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Table 1. Classification scheme for watercourse crossings over fish habitat types (Source: NSW Fisheries, 1999a).

Classification	Characteristics of Watercourse Type	Minimum Preferred Engineering Solutions
Class 1 – Major fish habitat	Large named permanently flowing stream, creek or river. Threatened species habitat or area of declared “critical habitat” under the threatened species provisions of the Act. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge or tunnel crossing only. Prefomed spans or arches are the preferred option (up to 30 m width of stream) to minimise instream construction impacts.
Class 2 – Moderate fish habitat	Smaller named permanent or intermittent stream, creek or watercourse. Clearly defined drainage channels with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and / or fish observed inhabiting the area.	A large box culvert or a bridge crossing. Cross-sectional area of structure should aim to equal the cross-sectional area of the watercourse.
Class 3 – Minimal fish habitat	Named or unnamed watercourse with intermittent flow, but has potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). None to minimal defined drainage channel. Semi-permanent pools, ponds, farm dams or wetlands nearby or form in the watercourse after a rain event. Watercourse interconnects wetlands or stream habitat.	Culverts required and designed to allow fish passage. Invert should be designed to ensure it is below the bed level of the watercourse, and that ponding can occur.
Class 4 – Unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event finishes (e.g. dry gully, shallow floodplain depression with no permanent wetland aquatic flora present). No aquatic or wetland vegetation present.	Causeway, floodway or culvert with allowance for flow of water to downstream areas unhindered.

Table 2a: Comparison of waterway grades (NSW Fisheries 1999b) assigned to each waterway in the study area by The Ecology Lab and NSW Fisheries (S. Fairfull). NA = Waterway not assigned a grade.

Waterway	Location	Grade	Assigned	Structure
(Arup 1a)	Unnamed	3/4	NA	8' x 4' culvert
(Arup 2)	Unnamed	3/4	NA	8' x 4' culvert
3b	Stewarts River Rd; existing highway	3	2	3 x 2.4 m box culverts
4b	Existing highway	3	NA	2 x 2.4 m box
6b	Stewarts River; existing highway	1	1	Bridge
7	Yaralin	4	NA	2 x 0.5m pipes
8	Passionfruit Gully	3	2	3 x 2.4 m box
9	750m N of Algona Rd	4	NA	3 x 0.5 m pipes
10	200m S of Haydons Rd	4	NA	2 x 1 m pipes
11	Stony Ck	2	2	Bridge
12-15	S of Ross Glen Rd	4		1 m pipe
16	Camden Haven River; existing highway	1	1	Bridge
17	Christmas Hill	4	NA	2 x 1.8 m pipes
20a	Walkers Creek	2	2	2 x 2.4 m box
22a	Small tributary of Herons Creek	3	NA	2 x 2 m box culvert
22b	Herons Creek	1	2	Bridge

Table 2b: Description of aquatic habitats in waterways surveyed by The Ecology during the EIS phase, November 2001.

Location	Descriptions
Stewarts River	<p>Class 1 watercourse which was crossed by a single span bridge at the existing highway. At the crossing, the wetted width of the channel was approximately 25m wide and averaged about 1.5 deep. Banks of the river were moderately sloping. The banks were generally consolidated by <i>Eucalyptus</i> spp., <i>Casuarina</i> spp., <i>Lantana</i>, <i>Juncus</i> spp. and <i>Lomandra</i> spp.. Beyond the riparian zone, the channel was surrounded mostly by pasture. Numerous snags (mostly logs) were scattered through the channel. Clarity of water was rated good. About 500 m upstream of the crossing, a weir constructed of loose earth and rubble separated estuarine from freshwater habitat.</p>
Passionfruit Gully	<p>A Class 3 watercourse which was crossed by 3 box culverts at the existing highway. Channel was gently incised at the crossing with a wetted width of approximately 3m. Substratum comprised sands and silts. Small pools of standing water on the downstream side of the existing highway. No pools of standing water upstream of the crossing. Instead, channel was choked with <i>Bolboschoenus fluviatilis</i>, <i>Typha</i> spp., <i>Juncus</i> spp. and crofton weed. A small farm dam upstream of the road reserve may form a barrier to fish passage. Riparian vegetation within the road reserve had mostly been cleared. Catchment to the west of the road reserve was devoted to pasture. To the east of the road reserve, the riparian vegetation appeared relatively undisturbed.</p>
Stony Creek	<p>A Class 2 watercourse which was crossed by a single span bridge. The channel was incised at the crossing, with relatively steep sloping, but well vegetated banks. The wetted width of the channel was approximately 8m. Most of the catchment above the crossing was devoted to pasture. As such, riparian vegetation along this reach of river was patchy. Sections of river bed were dry upstream of the crossing. Where there were hollows in the creek bed, pools of water had collected. Substratum comprised mostly cobble and pebble sized rock material.</p>
Camden Haven River - Existing Crossing	<p>Class 1 waterway in excess of 100 m wide. The river was crossed at the existing highway via a bridge with several piles. The surrounding catchment was flat and devoted to pasture. Upstream of the crossing, the southern foreshore of Camden Haven River was afforded less protection from bank collapse by the removal of riparian vegetation. The northern foreshore, however, was lined by trees and shrubs including Casuarinas, Eucalypts and Lantana which appeared to provide greater consolidation to the riverbank. Stands of <i>Phragmites australis</i> and <i>Juncus</i> spp. were scattered throughout the littoral zone up- and downstream of the crossing. A few mangrove saplings were also scattered along the foreshore immediately upstream of the existing crossing. A patch of seagrass (<i>Zostera capricorni</i>) was located about 200 m downstream of the crossing, on a sandy shallow flat of the southern shoreline. This reach of waterway was also inhabited by mature mangroves along the southern shoreline.</p>

Continued

Table 2b. Cont'd.

Location	Descriptions
Camden Haven River - KA Option	<p>The K-A option was located approximately 5 km upstream of the existing crossing. The confluence between Camden Haven River and an un-named waterway designated the crossing or middle of our three sites. The catchment surrounding the river was gentle sloping and devoted to pasture. The river was in excess of 80 m wide. The riparian vegetation mostly comprised camphor laurels. The banks of river were relatively steep and there was some bank undercutting and bank slumping at all three sites.</p>
Walkers Creek	<p>Class 2 waterway crossed by 2 box culverts. A clearly defined channel with a wetted width of about 3 m. Shallow pools were interspersed amongst beds of macrophytes, which including <i>Triglochin</i> spp., <i>Typha</i> spp. and <i>Juncus</i> spp.</p>
Herons Creek	<p>Class 1 waterway which was crossed via a multi-span bridge. Channel was about 8 m wide and in excess of 1 m deep. Banks of the creek were relatively steep but well vegetation with native and introduced trees and shrubs</p>

Table 3: List of scheduled aquatic species, populations, communities or threatening processes under the *Fisheries Management* (FM) Act (1994) and *Threatened Species Conservation* (TSC) Act (1995) as of February 2003. Those species that are "to be considered" relevant to the proposal.

