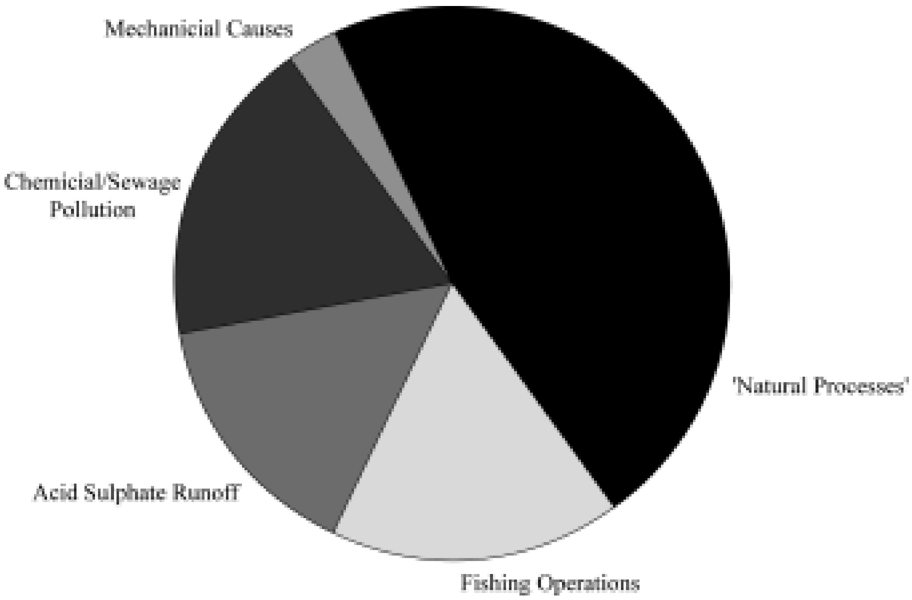

Figure F1. Breakdown of all fish kills in NSW estuaries attributable to a particular cause (data from 1970 to 2000 inclusive).

'Natural' processes include events such as water column de-oxygenation and algal blooms; chemical and sewage pollution includes toxic spills, pesticide contamination and sewage discharge; acid sulfate runoff refers to the low pH waters generated from the exposure of acid sulfate soils; fishing operations relate mainly to the discard of unwanted commercial catches; and mechanical causes include underwater explosions and impingement on intake screens. (Allan Lugg, NSW Fisheries, pers. comm.).

Whilst the number of reported fish kills in NSW estuaries directly attributed to pollution (including industrial chemicals, pesticides, sewage or acid runoff) only averages around 10 to 15 per year (Allan Lugg, NSW Fisheries, pers. comm.), many of these kills involve thousands of fish and several species. In severe cases, such as a major spillage into a confined creek, whole fish communities can be killed within the affected area.

With respect to the above-discussed forms of pollution, some estuaries or parts thereof are intrinsically more vulnerable than others. The lower reaches of large 'drowned valley' type estuaries such as Sydney Harbour are kept relatively clean by efficient tidal exchange with ocean waters. However, coastal lagoons which are intermittently open to the sea, and barrier estuaries which have restricted tidal exchange, are particularly susceptible to water pollution. In these cases the reduced tidal flushing means that any pollutants readily accumulate. Even within generally well flushed estuaries, pollutants (including sediment) often accumulate in upper reaches and in tributary bays (Birch, 1996; Irvine and Birch, in press). Also, estuaries with heavily urbanised or intensively farmed catchments suffer far more pollution and/or fish kills than those with unaltered (e.g. forested) catchments. Furthermore, within altered catchments, a greater proportion of incident rainfall ends up as overland runoff, resulting in a more direct and efficient delivery of pollutants to receiving waters.

Overall these pollutants affect the Estuary General Fishery chiefly through decreasing water quality which can lead to deformities in fish and decreasing abundance and diversity of targeted fish species. Generally, if polluted waters are identified they would be avoided by commercial fishers and who would fish elsewhere. Thus pollutants could temporarily or permanently close an area/estuary to fishing.

b) Water based activities likely to affect the environment on which the fishery relies

i) Vessels

A variety of vessel activities may affect the Estuary General Fishery, including commercial shipping, vessels from other commercial fisheries and recreational boating. The associated effects are outlined in the following paragraphs.

Commercial shipping is concentrated in a small number of deepwater ports, particularly Newcastle Harbour, Port Jackson, Botany Bay and Port Kembla. Large scale shipping operations are generally incompatible with commercial fishing, especially where hauling or meshing are concerned. However, the effected areas represent only a very small fraction of the potentially available fishing area within the state’s estuaries, and are usually characterised by very deep water and a lack of productive shallow water habitats. Commercial shipping does bring with it the risk of a major pollution incident such as an oil spill. Whilst such incidents can cause significant damage to shallow water and intertidal habitats (e.g. mangroves and rocky shores), major events are very rare, and are unlikely to have major long term effects. Chronic or repeated pollution, as from some land-based activities, is likely to be far more serious in this regard (Skilleter, 1995). Commercial shipping may also result in introductions of exotic pest or disease organisms with potentially serious ecological consequences (section 4 of this chapter).

Berthing facilities for large ships typically include large ‘finger wharves’ and/or smooth vertical walls plunging into deep water. Whilst the wharves have some value as artificial habitat for certain species, their shear size means that extensive dark areas are created. Such areas have been shown to affect significantly fish behaviour, particularly in relation to feeding. For example, (Glasby, 1999) found that species were less abundant under large wharves than in either open areas or unshaded areas with pylons. Also, the smooth vertical walls typical of berthing facilities provide few opportunities for small fish to hide, and are likely to be far less attractive as habitat than natural rocky reef or structures made of broken rock (Coleman and Connell, 2001)

The only commercial fishery other than the Estuary General Fishery that operates within estuaries to any significant extent is the Estuary Prawn Trawl Fishery, although lobsters are occasionally trapped as part of the Lobster Fishery over rocky reefs near the entrances of larger (drowned valley) estuaries such as Sydney Harbour. Estuary prawn trawlers only operate in five estuaries: Clarence River, Hunter River, Hawkesbury River, Sydney Harbour and Botany Bay. Estuarine prawn trawlers capture (either as bycatch or as target species) several of the primary target species taken in the Estuary General Fishery. The associated mortality, along with trophic effects related to discards, and the possible habitat damage relating to trawl net operations, may affect the Estuary General Fishery (Alverson *et al.*, 1994; Kaiser and de Groot, 2000). However, whilst specific information on the magnitude of some of these interactions is lacking (an exception is the bycatch of the Estuary Prawn Trawl Fishery), they are not likely to have any significant effect on the Estuary General Fishery as a whole, as the affected areas represent only a very small fraction of the fishing area that it potentially available to the Estuary General Fishery within the state's estuaries.

