2006

Separation Point Easement : baseline benthic mapping and faunal survey

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Report No	2006 – 03
Title	Separation Point Easement Baseline Benthic Habitat Mapping and Faunal Survey Jason How & Paul Lavery

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Baseline Benthic Habitat Mapping and Faunal Survey

Prepared for

Central West TAFE

by

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Background

The Batavia Coast Marine Centre forms part of the Separation Point Marine Precinct in Geraldton, Western Australia, a collaborative initiative between the Mid West Development Commission, Department of Fisheries, City of Geraldton and the Department of Education and Training. To service an aquaculture facility planned as part of the Batavia Coast Marine Centre, a salt water intake pipe is being constructed on the coast adjacent to the facility. The easement for the intake pipe is situated to the east of an intertidal reef and runs for approximately 540 m at a bearing of 180° from a production bore (PB 1) on shore (Figure 1).

As part of background studies for the project, and in order to provide a baseline for future assessment of any impacts resulting from construction of the pipeline, the Central West TAFE commissioned Edith Cowan University (ECU) to:

1. provide a benthic habitat map of the easement; and
2. describe the flora and fauna associated with the easement and surrounding areas.

The survey was limited to the easement, to determine habitat type that would be impacted directly by laying of the pipeline, and the adjacent reef habitat, which may be indirectly affected by the construction and ongoing presence of the pipeline.