Scheduled category or species	Common name	Act	Relevance to the proposal
Endangered Species:			
Fish			
<i>Carcharias taurus</i> (Rafineque 1810)	Grey nurse shark	FM	to be considered
<i>Craterocephalus fluviatilis</i> (McCulloch 1913)	Murray hardyhead	FM	not relevant
<i>Maccullochella ikei</i> (Rowland)	Eastern freshwater cod	FM	not relevant
<i>Maccullochella macquariensis</i> (Cuvier)	Trout cod	FM	not relevant
<i>Nannoperca oxleyana</i> (Whitley)	Oxleyan pygmy perch	FM	not relevant
<i>Pristis zijsron</i> (Bleeker 1851)	Green sawfish	FM	to be considered
Invertebrates			
<i>Notopala sublineata</i> (Conrad 1850)	River snail	FM	not relevant
Endangered Populations:			
Western pop. of <i>Mogurnda adpersa</i> (Castlenau 1878)	Purple spotted gudgeon	FM	not relevant
Western pop. of <i>Ambassis agassizii</i> (Steindachner 1866)	Olive perchlet	FM	not relevant
Manly Pt. pop. of <i>Eudiptula minor</i> (Forster 1781)	Little Penguin	TSC	not relevant
Endangered Ecological Communities			
Coastal Saltmarsh of the North Coast, Sydney Basin and Bioregion	-	TSC	to be considered
Vulnerable Species:			
Fish			
<i>Bidyanus bidyanus</i> (Mitchell 1838)	Silver perch	FM	not relevant
<i>Carcharodon carcharias</i> (Linnaeus 1758)	Great white shark	FM	to be considered

Cont'd

Table 3. Continued

Scheduled category or species	Common name	Act	Relevance to the proposal
<i>Epinephelus daemeli</i> (Gunther 1876)	Black cod	FM	to be considered
<i>Macquaria australisica</i> (Cuvier 1830)	Macquarie perch	FM	not relevant
<i>Nannoperca australis</i> (Gunther 1861)	Southern pygmy perch	FM	not relevant
Key Threatening Processes:			
Introduction of fish to freshwaters in a river catchment outside natural range	-	FM	not relevant
Removal of large woody debris	-	FM	to be considered
Degradation of native riparian vegetation along NSW water courses	-	FM	to be considered
Installation and introduction of instream structures and other mechanisms that alter natural flow regimes of rivers and streams	-	FM	to be considered
Predation by <i>Gambusia holbrooki</i> (Girard 1859)	Mosquito fish	TSC	to be considered

Table 4a: Records of commercial catch for the Camden Haven River area between 1993/94-1998/99. (source: NSW Fisheries 2000a; 2000b).

Year	Catch (t)	Value (\$'000)	No. of Fishers	No. Days Effort
1993/94	146	479	32	5029
1994/95	138	481	36	4849
1995/96	121	447	32	4858
1996/97	140	639	42	6318
1997/98	155	673	35	6495
1998/99	175	673	32	6449

Table 4b: Oyster production statistics for the Camden Haven River for the years 1994/95-1996/97 and 1999/00. (Source : NSW Fisheries undated)

Year	Total Production		Total value (\$)
	Bags	Dozens	
1994/95	1906	211,336	592,200
1995/96	977	105,610	336,361
1996/97	1259	139,070	431,626
1999/00	1411	155,430	601,735

Table 5: Mean (+/- standard error) number of individuals of each species per a) bait trap and b) gill net at each site in Stewarts River and Camden Haven River during November 2001. (* Species of economic importance), CHR = Camden Haven river, SR = Stewarts River.

Family name	Common name	Scientific name	CHR - K-A Option						CHR - Existing Crossing						SR							
			Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Total	% contrib.									
a) BAIT TRAPS																						
FISH																						
Ambassidae	Ramsey's perchlet	<i>Ambassis marianus</i>	0.60	0.34	0.20	3.90	3.68	0.10	0.10	1.60	0.91	3.30	1.37	0.00	0.40	2.20	1.77	123	4.2			
Ambassidae	Port jackson perchlet	<i>Ambassis jacksonensis</i>	6.90	4.62	2.50	2.28	5.70	3.00	0.60	29.80	12.55	29.20	22.17	0.30	1.60	5.80	2.24	824	28.0			
Eleotridae	Empire gudgeon	<i>Hypseleotris compressa</i>	5.60	4.19	5.80	2.54	0.70	0.33	0.00	0.10	0.10	0.80	0.42	7.60	2.02	4.40	1.87	12.80	4.26	378	12.8	
Eleotridae	Flathead gudgeon	<i>Platyphodon grandiceps</i>	0.20	0.13	0.20	0.13	0.70	0.40	0.00	0.00	0.00	0.00	0.00	0.20	0.13	0.10	0.10	0.10	15	0.5		
Eleotridae	Striped gudgeon	<i>Gobionomphalus australis</i>	0.80	0.25	0.40	0.22	0.50	0.22	0.10	0.10	0.10	0.10	0.10	0.20	0.13	0.40	0.22	0.70	0.40	32	1.1	
Gobiidae	Large-mouth goby	<i>Redgobius macrostoma</i>	0.10	0.10	0.00	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	5	0.2		
Mugilidae	Flat-tail mullet*	<i>Liza argentea</i>	0.30	0.15	12.40	10.36	6.50	19.70	8.82	10.20	9.65	11.80	6.11	19.10	19.10	0.80	0.70	0.00	0.00	808	27.4	
Mugilidae	Sand mullet*	<i>Myxus elongatus</i>	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.0		
Pseudomugilidae	Pacific blue-eye	<i>Pseudomugil signifer</i>	0.40	0.22	14.50	11.64	15.70	13.72	1.70	1.10	1.80	1.12	6.70	5.83	2.80	1.40	0.65	1.40	0.98	464	15.8	
Spanidae	Tarwhine*	<i>Rhabdosargus sarba</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.13	0.00	0.00	0.00	0.00	0.00	2	0.1		
Spanidae	Yellow-finned bream*	<i>Acanthopagrus australis</i>	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.60	0.22	1.40	1.08	0.00	0.00	0.10	0.10	0.10	23	0.8		
Tetraodontidae	Smooth toadfish	<i>Tetraodon glaber</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	1	0.0		
INVERTEBRATES																						
Caridae	Canid shrimp	<i>Palaemonidae</i>	0.20	0.13	0.10	0.10	0.00	0.00	2.10	0.48	3.80	1.79	9.60	3.66	3.30	1.64	5.40	2.46	2.10	1.49	266	9.0
Penaeidae	Greasy back prawn*	<i>Metapenaeus bennettiae</i>	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3	0.1	
Summary Statistics			850						1363						735							
Total abundance			9						13						10							
Total no. economic species			2						5						3							
Economic ind. as % of total abundance			35						40						59							
b) GILL NETS																						
FISH																						
Clupeidae	Southern herring*	<i>Herklotsichthys castelnaui</i>	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	3.4		
Gerreidae	Silver biddy*	<i>Gerrus subfasciatus</i>	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6	10.2		
Girellidae	Luderick*	<i>Girella tricuspidata</i>	0.33	0.33	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	4.00	2.65	0.33	0.00	0.00	18	30.5		
Monodactylidae	Diamondfish	<i>Monodactylus argenteus</i>	0.67	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	3.4		
Mugilidae	Flat-tail mullet*	<i>Liza argentea</i>	0.00	0.00	0.00	1.33	0.88	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6	10.2		
Mugilidae	Sea mullet*	<i>Mugil cephalus</i>	0.33	0.33	0.00	0.67	0.33	1.67	1.20	0.33	0.33	1.00	0.00	0.67	0.33	0.00	0.33	0.33	15	25.4		
Scatophagidae	Striped scat	<i>Scalenotoca multifasciata</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	1	1.7		
Scorpaenidae	Bullrout	<i>Notesthes robusta</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	1.7		
Sillaginidae	Trumpeter whiting*	<i>Sillago maculatus</i>	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	1.7		
Spanidae	Tarwhine*	<i>Rhabdosargus sarba</i>	0.33	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3	5.1		
INVERTEBRATES																						
Portunidae	Mud crab*	<i>Scylla serrata</i>	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4	6.8		
Summary Statistics			23						20						16							
Total abundance			7						6						2							
Total no. economic species			6						5						2							
Economic ind. as % of total abundance			91						90						100							