Unlike commercial shipping, and vessel activity associated with other commercial fishers, recreational boating significantly affects most estuaries within the state. On many of the more popular waterways, weekend closures affecting estuary general operations have been established to minimise conflicts between estuary general fishers and recreational users. Cumulatively, these closures affect a large portion of the state's estuaries. Recreational boating is also associated with competition for fish stocks from recreational fishers (West and Gordon, 1994) and possible damage to habitats such as seagrasses (Hannan and Simpson, 1999). Whilst the ultimate effect of these interactions is difficult to quantify, it is clear that recreational boating and its associated activities have had a major influence on the development and operation of the Estuary General Fishery.

ii) Dredging

Dredging refers to the removal of substrata (e.g. sand, mud or rock) from aquatic or intertidal areas. Apart from the direct loss or modification of habitats in the immediate works area, dredging is likely to cause increased turbidity and/or sedimentation over a much wider area, depending on the nature of the sediments involved and the prevailing waves and currents (NSW Fisheries, 1999a). Habitats such as seagrass and rocky reef may therefore be degraded well outside of the actual area dredged. Dredging may also create stagnant deep holes, alter currents, cause seabed or river bed erosion and liberate pollutants previously trapped in sediments (Scanes and Scanes, 1995; NSW Fisheries, 1999a). Dredging can, however, be used to rehabilitate fish habitats: in some situations appropriate dredging can improve water circulation and quality and promote habitat diversity (NSW Fisheries, 1999a).

The long term effects of dredging on fish habitats can be far reaching. Quigley and Hall (1999) found that a control site 500 metres away from the dredged site had been affected and both areas had not recovered six months after dredging ceased. *Posidonia* (strapweed) seagrass, if removed, will take many decades to recover, if it occurs at all (King, 1981; Keough and Jenkins, 1995). Even with more vigorous seagrasses such as *Zostera* (eelgrass), recovery may be prevented by instability of the remaining sediment, particularly in areas subject to strong waves or currents (Hannan, in prep).

Whilst most dredging projects involve small-scale works and only localised effects, large scale works for projects such as port development or entrance maintenance can have estuary-wide effects involving to altered tidal and/or wave regimes. Possibly the best example of such effects can be found in Botany Bay, where configuration dredging was done in the early, 1970s. This dredging altered the path of incoming swells, substantially increasing wave heights on the southern shores, including those at Towra Point. Seagrasses were damaged, and many sections of shoreline began eroding at accelerated rates. Consequently, protective works such as rocky groynes and concrete seawalls have had to be installed and the availability of shorelines for commercial fishing operations has been compromised. The rocky groynes have not only interfered with some fishing operations but they have also modified the habitat. Seagrasses and benthos have been directly lost, although the effects of this on associated fish communities is unknown. However, habitat diversity has been increased (by the addition of rocky substrata) and anecdotal information suggests that certain species such as luderick have benefited.

iii) Structural engineering works

These include barriers to river flow (such as dams and weirs), groynes and training walls. Potentially these works can impact on the fishery, either on operations, or through effects on fish communities and/or their habitats.

Groynes are normally constructed out of large rocks and are used to prevent shoreline erosion. They work by intercepting longshore drift and the associated sand movement: sand becomes trapped on the up-drift side, thereby stabilising the shoreline in this area. Unfortunately, this process deprives the beach on the down-drift side of sand, thereby worsening any erosion in that area. So, consequently, several groynes are often needed to stabilise a substantial length of shoreline. Groynes have both negative and positive effects on fish habitats. Whilst their construction is often at the expense of seagrass, they provide good substitutes for natural rocky reef habitats (SPCC, 1981a; Burchmore *et al.,* 1985; Lincoln-Smith *et al.,* 1992). Groynes can interfere with fishing operations, particularly beach hauling. Large numbers of groynes have been placed within Botany Bay (see also under ‘dredging’ above), but in general they are rare or non-existent in most estuaries.

Training walls are used to stabilise estuary entrances. They are constructed with the same material as groynes and have similar implications for fish habitat. Training walls normally ensure that an estuary entrance remains open either permanently, or at least more consistently than would otherwise be the case. They can therefore have far-reaching effects on an estuary’s ecology: essentially they promote greater tidal exchange, which in turn leads to higher salinities and better overall water quality. Larval distributions, patterns of juvenile recruitment, and overall community structure among fish and invertebrates are also likely to be affected due to reduced effective distance from the ocean (Bell *et al.,* 1988; Hannan and Williams, 1998) and by altered salinity regimes and habitat condition. Furthermore, productivity may be reduced due to increased flushing by ocean waters which may lower nutrient concentrations and therefore reduced phyto-plankton numbers. This possibility is partly supported by the findings of Gibbs (1997) who, in an analysis of south coast commercial catch data, found that intermittently open estuaries are frequently more productive (in terms of reported values and weight of finfish and prawn catches) than are permanently open estuaries. Although the above-mentioned effects are potentially very significant, and training walls are present at the entrances of many of the state’s estuaries, there is no clear evidence of any overall negative impact on the Estuary General Fishery.

There are more than 2,500 barriers to river flow, including dams, weirs and floodgates within the freshwater reaches of the major coastal catchments of NSW (Thorncraft and Harris, 2000). On the basis of field observations and or literature review 4,229 structures impeding tidal flow were found in NSW estuaries, with 1,388 considered to have remediation potential (Williams and Watford, 1996). These structures serve various purposes including the supply of drinking and irrigation water, flood mitigation and the improvement of in-stream aesthetics. Dams are the largest of these structures, many being more than 50 metres high. Weirs are essentially low dams and are typically between 0.5 and 5 metres high. Floodgates (also known as ‘tidal barriers’) are specialised structures designed to exclude tides and backed-up floodwaters whilst allowing local runoff to escape. Among the major coastal river systems, the Tweed, Richmond, Clarence, Bellinger, Macleay, Hasting, Hunter, Hawkesbury and

Shoalhaven rivers all have at least 100 barriers of one kind or another (Thorncraft and Harris, 2000). Other in-stream structures that result in at least a partial barrier include road crossings and culverts (Williams and Watford, 1996; NSW Fisheries, 1999b). These structures are quite numerous, particularly in urban and well populated rural areas.