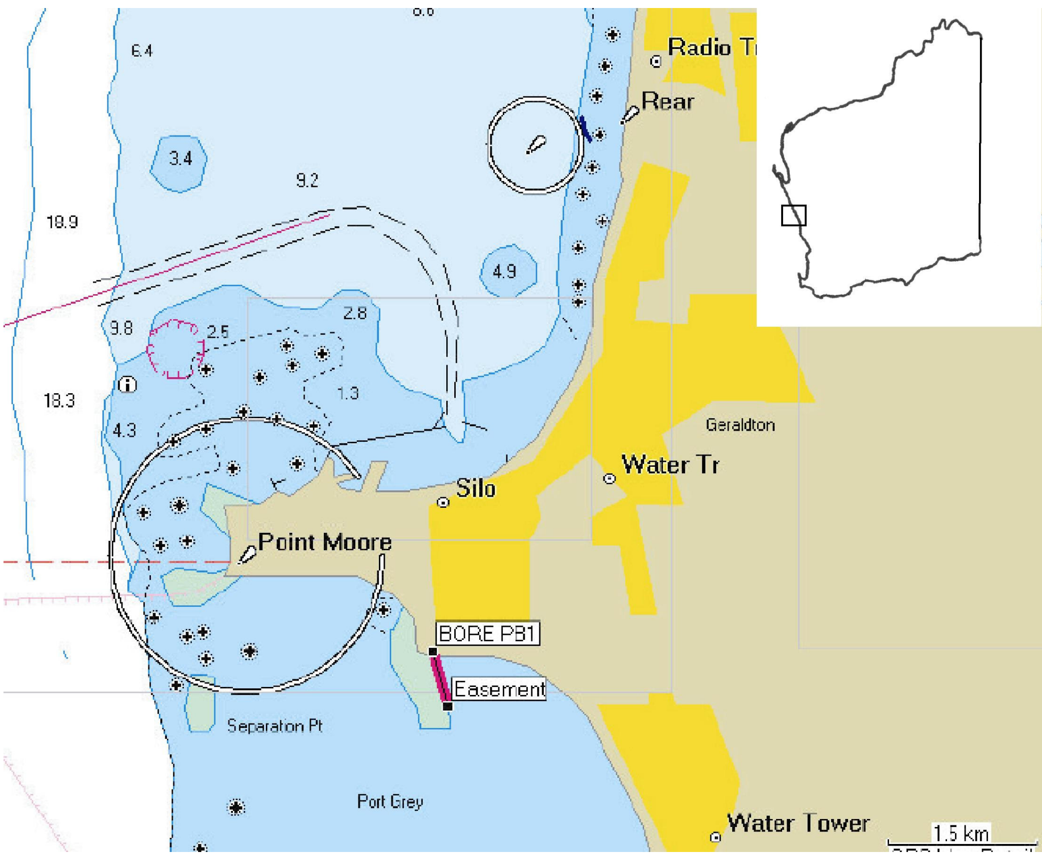

Figure 1 – Location of study sight and easement

This report summarises the findings of the surveys in the form of a benthic habitat map of the survey area and both qualitative and quantitative descriptions of the habitats that provide a baseline for future comparisons. Data are presented separately for seagrasses, reef algal assemblages, fish and macro-invertebrates.

Methods

Surveys were conducted on the 11th and 12th of April 2005 from the Central West TAFE vessel "Masterclass". Participants included members of Edith Cowan University, University of Western Australia and Central West TAFE with scientists experienced in algal, seagrass and marine faunal assessment.

Easement Mapping

The easement was marked by Central West TAFE prior to any surveying. Due to excavation work on the beach, the start point for sampling transects along the easement was placed at survey marker 009 (Figure 2). Measurements therefore will differ from those made in previous reports (Aquatech Australia Pty Ltd) by approximately 40m. This distance was calculated from GPS way points for the survey marks and production bore (PB1) provided by Engineered Water Systems.

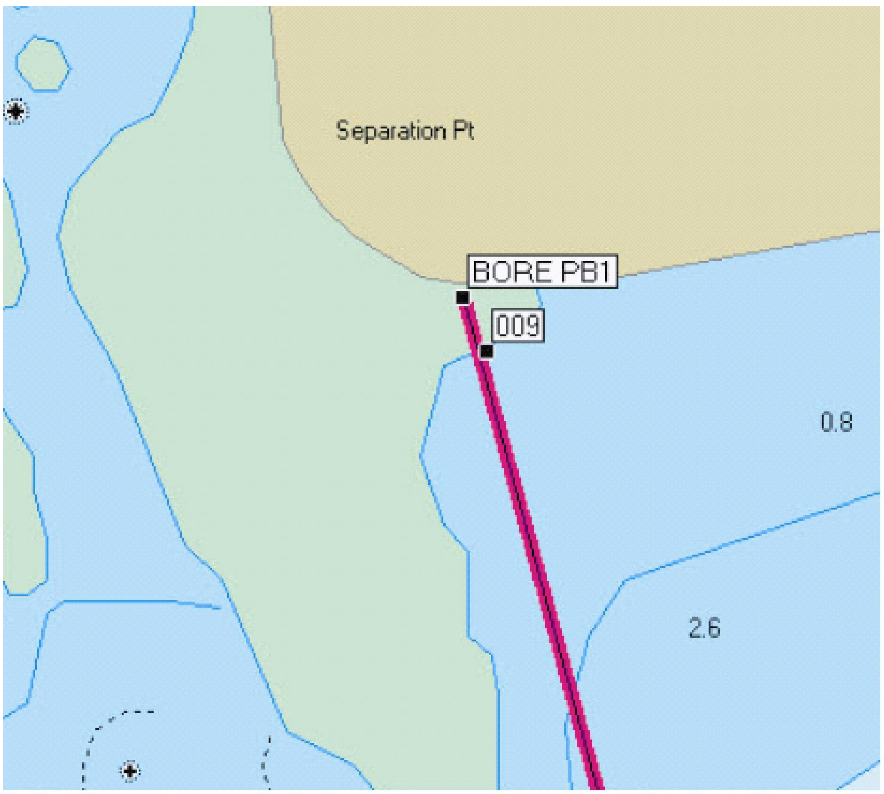

Figure 2 – Location of bore PB 1 relative to survey mark 009 which marked start of the easement surveys for this study.

A weighted rope marking the easement was laid with every effort being made to mark the central longitudinal axis of the easement. Bathometric and benthic habitat information were collected along the transect line by SCUBA divers. Bathymetry was approximated relative to survey mark 009 at the start of the transect, as no survey equipment was available to gain accurate bathymetry. Depth was recorded every 10 m along the transect using a Sunto ™ Octopus computerised depth gauge recording depth to the nearest 0.1m. In the first 100 m, due to rough conditions in the surf zone, only occasional depth recordings were possible between swells.