Table 6: Two 2-way nested Analysis of Similarity (ANOSIM) results comparing fish assemblages among locations and sites within locations.

a) Bait traps (n= 10)			Fourth root transformations
Factor	Permtations	Global R	P
Location	280	0.506	0.011
Site(Location)	999	0.079	0.011

b) Gill nets (n= 3)			No transformations
Factor	Permtations	Global R	P
Location	280	0.202	0.175
Site(Location)	999	0.146	0.147

Note: Whilst there were significant differences between locations, there were not enough permutations available to differentiate locations using pairwise comparisons.

Table 7: Similarity Percentages (SIMPER) results comparing the relative contribution of various fish species (captured by bait traps) to the dissimilarity of the assemblages at each location. Only those species that appear in the top 90% of cumulative contribution are displayed in these tables.

a) Loc 3 (Stewarts River) and Loc 2 (Camden Haven River - existing crossing) Average dissimilarity = 79.14

Species	Av. Abundance Stewarts River	Av. Abundance Existing crossing	Av. Diss	Diss/SD	Contrib	% Cum%
<i>Hypseleotris compressa</i>	8.27	0.33	17.16	1.45	21.69	21.69
<i>Ambassis jacksoniensis</i>	2.57	22.07	15.18	1.12	19.18	40.87
<i>Liza argentea</i>	6.63	15.44	13.18	0.91	16.66	57.53
<i>Pseudomugil signifer</i>	1.87	3.78	9.61	0.9	12.15	69.67
<i>Ambassis marianus</i>	0.87	1.85	8.25	0.87	10.42	80.09
<i>Acanthopagrus australis</i>	0.07	0.78	6.21	0.7	7.85	87.94
<i>Gobiomorphus australis</i>	0.43	0.07	4.7	0.64	5.93	93.88

b) Loc 3 (Stewarts River) and Loc 1 (Camden Haven River- K-A option) Average dissimilarity = 66.40

Species	Av. Abundance Stewarts River	Av. Abundance K-A option	Av. Diss	Diss/SD	Contrib	% Cum%
<i>Hypseleotris compressa</i>	8.27	4.17	15.29	1.12	23.03	23.03
<i>Ambassis jacksoniensis</i>	2.57	5.21	12.11	1.04	18.24	41.26
<i>Pseudomugil signifer</i>	1.87	10.55	10.32	0.81	15.54	56.8
<i>Gobiomorphus australis</i>	0.43	0.59	8.62	0.85	12.98	69.78
<i>Liza argentea</i>	6.63	6.62	6.58	0.59	9.92	79.69
<i>Ambassis marianus</i>	0.87	1.62	5.42	0.62	8.16	87.85
<i>Philypnodon grandiceps</i>	0.13	0.38	5	0.6	7.54	95.39

c) Loc 2 (Camden Haven River- existing crossing) and Loc 1 (K-A option) Average dissimilarity = 79.90

Species	Av. Abundance Existing crossing	Av. Abundance K-A option	Av. Diss	Diss/SD	Contrib	% Cum%
<i>Ambassis jacksoniensis</i>	22.07	5.21	15.77	1.11	19.74	19.74
<i>Liza argentea</i>	15.44	6.62	13.63	0.96	17.06	36.8
<i>Hypseleotris compressa</i>	0.33	4.17	11.42	0.97	14.3	51.1
<i>Pseudomugil signifer</i>	3.78	10.55	10.02	0.86	12.54	63.63
<i>Ambassis marianus</i>	1.85	1.62	8.63	0.87	10.8	74.44
<i>Gobiomorphus australis</i>	0.07	0.59	7.29	0.81	9.13	83.56
<i>Acanthopagrus australis</i>	0.78	0	6.07	0.67	7.6	91.16

Table 8: Two-way nested Analysis of Variance (ANOVA) results for the bait trap data comparing the means among locations and sites within locations.

a) Bait traps: Total number of species Transform = None Cochrans C = 0.2094, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	10.47	5.23	2.05	0.210	Si(Loc)
Si(Loc)	6	15.33	2.56	1.57	0.166	RES
RES	81	131.80	1.63			
TOT	89	157.60				

b) Bait traps: Total number of fish species Transform = None Cochrans C = 0.1807, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	0.16	0.08	0.03	0.974	Si(Loc)
Si(Loc)	6	17.47	2.91	2.13	0.059	RES
RES	81	110.70	1.37			
TOT	89	128.32				

c) Bait traps: Total number of individuals Transform = None Cochrans C = 0.2372, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	7377.22	3688.61	1.51	0.228	1-POOLED DATA
Si(Loc)	6	11926.13	1987.69	0.81	0.564	1-POOLED DATA
RES	18	201226.70	2484.28			
TOT	26	220530.06				
POOLED DATA	24	213152.83	2450.03			

d) Bait traps: Total number of fish individuals Transform = None Cochrans C = 0.2380, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	5611.67	2805.83	1.20	0.305	1-POOLED DATA
Si(Loc)	6	10015.53	1669.26	0.72	0.638	1-POOLED DATA
RES	18	192978.40	2382.45			
TOT	26	208605.60				
POOLED DATA	24	202993.93	2333.26			

a) Bait traps: Total number of economic individuals Transform = Sqrt(X+1) Cochrans C = 0.2205, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	30.7123	15.3562	1.73	0.1828	1-POOLED DATA
Si(Loc)	6	43.2707	7.2118	0.81	0.562	1-POOLED DATA
RES	18	727.6146	8.9829			
TOT	26	801.5976				
POOLED DATA	24	770.8853	8.8608			

Table 8: Cont...