These various barriers can have a range of environmental impacts, the most notable relating to fish passage, environmental flows and thermal (cold water) pollution. These are discussed in the following paragraphs.

Fish passage

Fish passage is the process by which fish move around within their environment (NSW Fisheries, 2000). These movements can be for a variety of reasons including reproduction, feeding and habitat selection. Fish populations subject to restricted passage are likely to suffer reductions in overall distribution, reduced juvenile recruitment, increased predation and/or disease at sites of enforced overcrowding and/or reduced genetic diversity. Even the best possible habitat is of no value to fish if they cannot reach it.

Structures such as dams, weirs, floodgates, culverts and road crossings present a physical barrier that completely or partially blocks fish passage, by creating either a complete break in the aquatic medium, a tight constriction or an impassable current. Partial blockage occurs where a weir or road crossing is low enough for fish to negotiate under high flows, where a culvert admits water at high tide or where a floodgate leaks.

Complete barriers such as dams and high weirs have the most dramatic effects on fish passage. For example, nine species are now locally extinct upstream of Tallowa Dam on the Shoalhaven river (NSW Fisheries, 2000). Within the coastal rivers of NSW, species such as sea mullet, freshwater (pink eye) mullet, Australian bass and Australian grayling have become extinct upstream of major barriers (NSW Fisheries, 2000). Each of these species have life cycles that involve juveniles migrating upstream from estuarine waters (McDowall, 1996), making them particularly vulnerable to such barriers. Whilst the adults may be able to descend some major barriers under certain conditions, they (like the juveniles) cannot return upstream. In fact, only specialised species such as eels and galaxiids are likely to be able to ascend these barriers.

Partial barriers, such as most weirs, can still have dramatic effects on fish populations. Such barriers are generally only passable by upstream-migrating fish when the structure is 'drowned out' by floods. Under these (relatively rare) conditions, fish are able to swim around the structure by keeping close to the waters edge where currents remain weak. The problem is that, within the coastal river systems of NSW, most of the species affected by in-stream barriers have specific seasons for upstream migration, particularly as juveniles (McDowall, 1996) so, any given species, correspondence between the timing of a suitable flood and juvenile migration would be rare: in the case of a particular community of species, it would probably never happen. Furthermore, the suppression of flows by river regulation (as discussed below) has compounded the effects of barriers such as weirs by making them less likely to 'drown out', and by denying many species the environmental cues needed for spawning and migration.

Even relatively modest structures can seriously affect fish passage. Bridges, road crossings, culverts, floodgates and causeways can impede or prevent fish passage because of factors such as excessive water velocity or turbulence, dark passages, sudden drops in water level across the structure, loss of tidal exchange and poor maintenance (Pollard and Hannan, 1994; NSW Fisheries, 1999b;

Williams *et al.*, unpublished data). Small juveniles that recruit to shallow habitats can thus be denied access to creeks, drainage channels, saltmarsh and shallow lagoons. This problem is often compounded by habitat modifications above the barrier. For example, a lack of tidal flushing can result in poor quality water and the loss of mangroves upstream of a structure. Furthermore, if the barrier stops all saline water intrusion, the area above will become freshwater wetland.

Of the species regularly taken in the Estuary General Fishery, only sea mullet regularly travels far into freshwater, and this species would probably be the most affected in terms of spatial extent of habitat lost due to barriers. However, many other commercially important species, including yellowfin bream, tarwhine, luderick, silverbiddy, flat tail mullet and yellowfin leatherjacket might just as seriously be affected in terms of the amount of habitat lost, judging by the results of Pollard and Hannan (1994) and Williams *et al.*, (unpublished data).

Environmental flows

Dams not only block fish passage, they alter natural river flow patterns. In most cases, overall flows are reduced as a consequence of water being removed from the system for drinking supply and/or irrigation. In highly regulated rivers, such as the Hawkesbury-Nepean west of Sydney, only the largest floods are likely to wash down through the whole length of the system. More specifically, dams affect downstream flows in the following ways (NSW Fisheries, 1999a).

- suppression of moderate flows and minor floods, as they are normally taken up by spare capacity in the reservoir rather than allowed to pass downstream
- changes in the seasonal pattern of flows
- reduction in the variability of flows
- increased rates of change in flow volumes due to the sudden ‘switching’ on or off of spillways etc. as reservoir levels change.

Water abstraction also reduces overall stream flows, and consequently the amount of fish habitat available in a stream. ‘Water abstraction’ refers to the manipulation and/or diversion of river flows to supply needs such as irrigation, urban and industrial use, and hydro-electric power generation (NSW Fisheries, 1999a). In eastern NSW, the greatest amount of abstraction is likely to occur in those catchments where dams and weirs are most numerous. According to Thorncraft and Harris (2000), these catchments are those of the Richmond, Clarence, Bellinger, Macleay, Hastings, Hunter, Hawkesbury, Shoalhaven and Bega rivers.

Secondary effects of reduced flows (whether caused by abstraction or dams) may include increased summer water temperatures, alteration of habitat from a running water to a still water environment, and reduction in water quality (NSW Fisheries, 1999a).