Sub tidal habitats along the easement were classified in three types: seagrass, sand or wrack by recorded to the nearest meter along the easement transect by SCUBA divers. The benthic habitats were also recorded using video footage recorded for future records of the sites condition. With habitats identified and located, seagrass meadow were then randomly sampled for a number of morphological characters, and fish / macro-invertebrate abundances, while sand habitats were also randomly sampled for fish / macro-invertebrate abundances. The adjacent reef habitat was also sampled as this was a habitat which may have been impacted the laying of the pipeline on the easement

Seagrass

Within the *Halophila ovalis, Halophila ovalis / spinulosa* and *Amphibolis antarctica* meadows mapped in the easement transect, transects were established to quantify the meadow characteristics. Six transects (10 m long) were randomly allocated within the *Halophila ovalis* and *Halophila ovalis / spinulosa meadows*. While *A. antarctica* meadows were identified as a distinct habitat that needed to be quantified, only two transects were established the *Amphibolis* meadow due to its limited size.
Each transect was marked by a tape measure and ran 10 m perpendicular from the easement transect. Where there was meadow present on either side of the easement transect, the seagrass transect was randomly assigned to the east or west. On each transect, shoot densities for *Amphibolis antarctica*, *Zostera tasmanica* and *Syringodium isoetifolium* leaf densities for *Halophila ovalis* and *Halophila spinulosa* and percentage cover of each species present was recorded in six randomly assigned quadrats (20 x 20cm). Leaf density was recorded for *H. ovalis* and *spinulosa* but was converted to shoot density for comparison with other studies (see below). For those transects in the *A. antarctica* meadow, maximum and average height (height of the 80^{th} percentile leaf; (Duarte and Kirkman 2001)) were also recorded. Every second quadrat in the *Amphibolis* meadow was harvested and stored for subsequent leaf and cluster counts should they be required in the future; these samples are stored at Edith Cowan University, School of Natural Science.

Reef Macro algal Assemblages

Macro-algal assemblages were sampling on the reef habitat adjacent to the easement. The reef was stratified into three regions, A, B and C (Fig. 3). In each region, algal species composition, percentage cover and densities of canopy species were recorded in four randomly located 0.25 m^2 quadrats. A further four 0.25 m^2 quadrats were harvested from regions A and B for biomass analysis. Due to unfavourable conditions, only 3 biomass samples were collected in region C. Biomass samples were frozen as a record for subsequent detailed taxonomy and biomass should it be required, and are stored at Edith Cowan University, School of Natural Science.

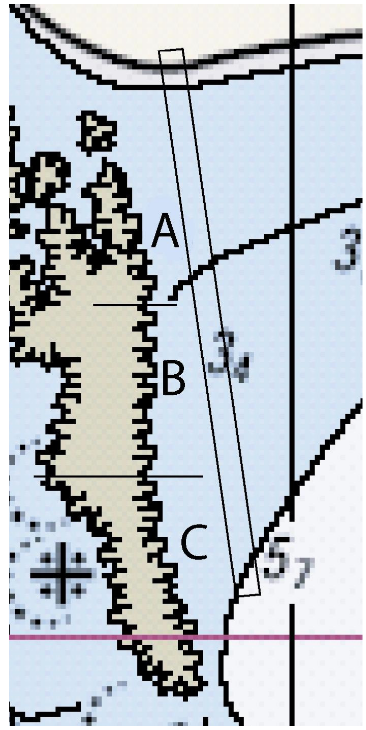

***Figure 3 – Division of the adjacent reef habitat to the easement (open rectangle) into 3 region**s*

Fish

Underwater visual censuses (UVC) were conducted to determine the composition and abundance of fish in the major benthic habitats. Four transects were randomly assigned in the seagrass and sand habitat identified through the easement mapping. Each transects (25 x 5 m) ran perpendicular to the easement transect. Fish species and the abundance of each species were recorded visually by a SCUBA diver in each transect. It was not possible to stratify the fish counts by the dominant seagrass genera, as replicate transects in the *A. antarctica* meadow lacked spatial independence due to its small size. As a result, 3 transects were located in *Halophila* meadows and one in the *A. antarctica* meadow.