f) Bait traps: Total number of carid shrimp Transform = Ln(X+1) Cochrans C = 0.2592, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	22.94	11.47	11.02	0.010	Si(Loc)
Si(Loc)	6	6.24	1.04	1.44	0.209	RES
RES	81	58.44	0.72			
TOT	89	87.63				
SNK:	K-A option < Stewarts River = Existing crossing (see figure 5a)					

g) Bait traps: Total number of empire gudgeon Transform = Ln(X+1) Cochrans C = 0.2079, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	36.21	18.10	11.16	0.010	Si(Loc)
Si(Loc)	6	9.73	1.62	2.12	0.059	RES
RES	81	61.84	0.76			
TOT	89	107.77				
SNK:	Existing crossing = K-A option < Stewarts River (see figure 5b)					

h) Bait traps: Total number of flat-tail mullet Transform = Ln(X+1) Cochrans C = 0.1968, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	14.55	7.28	4.04	0.021	1-POOLED DATA
Si(Loc)	6	11.26	1.88	1.04	0.403	1-POOLED DATA
RES	18	145.29	1.79			
TOT	26	171.10				
POOLED DATA	24	156.55	1.80			
SNK:	Stewarts River = K-A Option < Existing crossing (see figure 5c)					

i) Bait traps: Total number of pacific blue-eye Transform = Ln(X+1) Cochrans C = 0.2519, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	0.06	0.03	0.02	0.977	1-POOLED DATA
Si(Loc)	6	2.58	0.43	0.33	0.918	1-POOLED DATA
RES	18	109.48	1.35			
TOT	26	112.12				
POOLED DATA	24	112.06	1.29			

j) Bait traps: Total number of Port Jackson perchlet Transform = None Cochrans C = 0.7120, (P < 0.01)

Source	DF	SS	MS	F	P	F versus
Loc	2	5254.02	2627.01	3.36	0.039	1-POOLED DATA
Si(Loc)	6	5838.60	973.10	1.25	0.291	1-POOLED DATA
RES	18	62131.20	767.05			
TOT	26	73223.82				
POOLED DATA	24	67969.80	781.26			

Table 9: Two-way nested Analysis of Variance (ANOVA) results for the gill net data comparing the means among locations and sites within locations.

a) Gill nets: Total number of fish species Transform = None Cochrans C = 0.4565, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	7.41	3.70	2.27	0.125	POOLED DATA
Si(Loc)	6	8.44	1.41	0.86	0.535	POOLED DATA
RES	18	30.67	1.70			
TOT	26	46.52				
POOLED DATA	24	39.11	1.63			

b) Gill nets: Total number of fish individuals Transform = None Cochrans C = 0.4551, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	3.63	1.81	0.28	0.761	POOLED DATA
Si(Loc)	6	46.00	7.67	1.17	0.355	POOLED DATA
RES	18	111.33	6.19			
TOT	26	160.96				
POOLED DATA	24	157.33	6.56			

c) Gill nets: Total number of economic individuals Transform = SQRT(X+1) Cochrans C = 0.4419, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	0.32	0.16	0.43	0.652	POOLED DATA
Si(Loc)	6	2.87	0.48	1.28	0.303	POOLED DATA
RES	18	6.08	0.34			
TOT	26	9.28				
POOLED DATA	24	8.95	0.37			

d) Gill nets: Total number of luderick Transform = None Cochrans C = 0.4551, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	8.67	4.33	0.83	0.481	Si(Lo)
Si(Loc)	6	31.33	5.22	1.88	0.140	RES
RES	18	50.00	2.78			
TOT	26	90.00				

e) Gill nets: Total number of sea mullet Transform = Ln (x+1) Cochrans C = 0.4487, N.S.

Source	DF	SS	MS	F	P	F versus
Loc	2	0.66	0.33	1.97	0.162	POOLED DATA
Si(Loc)	6	1.15	0.19	1.13	0.374	POOLED DATA
RES	18	2.91	0.16			
TOT	26	4.72				
POOLED DATA	24	4.05	0.17			

Table 10: List of fish species recorded electrofishing by The Ecology Lab during November 2001 in waterways that will be crossed by the proposed highway upgrade between Moorland and Herons Creek on the mid north coast of NSW. In those watercourses with box culverts, where possible sampling was done up- and downstream of the culvert to allow an assessment of the impact this crossing has on fish passage in this waterway.

Family	Species	Common name	Watercourse Exist. Structure Position	Stewarts River		Passionfruit Gully		Stony Creek		Walkers Ck		Herons Ck	
				Single span bridge	Box culvert	Box culvert	Within	Single span bridge	Box culvert	Up	Down	Box culvert	Single span bridge
Fish													
Angillidae	<i>Anguilla reinhardtii</i>	Long-finned eel		✓		✓		✓					✓
	<i>Anguilla australis</i>	Short-finned eel						✓		✓			
Galaxidae	<i>Galaxias maculatus</i>	Common jollytail			✓								
	<i>Gambusia holbrooki</i>	Mosquito fish			✓								
Eleotrididae	<i>Gobiomorphus australis</i>	Striped gudgeon		✓		✓		✓		✓			✓
	<i>Hypseleotris compressa</i>	Empire gudgeon		✓		✓		✓		✓			✓
	<i>Hypseleotris galii</i>	Firetailed gudgeon				✓							✓
Macroinvertebrates													
	<i>Atya striolata</i>	Mohawk shrimp											✓

✓ = species recorded

Note sampling in Stewarts River was not done at the existing crossing but in freshwater habitat above a weir at Bulley's Rd crossing.

Up = upstream of road corridor

Down = downstream of road corridor

Table 11: Summary of water quality data in comparison to the ANZECC (2000) Guidelines for the protection of aquatic ecosystems. ANZECC range for each parameter is in brackets. - Satisfactory; ↑ Too high; ↓ Too low; ND No data.

	Camden Haven River												Stewart's River																							
	K-A Options						Existing Crossing						Mouth						Airport						Existing Crossing						Jali					
	S1		S2		S3		S4		S5		S6		S7		S8		S9		S10		S11		S12													
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3												
River surface																																				
pH (7-8.5)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
Turbidity (NTU) (0.5-10)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
DO (%) (80-110)	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓											
River bottom																																				
pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
DO (%)	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓											
b) Freshwater																																				
Location	Herons Creek						Walkers Creek						Stony Creek						Passionfruit Gully																	
Site	S13		S14		S15		S16																													
River surface	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2										
pH (6.5-8.0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										
Turbidity (NTU) (5-60)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										
DO (%) (85-110)	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓										
Conductivity (us/cm)(125-2200)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										

Table 12: Summary of mitigative measures to assist during the planning and construction phases of the project to protect aquatic habitats and biota.