Alteration to natural flow regimes are most noted for their effects on freshwater fish communities (Pollard and Growns, 1993; NSW Fisheries, 1999a). However, such changes also affect some estuarine fish and invertebrates. Species that migrate upstream into freshwaters (such as sea mullet and eels) are likely to be affected by a loss of habitat wherever suppressed flows reduce either the area of suitable habitat, or access to such habitat. Sea mullet, in particular, are also more likely to become trapped in freshwater areas (e.g. lagoons and billabongs) under a regulated flow regime, and whilst affected individuals may grow to large sizes, they are prevented from spawning (at sea) and therefore from recruiting to populations. Some species, however, are unable to tolerate low salinities, and may be flushed out of upper estuarine areas during natural flood events. Under such conditions, these species may be rendered more vulnerable to capture by commercial fishers. This is the likely reason behind the association between high catches of school prawns and increases in river discharge (NSW Fisheries, 2000). It follows that any suppression of major discharge events (say as a result of river regulation) may adversely affect estuarine prawn fisheries. Also, the distributions and abundances of a wide range of organisms may be altered because of changed salinities associated with altered flow regimes (Pollard and Growns, 1993). For example, some estuarine species may extend further upstream than before the altered flow regimes. Such changes may have far-reaching food web and community effects, and may therefore also affect commercial fishing.

Unnaturally rapid recession of flood waters, as a result of river regulation (particularly due to large dams), can result in bank slumping (Pollard and Growns, 1993). Sudden drops in water level leave banks saturated with water, but without the support of surrounding floodwaters. The resultant bank collapses release sediment that may then cover fish habitats such as macrophyte beds and snags. Also, banks affected by slumping are left vulnerable to on-going erosion of the exposed sediment. River systems badly affected by sedimentation are likely to provide fewer suitable fish habitats for species such as sea mullet, yellowfin bream, Australian bass and estuary perch.

Thermal Pollution

Water released from the deeper layers of large reservoirs (such as Lake Burragorang on the Nepean River) can be up to 15 degrees cooler than surface waters (Pollard and Growns, 1993; NSW Fisheries, 1999a). Such cold waters have been shown to have profound effects on the distribution and abundance of native fish in coastal and inland river systems, and effects have been noted up to 400 km downstream (Pollard and Growns, 1993; NSW Fisheries, 1999a; Astles *et al.,* 2000). Within estuaries, the possible effects of upstream releases include reductions in juvenile abundance and growth (particularly for species that spend significant amounts of time in upper estuaries, such as sea mullet, eels and school prawns), reductions in abundance of prey, and shifts in community composition (NSW Fisheries, 1999a). Such changes could easily have flow-on effects on commercial fishing, particularly in upper estuarine areas.

iv) Other issues

Sea level rise

Sea level is predicted to rise over the next 40 years (Eliot *et al.,* 1999). For estuarine areas this poses a potentially serious threat as it could result in the loss of fish habitat and numerous fishing areas. The effects of sea-level rise will vary depending upon the type of estuary (drowned river valley to barrier estuary) and whether it is located in a temperate or tropical environment (Dame *et al*., 2000). A study on South African estuaries concluded that sea level rise will increase the occurrence of extreme flood and erosional events (Hughes and Brundrit, 1995). Similar events are likely to occur in NSW estuaries. It is clear from a number of studies that the impacts of sea level rise and its accompanying climatic changes will vary from place to place. In NSW the best predictor of change is an analysis of structure and function of existing estuaries compared to their size and distribution of habitats in the postglacial marine transgression (Roy *et al.,* 2001). The comparison indicates that drowned river valleys may have less shallow habitats while barrier estuaries will have increased shallow habitats. Therefore, it is impossible to predict precisely what impact sea level rise will have in NSW. However, the vulnerability of the Estuary General Fishery to impacts from sea-level will need to be assessed in more detail for each estuary.

Recreational Fishing

Recreational fishing is an increasingly popular past time. The activities of recreational fishers impacts estuarine environments in a number of ways including bait collection (Cryer *et al.*, 1987; Underwood and Kennelly, 1990), trampling (Keough and Quinn, 1998), physical damage to habitats, lost or discarded fishing gear, hook and handling damage of fish and landings of commercial fish species (West and Gordon, 1994). The large numbers of people engaged in this type of fishing suggests that the collective impact of these activities could be quite large.

A management strategy is to be developed for the recreational fishing sector as required under the *Fisheries Management Act 1994*. As part of this an environmental impact assessment is to be done on all aspects of how this fishery may impact the environment and other fishing sectors. Therefore, whilst it is acknowledged that recreational fishing is potentially having a substantial impact on the Estuary General Fishery a comprehensive assessment of these impacts will be given in the environmental impact study of the recreational fishery management strategy.

Aquaculture

Aquaculture in NSW estuaries largely consists of oyster leases and more recently cages for rearing of cultured fish (McGhie *et al.*, 2000). Mather (1993) gives a review of the environmental impact of all types of aquaculture in Australia. For estuaries these include introduced species, alterations to trophic structures, sediment degradation and hydrological modifications (Mather, 1993). Such is the extent of and growth of aquaculture in NSW that the NSW Government has developed the NSW North Coast Sustainable Aquaculture Strategy (2000). This strategy covers all isuues to do with the environmental impacts of aquaculture and includes management responses to mitigate these impacts. Further strategies are being developed for other parts of coastal NSW (D. Ogburn, pers. comm.).

c) Dredging works necessary to maintain access necessary for the fishery activities proposed under the strategy

Dredging specifically to maintain or provide access for vessels used in the Estuary General Fishery is not likely to be required: the vessels are relatively small (usually between 3 to 6 metres) and general navigation dredging (as administered by NSW Waterways, Department of Land and Water Conservation and/or NSW Fisheries) is likely to be sufficient. This dredging is carefully managed, with a range of safeguards to minimise environmental harm (NSW Fisheries, 1999a). Under these present circumstances, there is minimal risk to boats or fisher access of in the Estuary General Fishery.

d) Management measures necessary to limit impacts of external factors

i) Landuse planning and development controls

A wide range of landuse planning and development controls, including controls on infrastructure design and operation, are necessary to minimise the various impacts of external factors to the Estuary General Fishery. These controls need to focus on habitat protection, and must operate within a total catchment management (TCM) framework. The new catchment management boards will be instrumental in the development and on-ground application of these controls. The necessary controls are discussed under the following subheadings.