Three addition fish transects were established on the reef, one in each of the three regions (Figure 3). As visibility on the reef was poor these transects are considered 25 x 2.5 m. Due to the poor visibility, the results from these transects should be interpreted with caution.

Macro invertebrates

Underwater visual census (UVC) of the reef was conducted to record densities of the urchins and the Western Rock Lobster *Panulirus cygnus*. Three replicate 30 x 5m transects were established, one assigned to each of the three reef areas (Figure 3) in ledge or high relief areas. The reduced visibility which affected the fish transects on the reef didn't pose a significant problem for the macro invertebrate census as the width of the transect could be searched without the chance of recounting the same individual due to the sedentary diurnal habit of *P. cygnus* (Phillips and Melville-Smith 1999). Densities of large epi-benthic macro invertebrates were also scored in the sand and seagrass habitats using the fish visual census transects after fish censes had been conducted.

Results and Discussion

Easement Mapping and Seagrass Habitat

Bathymetry

There were some discrepancies between previous mapping (Aquatech Australia Pty Ltd) and that derived from this survey. Despite adjustment back to the production bore (PB1), the length of mapping for this report was longer by approximately 30 m. This was due to the transect rope, predominantly in the surf zone, being bowed eastwards due to the strong swell and surge, despite placing weights along the transect to reduce this. As a result, the actual metre values for the start and end of benthic habitat types may alter, especially within the first 300 m. This part of the easement was in the surf zone and contained bare sand. Given the consistency of habitat in that area, it would have little impact on the mapping of the seagrass meadows.

The first 40 m of the easement was above the swash zone, with a surf zone that extended from the 50 m to the 100 m mark. From here the easement became deeper, to a depth of 4.4 m at the 280 m mark. From the 280- 420 m mark the bathymetry oscillated between 4.3 and 5 m then gradually deepening over the final 110 m to a final depth of 6.5 m at the end of the easement (530 m mark) (Fig. 4).

Seagrass & Algal Wrack

The habitat along the easement varied with depth (Figure 4). In the surf zone and through to the 280 – 290 m mark, there were considerable accumulations of wrack (detached macrophytes) over a bare sand substrate. These were thickest in the surf and adjacent zone, and occurred intermittently to the 290 m mark. This is a common feature of temperate Australian beaches with moderate to high wave action and associated offshore reefs or seagrass beds (Kirkman and Kendrick 1997). These macro-algal accumulations have recognised value as habitat for a number of juvenile and adult fish species (Lenanton et al 1982; Robertson and Lenanton 1984; Crawley et al submitted). Wrack accumulations are highly seasonal and transient on even a daily basis (Hansen 1984). Due to this high level of transience, wrack accumulations are not mapped on Figure 4.

With the plateau in bathymetry and, presumably, diminution of wave energy, at 290 m, meadows of *Halophila ovalis* and *H. spinulosa* occurred and were present, occasionally interspersed with small areas of bare sand, to the end of the easement. In deeper areas, around 5.8 m deep (500 m along the easement) *Syringodium isoetifolium* was also present in the *Halophila* meadow.

Halophila ovalis was the dominant species in the six transects located in *Halophila* meadow along the easement (Figure 5 a-f), with average leaf densities ranging from 7.5 - 33 leaves/0.04m^2. *H. spinulosa* was present in four of the six easement transects, always co-occurring with its congeneric *H. ovalis* to form mixed *Halophila* meadows and was only dominant (higher shoot densities) in the transect at 390 m (Figure 5 c). Within the easement there was also sparse occurrence of *Zostera tasmanica* (found in only one quadrat; density 30 shoots/0.04m^2) and *Syringodium isoetifolium*. (found in two quadrats; densities 40 and 10 shoots/0.04m^2).