Issue	Mitigation
Fish Passage	For Class 3 waterways, crossings which employ box culverts are preferred to pipe culverts. Culverts should be set into the creekbed to match the cross-sectional width of the waterway. Where are bridge crossings are to built across Stewarts River, Stony and Herons Creek, piers that are set into the riverbed should avoid the low-flow area.
Riparian Vegetation	Where possible, bridge abutments should be set back behind the high bank. If riparian vegetation is to be removed or trimmed during construction, NSW Fisheries prefer the "cut stump" method.
Erosion and Sedimentation	Develop site specific Erosion and Sedimentation Control Plans - these to outline soil erosion measures used in and surrounding waterways. These measures are designed in accordance with the "Blue Book" developed by the Department of Housing (1998) and NSW RTA's Road Design Manual (1993).
Acid Sulphate Soils	Prior to any disturbance of the sediments at the risk area (i.e. near waterways and wetlands), further sampling and testing would be done to quantify the risk of disturbing acid sulphate soils. Develop Acid Sulphate Soil Management Plans (ASSMP) in areas where disturbance to acid sulphate soils would occur. ASSMP to draw on recent NSW RTA experience from other sections of the Pacific Highway Upgrade in developing ways to treat and contain run-off from acid sulphate soils.
Water Quality	When working in areas of erodable and/or acid sulphate soils, monitoring water quality should focus on turbidity and pH levels in the context of background levels in similar habitats elsewhere in the system.
Commercial and Recreational Fishing	In Camden Haven River, commercial and recreational anglers should be able to navigate their vessels up- and downstream through the construction corridor in order to access areas regularly fished in the Camden Haven River.
Threatened Species	Protection of black cod be incorporated into a Construction Environmental Management Plan for the project, including the minimal removal of habitat (i.e. large woody debris), development of Soil and Water Management Plan that identifies best-practice engineering principles and procedures for minimising erosion and sediment inputs and a practical program for monitoring water quality in Camden Haven River when bridge piling/drilling activities are done in the river.
Key Threatening Processes	Snags (large woody debris) that are removed during site preparation for construction of waterway crossings should be stockpiled during construction and returned to near their pre-disturbance positions on completion of works. Areas adjacent to waterways that are cleared of riparian vegetation to allow access for people and machinery should be revegetated on completion of the construction works.

FIGURES

Figure 1: Map of study area showing sampling sites for fish and water quality in November, 2001. Purple line indicates preferred route option. Blue squares = Water Quality, Red triangles = Electrofishing, Bait trapping and Water Quality, Green circles = Gill netting, Bait trapping and Water Quality. Refer to Tables 1,4,9 and 10 for results.

Figure 2: Sampling design for the bait trap, gill net and water quality surveys, November 2001 (Bait trap $N = 90$; gill net $N = 27$; water quality river surface $N = 18$; water quality river bottom $N = 18$).

Figure 3: Map of Camden Haven Estuary which shows position of oyster leases in 1992. The red dots indicate the approximate location where new crossings would be constructed across waterways in the study area. (Source of Map; Carter 1995).

Figure 4: nMDS of fish assemblages captured in bait traps at each location and site at Camden Haven River and Stewarts River during November 2001. (Stress = 0.15)

Figure 5: nMDS of fish assemblages captured in gill nets at each location and site at Camden Haven River and Stewarts River during November 2001. (Stress = 0.06)

Figure 6: Mean abundances per bait trap at each location in Camden Haven River and Stewarts River during November 2001 ($n = 30$).

Figure 7: Mean (+/-SE) values for water quality parameters at each location in Camden Haven River and Stewarts River in November 2001. ($n = 9$) --- = ANZECC (2000) Guidelines for the protection of aquatic habitats.

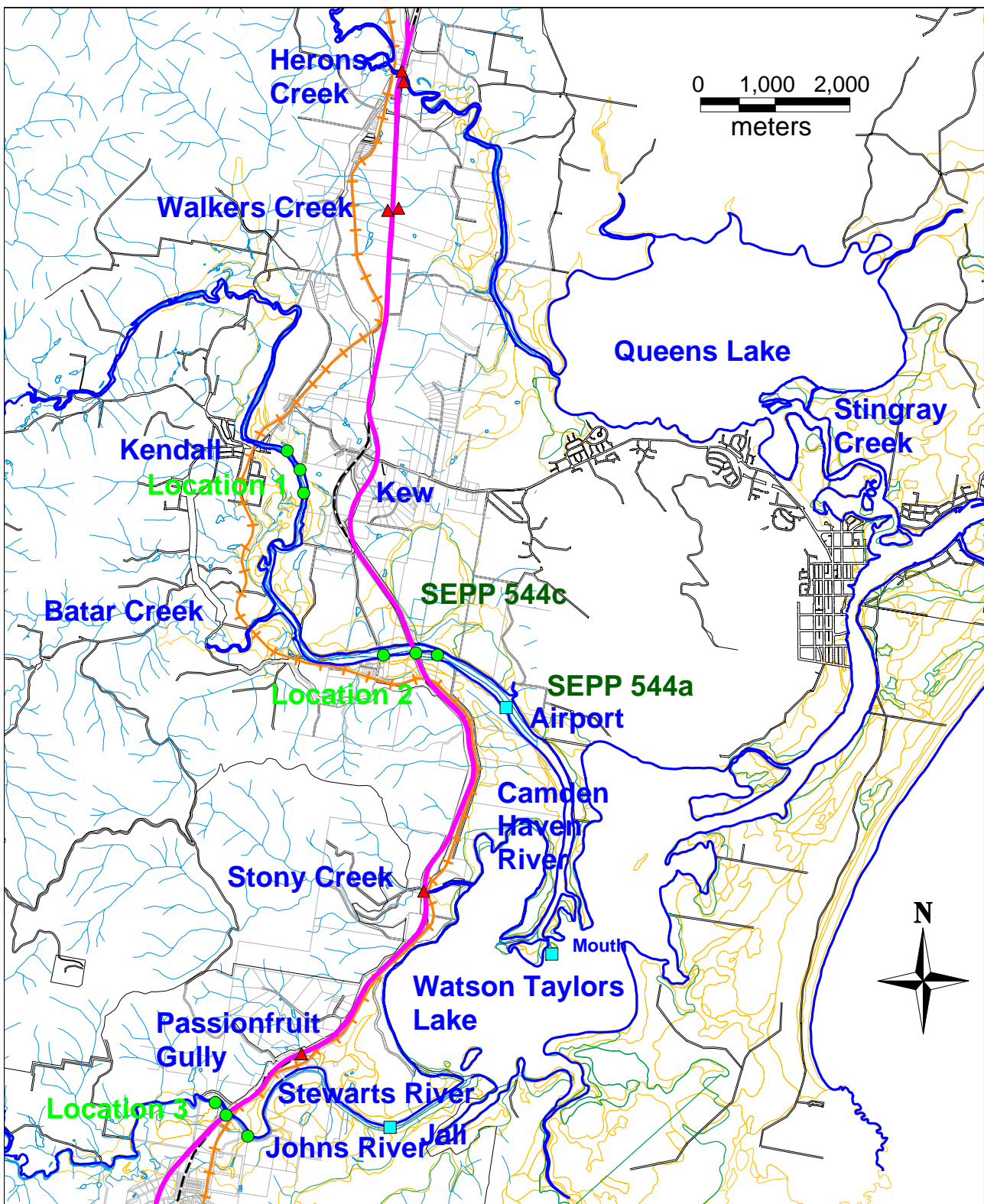


Figure 1. Map of study area showing sampling sites for fish and water quality in November, 2001. Purple line indicates preferred route option. Blue squares = Water Quality, Red triangles = Electrofishing, Bait trapping and Water Quality, Green circles = Cast netting, Bait trapping and Water Quality. Refer to Tables 1, 9 and 10 for results.