Urban landuse

Much of the pollution entering the State's estuaries originates from diffuse urban-related sources, and is transported via stormwater. To tackle effectively the serious issue of stormwater runoff from urban areas, a catchment-focused approach is required. In terms of landuse planning and development controls, the following measures are likely to be needed to protect nearby estuaries and their biota:

- provision of sufficient space for stormwater treatment devices (including artificial wetlands)
- preservation or restoration of all natural creek lines, including adequate provisions for protecting/ restoring aquatic habitats and fish passage
- provision of vegetated buffer zones along all creeks (including intermittent) and around all wetlands
- maximum possible use of on-site retention and porous surfaces
- stringent environmental safeguards in relation to all construction and associated works.

The preservation or restoration of natural creeks not only provides fish habitat, it helps in the treatment of runoff. Natural creeks (and properly restored ones) have aquatic vegetation, gravel and detritus to help filter and treat polluted runoff before it reaches an estuary or river. Concrete-lined drains, with their far less quantity of biologically active surfaces and their uninterrupted flows, are much less effective in this way. Riparian vegetation and porous surfaces also help to retard and filter stormwater flows.

Whilst these measures are likely to be very expensive, particularly in existing urban areas, they raise the broader planning issue of how and where people wish to live. Society must recognise the respective environmental costs of increased urban density and of urban expansion, and decide on the best trade-off between these in terms of environmental, social and economic needs. Recognising the pressures for development, particularly along the NSW coast, society must decide to what extent the state's estuaries can support further development in their catchments, and at what cost.

Treatment

Major point sources of pollution (such as an industrial discharge or major sewer overflows) can be addressed by upgraded treatment standards and/or engineering works at specific sites. This has been done successfully in many instances. For example, upgrades to sewage treatment plants along the Hawkesbury-Nepean River since the early 1980s resulted in improved water quality (in particular phosphorus levels) chlorophyll-a concentrations and turbidity (Williams *et al.*, 1993; Kerr, 1994). Also, the recently completed Northside Storage Tunnel and associated works are expected to reduce dramatically sewer overflows into the northern parts of Sydney Harbour. In terms of adequately protecting receiving waters, existing Environment Protection Authority requirements are likely to be sufficient for most point sources.

However, diffuse source pollution is far more difficult to isolate and treat, particularly in urban areas. In rural areas, individual farmers can at least be encouraged to follow best practice with respect to erosion prevention and the use of chemicals such as pesticides and fertilisers. However, in urban areas there are so many sources and individuals involved that it is extremely difficult to rely on education/encouragement alone. Stormwater runoff, in particular, requires a range of prevention and treatment measures to protect nearby estuaries and their biota. These measures are likely to include:

- ppropriate land use and planning controls as outlined above
- on-going community education, with an emphasis on source control
- use of large numbers of relatively small stormwater treatment devices located high in the catchment, rather than a few large devices close to receiving waters or major streams
- provision of artificial wetland(s) so that total area of wetlands (available to retain and treat stormwater) represents at least 3 to 5% of the urban area within the catchment
- adequate provision for the on-going maintenance of all treatment devices.

Whilst past efforts at stormwater treatment have often been focused on the protection of the ultimate receiving waters, councils are increasingly recognising the need to not only protect the main river, lake or estuary, but to also protect the major tributary creeks. However, given the ecological links between even small intermittent creeks and downstream waters (in terms of energy flows and fish passage), even minor creeks should be protected by placing devices higher in the catchment or offline wherever possible.

A fundamental problem is that urban areas, with their high proportion of hard surfaces and plethora of potential pollution sources, represent a highly artificial environment. Furthermore, the volume and rate of surface runoff is greatly enhanced with respect to that from more natural environments, thereby ensuring the rapid and efficient delivery of pollutants to receiving waters. The challenge is therefore to slow the passage of the runoff and its pollutants, so that natural and artificial treatment processes have an opportunity to work. However, to do this effectively is a complex and expensive exercise somewhat analogous to the setting up of a marine fish tank. A small aquarium with some fish and corals may require many hundreds of dollars worth of filtration, skimming and sterilisation equipment to maintain the necessary water quality, while an urban area is likely to require a commensurate expenditure on artificial wetlands and other stormwater treatment devices.

The fish tank analogy:

An urban area is like a crowded fish tank, in that it generates an unnaturally high amount of wastes which then have to be treated by an correspondingly extensive system of purpose-built 'filters' if adequate receiving water quality is to be maintained.

In most cases the required suite of measures, along with the necessary land acquisitions and changes to urban design, are likely to be very expensive. For established urban areas, the above planning and treatment measures could most realistically be considered as a long-term goal. However, for new or expanding areas, much money can be saved by making provisions for these measures in advance. Also, the 'polluter-pays' principle need to be implemented where feasible (NSW Fisheries, 1999a), possibly in the form of the environmental levies that have already been used by some local councils.

Sediments contaminated as a result of past industrial practices pose their own special problems, because they do not normally comply with guidelines for offshore dumping or 'clean fill' and have to be taken to special waste facilities for treatment and/or disposal. Remediation attempts, such as recently undertaken in Sydney's Homebush Bay, are therefore difficult and expensive. In most such cases it is likely that removal of the worst contamination, in conjunction with the capping of the remainder with clean sediment, would be the most feasible option.

Foreshore works, dredging and reclamation

Existing fisheries legislation and policy (particularly the *Fisheries Management Act 1994*, the Policy and Guidelines: Aquatic Habitat Management and Fish Conservation, 1999, and Habitat Protection Plan No. 2: Seagrasses) provide effective means to ensure that current and future works do not unduly affect fish or fish habitats (as discussed above under sections a(i) and b(ii) of this chapter). Specific information to allow foreshore structures to be designed in a way that minimises damage to sensitive habitats such as seagrass is now available (Shafer and Lundin, 1999; Hannan, in prep.). Essentially, jetties and similar structures should be designed to take into account prevailing conditions (such as waves or currents) and, ideally not built where highly sensitive habitats are present.

However, past works (particularly those done before the late 1980s) were not subject to the same degree of control. Some of these earlier works have consequently caused impacts that might not have been accepted today. Also, many works (including some of those undertaken in recent years) have been related to major projects of state or national interest (e.g. the 'Third Runway' in Botany Bay). In these cases, possible habitat protection measures were often constrained by overwhelming social and/or economic considerations, and outright refusals or major modifications based solely on fishery or habitat grounds would have been unrealistic.