Halophila ovalis is a widely distributed seagrass species and is capable of tolerating a wide range of environmental conditions. It is often a coloniser species forming a mono-specific meadow before becoming a component of a mixed meadow (Waycott et al. 2004). *H. ovalis* typically has 2 leaves per shoot (Waycott et al. 2004), so that shoot density can be approximated by halving the leaf densities reported here. The estimated shoot densities found at Separation Point of 93 – 412 shoots / m^{-2} are less than those reported for deep (2.5 m deep) *H. ovalis* meadows in Moreton Bay, Queensland of 609 - 678 shoots / m^{-2} (Longstaff et. al. 1999). The low shoot densities may be related to the site conditions; the species is often associated with deeper water habitats (>10m) and at more northerly latitudes (Waycott et al. 2004).

At the end of the easement (530 m), the *Halophila* meadows gave way to a small *Amphibolis antarctica* meadow (Figure 4). The densities in the meadow ranged from 0 – 650 stems/m^2 (average 295.75 stems/m^2 ± 66.25 SE) *A. antarctica* is a taller species found here to have an average height 39.8 (± 8.8 SE) than either of the *Halophila* species and has a dense growth form (Ducker et al. 1977). Consequently, it would require a greater reduction in incident wave energy to establish and may be why it is only found at the end of the easement in deeper water. While the area of *Amphibolis* in the easement is small, studies in the Perth metropolitan region (Hyndes et al, 1999) have shown *Amphibolis* meadows to provide a structurally complex habitat high in macro-algal and macro-invertebrate diversity and an important fish habitat (see section on Fish for further detail).

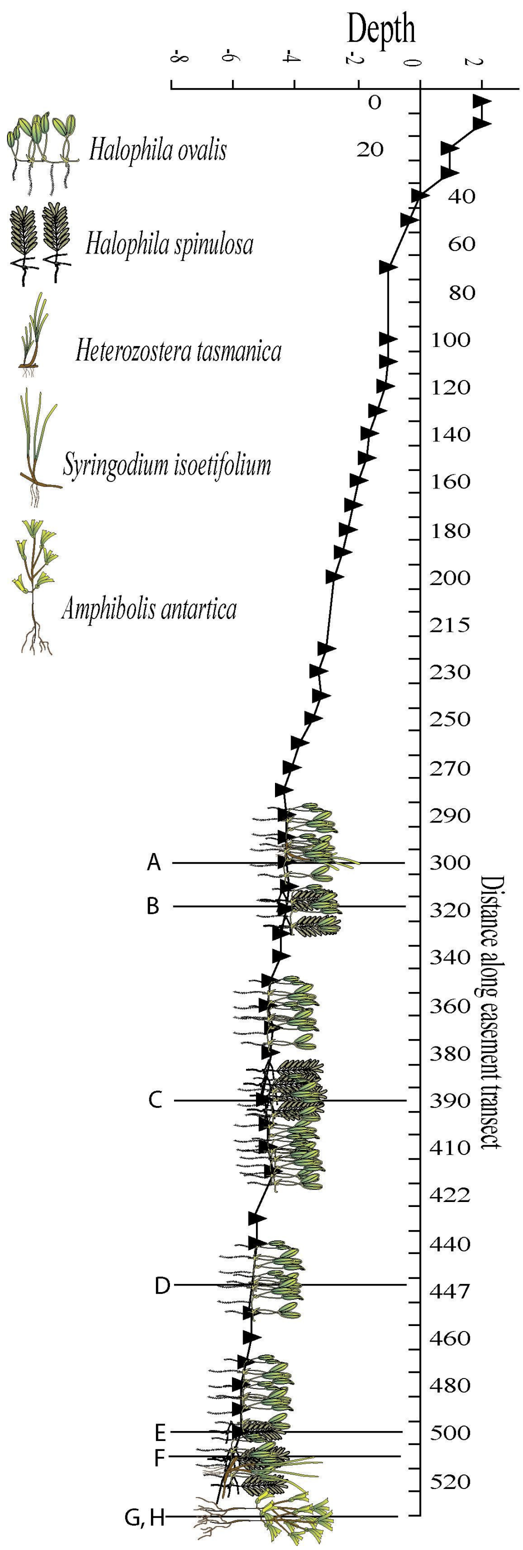

Figure 4 – Bathometry and seagrass habitat type for the easement at Separation Point. Location of transects on the easement are marked A – H.