<u>Factor</u>	<u>Code</u>	<u>Treatments</u>									<u>Designation</u>
<i>Location</i>	<i>L</i>	<i>K-A Option</i>			<i>Existing crossing</i>			<i>Stewarts River</i>			
<i>Site(Location)</i>	<i>SL)</i>	<i>S1</i>	<i>S2</i>	<i>S3</i>	<i>S1</i>	<i>S2</i>	<i>S3</i>	<i>S1</i>	<i>S2</i>	<i>S3</i>	
<i>Bait trap replicates</i>		x x	x x	x x	x x	x x	x x	x x	x x	x x	Random & orthogonal
		x x	x x	x x	x x	x x	x x	x x	x x	x x	
		x x	x x	x x	x x	x x	x x	x x	x x	x x	
		x x	x x	x x	x x	x x	x x	x x	x x	x x	
		x x	x x	x x	x x	x x	x x	x x	x x	x x	Random & nested
		x x	x x	x x	x x	x x	x x	x x	x x	x x	
<i>Bait net replicates</i>		x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	
<i>Water quality river surface replicates</i>		x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	
<i>Water quality river bottom replicates</i>		x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	

Figure 2: Sampling design for the bait trap, gill net and water quality surveys, November 2001 (Bait trap N = 90; gill net N = 27; water quality river surface N = 18; water quality river bottom N = 18).

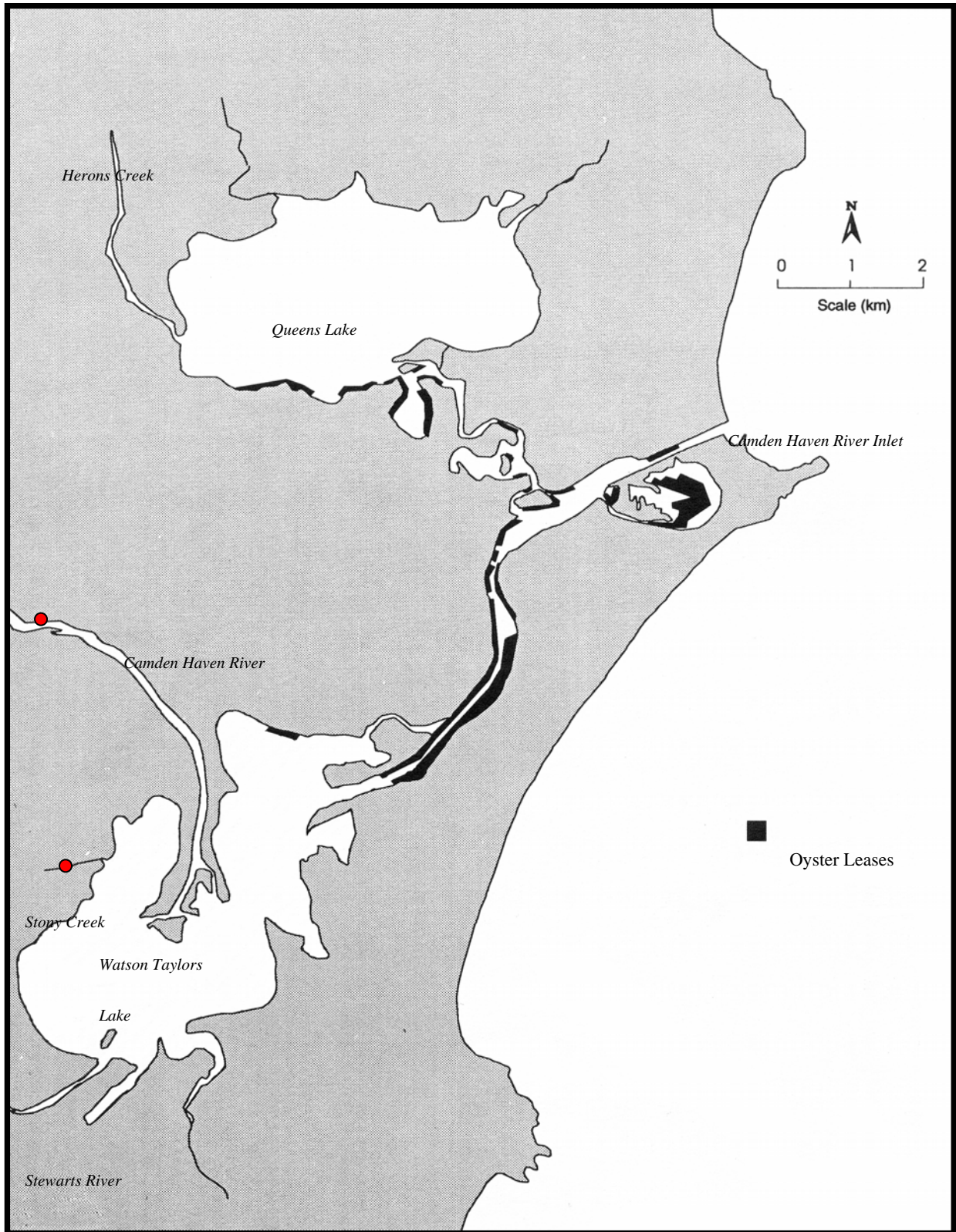


Figure 3: Map of Camden Haven Estuary which shows position of oyster leases in 1992. The red dots indicate the approximate location where new crossings would be constructed across waterways in the study area. (Source of Map; Carter 1995).