Other measures are available to help mitigate the impacts of future works. Of fundamental importance is prior consultation with commercial fishers. Such consultation allows fisher's concerns to be taken into account at an early stage of a project, at which time any suggested changes are more likely to be accommodated. Project planning would also be greatly assisted by an updated documentation of all recognised fishing grounds within NSW estuaries. More specifically, structures such as seawalls and berthing facilities can be designed to provide the best possible fish habitat consistent with their function and reasonable costs. For example, instead of a smooth vertical wall, one with indentations could be used to provide a greater surface area for sessile invertebrates and better opportunities for juvenile fish to hide (Chapman and Blockley, 1999).

Fish passage

Under the *Fisheries Management Act 1994*, NSW Fisheries may order that a fishway be installed on new weirs and dams, or on any that are being repaired or refurbished. NSW Fisheries policy also requires that all proposals for the construction/modification of dams, weirs, floodgates or any other such structure on a waterway be referred to the department for assessment (NSW Fisheries, 1999a). NSW Fisheries has also developed specific policies for addressing fish passage (and other environmental issues) associated with road crossings and related works (NSW Fisheries, 1999b).

Under the NSW Weir Policy, the NSW Government is attempting to reduce the environmental impacts of weirs. In particular, the construction/enlargement of existing weirs is discouraged; weirs no longer serving any useful purpose are to be removed where possible; and owners are encouraged to alter retained weirs to reduce their environmental impact. The State Weir Review Committee oversees the implementation of the policy. The committee has undertaken a comprehensive review of the states weirs and suggested actions for remediating the impacts of these structures.

A number of fishway options suitable for native fish such as mullet and bass have been developed (NSW Fisheries, 1999a, 2000). The best choice for a particular barrier depends on factors such as barrier height, flow rates and the species of fish present. For barriers up to six metres high, the most suitable option is likely to be the 'vertical slot' fishway. This is essentially a series of covered pools, each slightly higher than the last, through which the fish progressively ascend. The pools are linked by narrow vertical openings, through which currents are sufficiently restricted to allow native fish to pass. For low barriers (up to one metre high), a rock ramp fishway with a slope of 1:20 or less may be appropriate. Rock ramp fishways essentially mimic natural riffle zones instead of an impassible single fall, fish are presented with a series of small rocky pools each separated by transverse rock bars and a slight change in water level. Other fishway options, such as Denil fishways, lock systems, trap and transport and by-pass channels may also be suitable in some circumstances. Whilst these fishway types may be less expensive than vertical slot designs, their use in coastal streams remains experimental, and in need of further evaluation. For high barriers such as dams, trap and transport fishways offer the best potential. A system by which fish are attracted, trapped and then pumped through a pipe and over the barrier, is currently being considered for Tallowa dam on the Shoalhaven River. As an interim measure pending fishway construction, NSW Fisheries supports the periodic release of flows to drown-out weirs and other barriers to enable upstream fish passage (NSW Fisheries, 1999a).

In relation to road –related barriers, NSW Fisheries have developed the *Policy and Guidelines for Bridges, Roads, Causeways, Culverts and similar structures 1999* (NSW Fisheries, 1999b), which sets minimum preferred solutions depending on the value of fish habitat affected. In general terms, bridge or tunnel crossings are preferred, particularly where major fish habitat is concerned. Under the Policy and Guidelines where culverts are to be used, large box culverts are preferred to round pipes as the former provide a greater volume of water for fish movement. Also, causeways should be designed so that stream flows and stream widths remain unchanged. In relation to culverts, NSW Fisheries (1999a) provides the following specific guidelines to ensure habitat continuity and therefore assist fish passage:

- The cross-sectional area of the culverts should equal or exceed the cross-sectional area of the stream
- They should be as short as possible, so that dark passages are not created
- They should be as level as possible, so that natural flow velocities are maintained
- Their base should be set into (rather than on) the stream bed so that natural sediments can cover the bottom.

The timing of associated works is also important (NSW Fisheries, 1999b). Wet months should be avoided and every effort should be made to avoid predicted rain events. Also, known migratory seasons should be avoided, for example, juvenile sea mullet are known to recruit to estuaries during winter and spring and are likely to be moving up creeks and rivers during this period (SPCC, 1981b; Hannan and Williams, 1998).

NSW Fisheries is currently developing strategies for the opening regimes for floodgates (NSW Fisheries, 2000). Previous studies (Gibbs *et al.,* 1999) have shown that 'leaky' floodgates allow estuarine (rather than freshwater) habitats to be maintained above the gates as well as allow the recruitment of estuarine fish and invertebrates to these habitats.

Environmental flows

The issue of environmental flows is being addressed as part of the State government's Water Reform Package. The NSW Government has been developed Interim River Flow Objectives for most of the State's catchments. Particular flow issues being addressed include the need to protect low flows, freshes and natural variability and the importance of factors like floodplain connection, rates of rise and fall in river height, groundwater interactions, impact of weirs, estuarine processes and the quality of storage releases (NSW Fisheries, 1999a). Essentially what is needed is the "formal recognition of the environment as a water user" along with support for "changes which allow more water for the environment in over-allocated systems" (NSW Fisheries, 1999a).

Provision of appropriate environmental flows helps to ensure fish passage, water quality and maximum habitat availability. Also, the maintenance of natural rates of fall in river height helps to prevent bank slumping and associated erosion and sedimentation.

Under the Water Reform Package, the state government can also limit future abstraction from sensitive river systems. The placement of an appropriate 'cap' on abstractions from such systems, backed by strategies to reduce water consumption and increase efficiency of use, can help allow for environmental flows. Measures to reduce consumption could include the use of drought-resistant crops, the ongoing education of landholders with respect to current best practice, and the installation of water-efficient irrigation systems. In urban areas, the provision of advisory material to householders can help reduce town water consumption.

Thermal pollution

The release of unnaturally cold water from reservoirs can be avoided by the installation of variable-level offtakes and/or de-stratification by aeration or other mechanical means (NSW Fisheries, 1999a). The big challenge is retro-fitting the necessary works on existing dams. To do this cost-effective engineering solutions need to be further developed (Sherman, 2000). NSW Fisheries has recently held discussions with Department of Land and Water Conservation (DLWC) and State Water on progressing actions to address cold water pollution on State government owned structures.