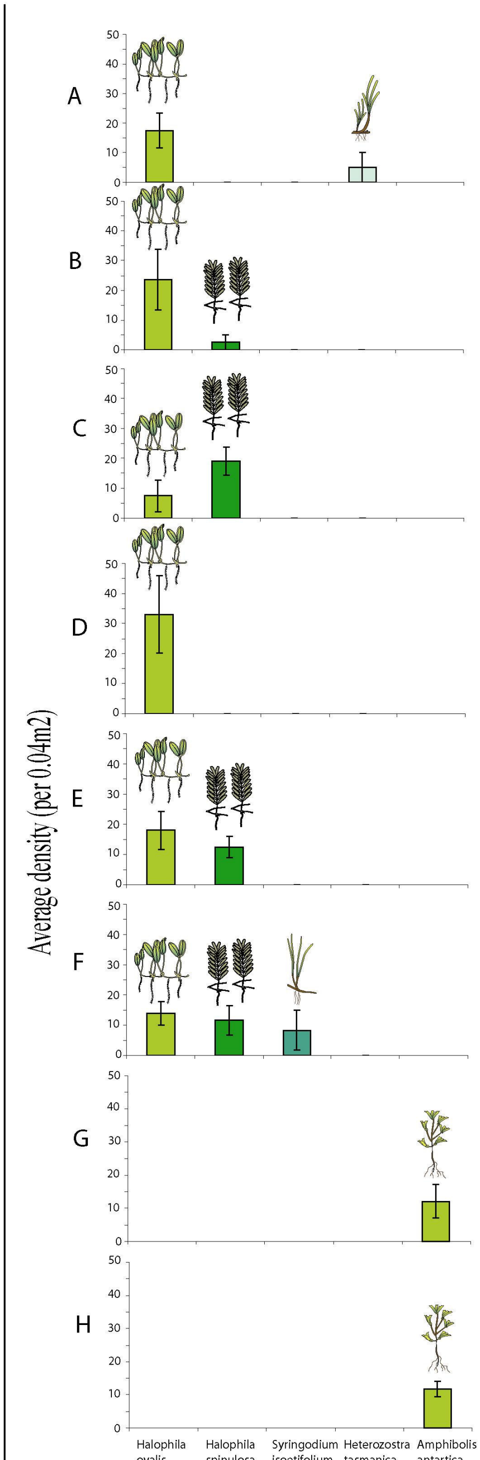

Figure 5 – Average leaf densities for Halophila spp and shoot densities for remaining taxon (with se error bars) for transects at A; 300m, B; 320m, C; 390m, D;446 m, E; 500m, F; 510m G and H end of transect in A. antarctica meadow

Reef Macroalgae

Multivariate analysis indicates a gradient in the similarity among algal assemblages based on reef location, as indicated by the clear separation of assemblages from the three reef regions C - outer, B - middle and A - inner areas of the reef (Figure 6). Analysis of Similarity confirmed that there was significant variation in the algal assemblages from the outer edge of the reef to the inner fringing part of the reef (Global R: 0.72; p=0.001), with all three regions having assemblages that differed significantly from each other.