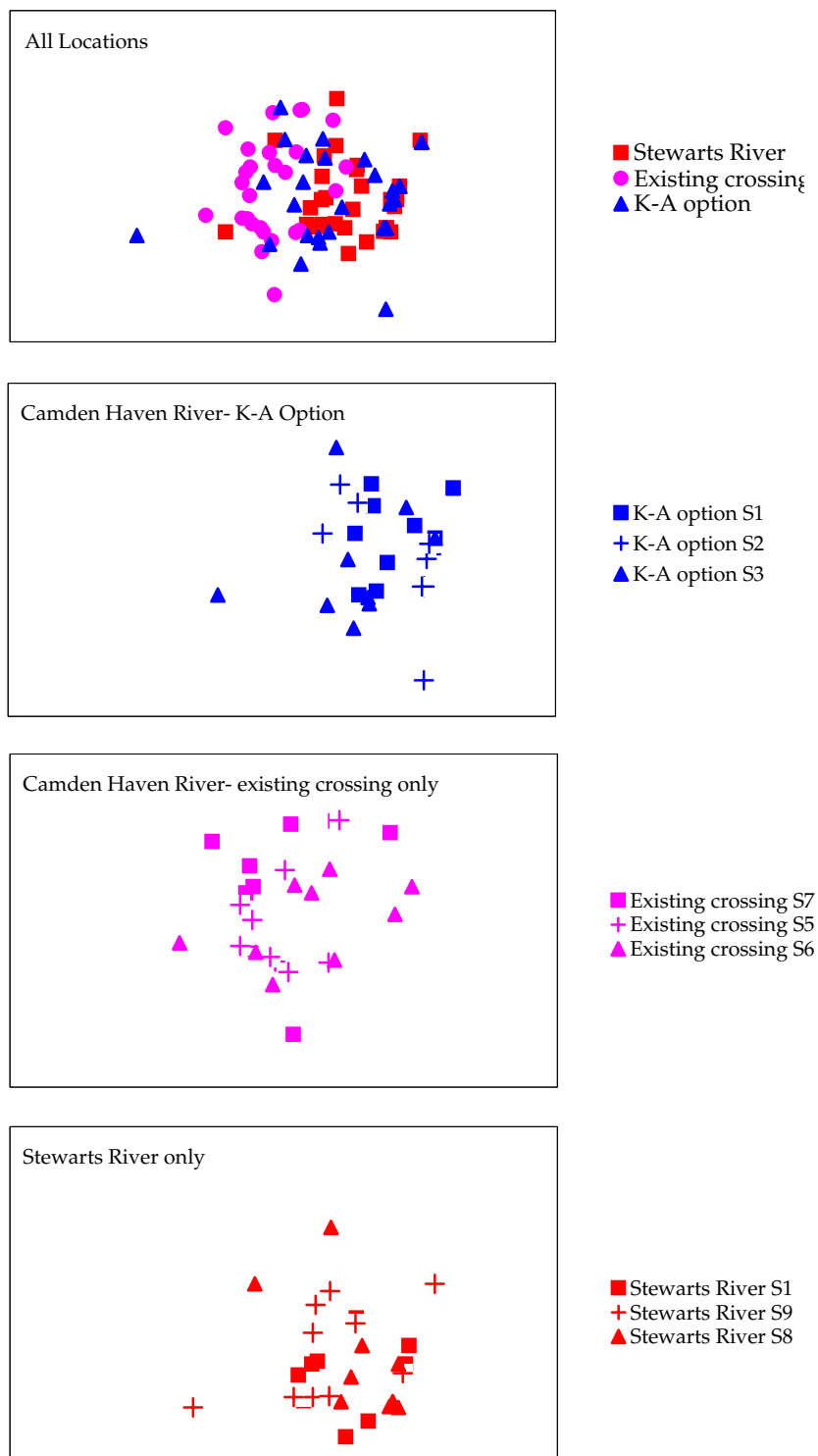


Figure 4: nMDS of fish assemblages captured in bait traps at each location and site at the Camden Haven River and the Stewarts River during November 2001. (Stress = 0.15)

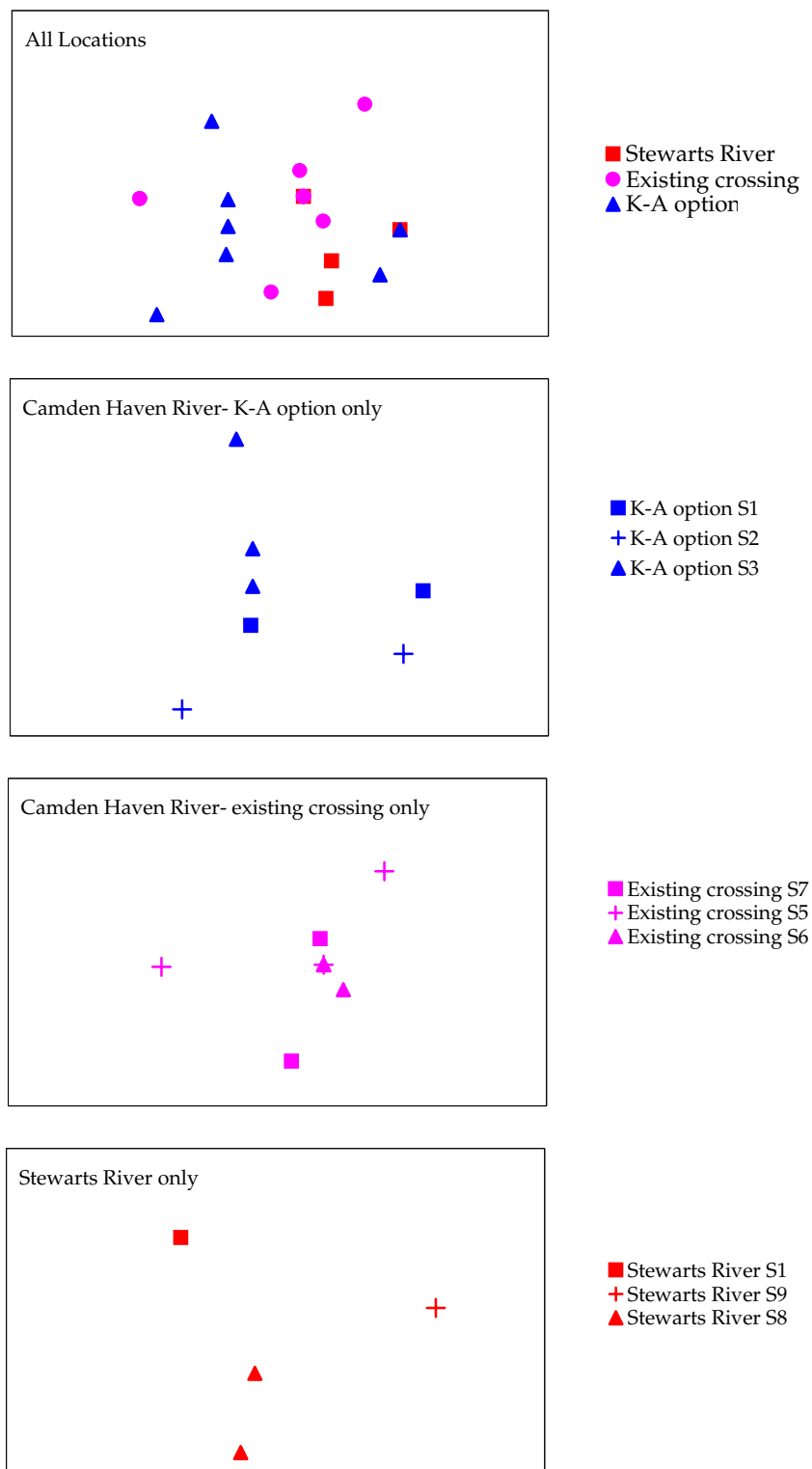


Figure 5: nMDS of fish assemblages captured in gill nets at each location and site at the Camden Haven River and the Stewarts River during November 2001. (Stress = 0.06)