Release of artificially warmed water from power stations into estuaries can cause a significant drop in species richness and decreased biomass of fish in the vicinity of their outlet works (Scanes, 1988). Solutions such as installing new designs of outfalls which enhance rapid stratification have been considered (Scanes, 1988).

Acid sulfate soils and flooding

Authorities are now well aware of issues relating to acid sulfate soils and proponents for developments are invariably required to test for the presence of such soils in areas where they may occur. A series of acid sulfate soil maps has been published by the DLWC. These maps show the risk of acid sulfate soil being present for any particular location in coastal NSW. Protocols such as keeping works shallow and not allowing the ground to dry out have been developed to minimise the likelihood of acid formation in high risk areas. Also, treatment with lime may help to neutralise any acid that forms. Protocols currently being developed for the management of barriers such as floodgates may also play a role in helping to mitigate the impact of chronic acid drainage (NSW Fisheries, 2000).

Major flooding and drainage from the river floodplains, which can result in significant fish kills, were addressed in section 10(a)(iii) of this chapter. Management measures to limit these impacts require coordination with the floodplain management and estuary management programs supported by the DLWC. The Estuary Management Manual currently being revised by DLWC also assists in the future management of these external factors affecting the Estuary General Fishery.

ii) Measures in the draft FMS with regard to fishery practices

A range of fishery practices can be adopted to minimise the impacts of external factors on the Estuary General Fishery. Useful measures include:

- closures of badly affected areas as occurred in the Richmond and Macleay Rivers after the February and March 2001 floods and as provided for in the draft FMS
- protocols to reduce risks to consumers (e.g. temporary closures triggered by particular environmental conditions – as has been done with pipis)
- consultation with commercial fishers to assist them in recognising and avoiding adverse conditions
- education of consumers, emphasising appropriate storage and preparation, and the low risk normally associated with most types of seafood
- fisher representation on boards and committees where decisions are made concerning catchment works and/or landuse liable to affect fish or fish habitats.

11. Data Requirements in Relation to Assessment of Impacts on the Biophysical Environment

a) Data and research

Data and information used to assess the impacts on the biophysical environment were obtained from a variety of sources, primarily state and commonwealth government agencies and peer reviewed scientific publications. Government agencies include the National Parks and Wildlife Service threatened species unit, Environment Protection Authority, Environment Australia and Australian Museum. The reliability of this information is variable. Peer-reviewed scientific publications clearly provide the most robust information for the assessments. The reliability of information from government agencies could range from low-medium to high depending upon the quality of the research that undergirds them. It was not possible to make a detailed assessment of this information. It should be recognised that information on many of the issues relating to impacts on the biophysical environment is not available from any source. The uncertainties associated with the data and assessments of the impacts are due to the gaps in knowledge of the effects of fishing, particularly in reference to the impacts of fishing on threatened and protected species and habitats.

i) Knowledge gaps

There are at least seven areas where we have little or no knowledge regarding the impact of the Estuary General Fishery on the biophysical environment. These are:

- knowledge of fish stocks
- relationship between fish stocks, habitats and biodiversity
- effects of recreational fishing
- effects on trophic structures in estuaries
- effects of different gear types on fish and habitats
- effects of fishing on threatened species
- potential for introduction of disease and foreign species.

The above knowledge gaps are in addition to those discussed in section 1(c) of this chapter. The seven knowledge gap areas are discussed below.

Knowledge of fish stocks

Significant gaps exist in our knowledge of the natural variability of distribution, abundance, mortality and recruitment patterns of the retained species of in the Estuary General Fishery. The most significant amount of information exists for the general ecology of two species of fish, yellowfin bream and sea mullet (Pollard, 1991; Vigona *et al.,* 1998; Gray *et al.,* 2000). But as noted in Chapter E very little else is known of the other retained species. Building a knowledge base on the ecology of the retained species will enable more realistic assessments to be made of the resilience of their populations (Underwood, 1989) to fishing pressure by Estuary General Fishery and other sectors.

Relationship between fish stocks, habitats and biodiversity

The relationship between fish stocks, their habitiats and biodiversity is an extension of the previous knowledge gap. Very little is known about how many of the retained species interact with their habitats, nor even what habitats are important to them. In addition, there are significant knowledge gaps about how retained species contribute to maintaining biodiversity in estuarine environments. Understanding these complex interactions will enable better strategies to be developed to protect threatened habitats, enhance biodiversity and maintain viable stocks of retained species for all fishing sectors.

Effects of recreational fishing

The Estuary General Fishery is one of a number of commercial fisheries in NSW that strongly interacts with recreational fishers because estuaries are among the most accessible and safest places for amateur fishers to fish (Henry and Vigona, 1984). The major proportion of recreational fishing occurs in estuaries and recreational fishers will often target the same species as does the Estuary General Fishery. For example, West and Gordon (1994) reported that recreational fishers in the Richmond River harvested yellowfin bream, dusky flathead and tailor in substantially greater quantities than commercial fishers in the same estuary. Given the large overlap between the two fishing sectors, there is substantial potential for there to be major effects of recreational fishing on retained species in estuaries (Lal *et al.,* 1992). Lack of knowledge concerning the magnitude, frequency and extent of the effects of recreational fishing inhibits our ability to develop effective management responses.

Effects on trophic structure within estuaries

Very little is known of the trophic structure within estuaries and the effects the Estuary General Fishery has on this. Given the extent over which fishing occurs in estuaries, trophic structures may be affected at several spatial and temporal scales but little is known specifically on what these affects are. Studies overseas have shown a number of effects on trophic structure that have been caused by commercial fishing (Dayton *et al.,* 1995). For example, large removals of schooling prey result in wider dispersal of these species increasing the difficulty for predators to capture their prey (Murphy, 1980). Other trophic changes could occur by substantially reducing the abundance of major algal feeders which could have effects on benthic habitats such as overgrowth by algae (Hatcher *et al.,* 1989). It is not known whether the magnitude of catches of certain species are substantial enough to affect biodiversity in some estuaries. Lack of understanding of the interactions between different trophic levels and the Estuary General Fishery adds to the uncertainty in the risks associated with the fishery.

Effects of different gear types on fish and habitats

There are few comprehensive studies that specifically test the effects of different fishing gears used in the Estuary General Fishery on fish (Broadhurst *et al.,* 1997; Broadhurst *et al.,* 1999; Gray *et al.,* 2000). For example, after hauling or meshing, discarded finfish (such as juveniles of commercial species) can suffer fin or scale damage making them susceptible to disease (Broadhurst *et al.,* 1999; Gray *et al.,* 2001). However, effects of gear on habitats has received relatively little attention for NSW estuaries. Some methods of fishing in the Estuary General Fishery not only affect mobile species but also potentially affect benthic flora and fauna in estuaries. Different forms of hauling and seining can affect the seabed by disturbance of the upper layer, damage or removal of epibenthos and macroalgae and damage to seagrassess. Apart from a study on the effects of hauling over seagrass (Otway and Macbeth, 1999), effects of other gears on seagrass and on other habitats in NSW estuaries have not been studied. Lack of knowledge of these effects contributes to the uncertainty of the effectiveness associated with the management strategy's input controls on gear types and usage. Therefore, it will be essential to understand the magnitude and extent of the effects of gear types on fish and habitats in order to determine more appropriate input controls on the Estuary General Fishery to maintain biodiversity within estuaries.

Effects of fishing on threatened species

There is currently little scientific data on the interaction between fishers and threatened species in the Estuary General Fishery. Despite the increasing awareness by the general public and the listing of numerous threatened species under several Acts (e.g. *Fisheries Management Act 1994*; *Threatened Species Conservation Act 1995*), little effort has been directed at understanding the effects of commercial fishing on these species. A lack of knowledge in this area seriously restricts our ability to make reliable predictions about the impacts of the proposed harvest strategy of the draft FMS on threatened species, or whether the management responses designed to protect threatened species and populations will be effective.

Potential for introduction of disease

Our understanding of the potential for the introduction of disease through imported bait products is limited. Given the recent outbreaks of a herpesvirus in the wild pilchard populations in southern Australia (Whittington *et al.*, 1997) this lack of knowledge poses a risk to the effectiveness of the draft FMS.

ii) Research assessment

All six of the proposed research areas potentially include the knowledge gaps outlined above (Table F16), with two exceptions: the potential for introducing diseases; and effect of recreational fishing. The former knowledge gap is more likely to be better addressed by another government department or organisation such as Center for Research on Introduced Marine Pests. But a process of communication between such groups needs to be acknowledged and established to ensure the issues, results and recommendations of research areas inform the on-going implementation of the draft FMS.

The latter knowledge gap, effect of recreational fishing, is not explicitly mentioned in the proposed research of the draft FMS. Theoretically it could be covered under effects of fishing methods but it would need to be explicitly identified as a need. The effect of recreational fishing on fish stocks and the environment is part of a wider issue of the interaction between other fishing sectors and their effects on fish stocks and the environment. For example, estuarine prawn species, such as school prawns, are fished by two estuarine commercial fisheries (estuary general and estuary prawn trawl) and also by recreational fishers in large quantities. These interactions could have a substantial effect on the estuarine environment as well as the prawn stocks themselves. There are no proposed research programs in the draft FMS that deal with these interactions and their effects. Clearly, a coordinated approach across fishing sectors is required to identify specific knowledge gaps and research needs.

Table F16. Summary of knowledge gaps and the research areas that can address them.

	Research Area					
Knowledge gap	**Stock assessments**	**Quantification of and reduction of bycatch and discards**	**Effects of fishing methods on habitats**	**Effects of habitats on fish populations**	**Impacts of fishing on trophic interactions and ecosystems**	**Impacts of fishing on threatened species**
Fish stocks	√					
Relationship between fish stocks, habitats & biodiversity			√	√		
Effects of recreational fishing			√		√	
Effects of trophic structures in estuaries					√	
Effects of different gear types on fish and habitats			√			
Effects of fishing on threatened species		√			√	√
Potential for introduction of disease and foreign species		√				

In designing projects within each research area, specific knowledge gaps will need to be articulated and addressed. For example, research into stock assessments will need to focus on aspects of the ecology of fish stocks, such as habitat use, juvenile mortality, feeding habits, life cycles etc, as well as traditional stock assessment information to fill knowledge gaps on the basic ecology of these species. Moreover, the interlinkage of research areas needs to be recognised and built into the research programmes. For example, research into the effects of fishing methods on habitats will need to use the outcome of research into the effects of habitats on fish populations in order to identify what habitats are important to target in the research. In addition, some knowledge gaps could be addressed by more than one research area depending upon the issue (Table F16). These linkages between research areas in addressing knowledge gaps on the impact on the biophysical environment will need to be clearly identified and addressed.

As in Chapter E section 4 it is difficult to assess the sufficiency of the research proposed as there are few details as to what specific research will be done, over what spatial and temporal scales, who it will be done by and the specific null hypotheses to be tested by the research. However, overall research needs are being discussed and prioritised (see Chapter C) and further details on the research programs will be available after this has process has been completed in 2002.

b) Performance and monitoring

i) Performance indicators and trigger points

Performance indicators relating to impacts of the fishery on the biophysical environment relate specifically to Goals 1 and 3. These indicators and their trigger points seem appropriate for gauging whether the goals are being met. Further discussion on the performance indicators and trigger points can found in Chapter E section 4 of the EIS.

ii) Monitoring and review

The proposed monitoring and review process for the biophysical environment is similar to that for the fishery resource, with two exceptions: monitoring for captures of threatened species; and reports of marine pests and disease. These monitoring programs depend on groups either outside of NSW Fisheries (e.g. NPWS) or in another division of NSW Fisheries, i.e. Office of Conservation. In order for these monitoring programs and consequent reviews to occur, a deliberate pathway or process between these groups will need to be made explicit. Such a process is suggested in the monitoring program but not elaborated upon. Clear communication between and within government departments will be essential for the proposed monitoring programs to be effective.

c) Relationship between research, performance indicators and review

The relationship between research and review has been discussed in Chapter E section 4(c). The same principles identified in that section are equally important to impacts on the fishery.

d) Timetable for developing information

The implementation timetable for research and monitoring is as set out in Chapter C section 4 of the draft FMS under each management response. However, a precise timeframe cannot be finalised for the research projects until priorities have been agreed to by all stakeholders.