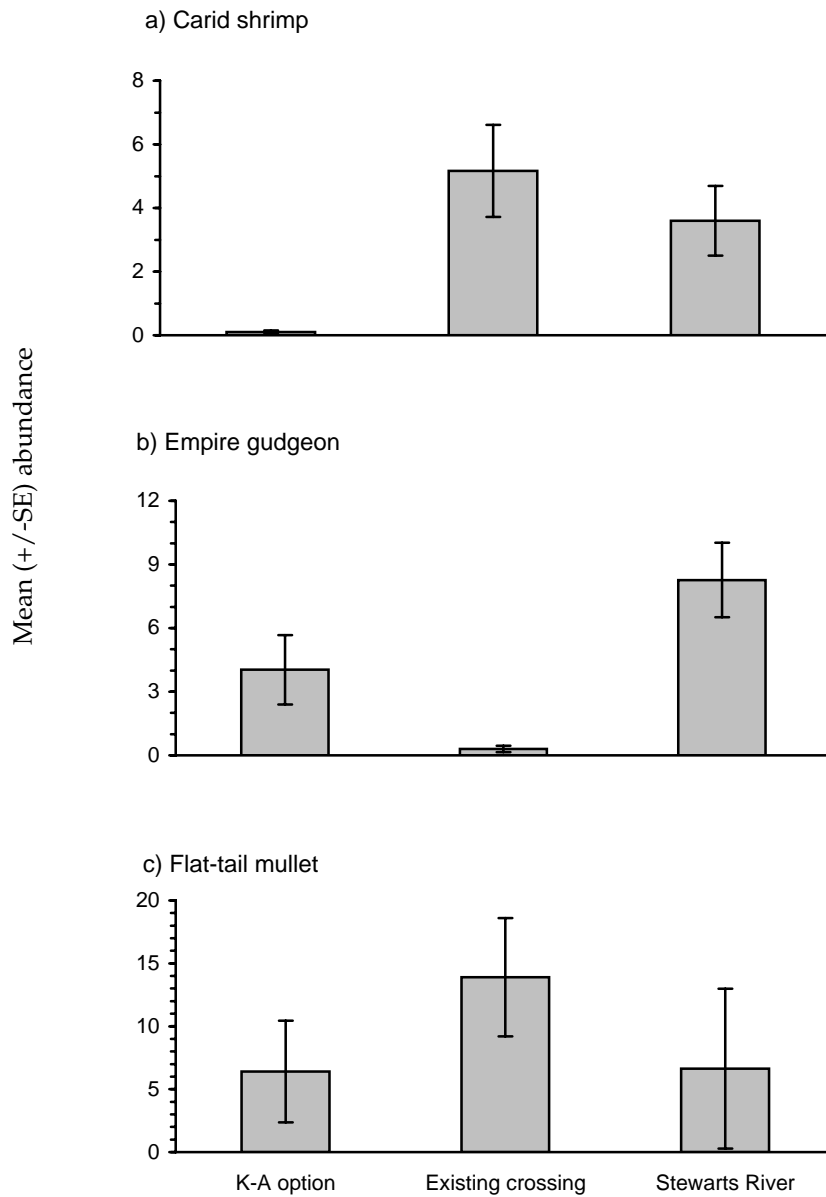


Figure 6: Mean abundances per bait trap at each location in the Camden Haven River and the Stewarts River during November 2001 ($n = 30$).

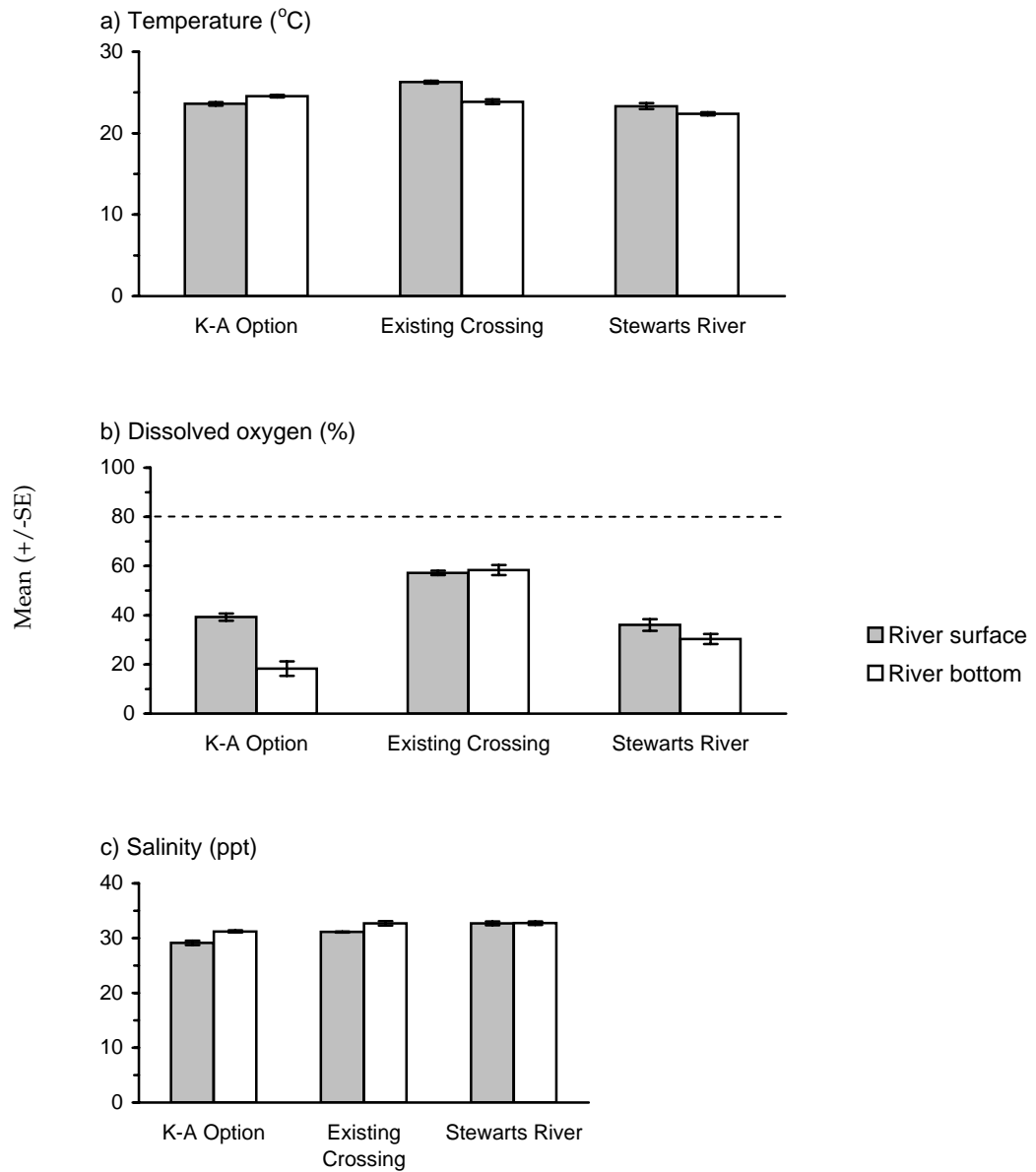


Figure 7: Mean (+/-SE) values for water quality parameters at each location in the Camden Haven River and the Stewarts River in November 2001. (n = 9) --- = ANZECC (2000) Guidelines for the protection of aquatic habitats.