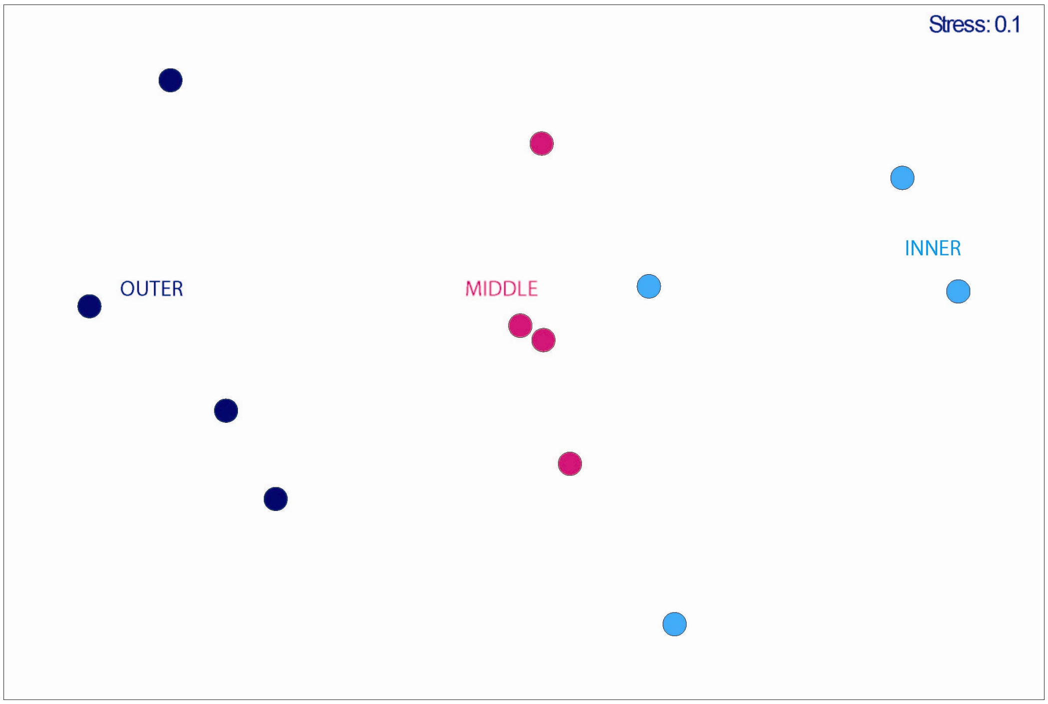

Figure 6 – Multidimensional ordination of reef algal assemblages from the three different reef areas; outer, middle and inner reef. The ordination was based on a Bray-Curtis similarity matrix calculated from square root transformed percentage cover of algal species and square root transformed* Sargassum *sp. and* Caulocystis uvifera *densities.

Subsequent similarity analysis (SIMPER) identified the species of macroalgae that contributed most significantly to the differences among reef areas. The outer reef was dominated by high covers of *Zonaria* sp. and *Lobophora* sp. and significant coverage of *Amphiroa gracilis*, *Padina*, *Rhodymenia* and the seagrass *Amphibolis antarctica* (Figure 7). The mid-reef section had lower percentage cover of *Zonaria* / *Lobophora* than the outer reef section but a greater density of *Sargassum* sp. and cover of *Dictyota dichotoma* (Figure 7). At the inner reef, *Dictyota dichotoma* was the dominant taxa in terms of percentage coverage though there was also a notable increase in *Colpomenia* coverage. *Sargassum* densities were similar in the middle and inner reef sections (middle 16.75; inner 14.25 thalli m^{-2}). *Zonaria* / *Lobophora* were not as abundant as at the outer reef of the reef (Figure 7).

Table 1 – Mean percentage covers of algal species (mean densities of* Sargassum *and* Caulocystis uvifera*) at each area on the reef (±SE).

Site	Reef Area Inner	Middle	Outer
Sargassum spp	14.25 (± 5.75)	16.75 (± 2.29)	3.75 (± 0.85)
Caulerpa racemosa	1.25 (± 1.25)		
Colpomenia sp.	13.75 (± 6.88)		
Dictyota dichotoma	21.25 (± 7.18)	3.75 (± 1.25)	
Caulocystis uvifera		0.25 (± 0.25)	
Peyssonnelia sp.		1.25 (± 1.25)	
Plocamium mertensii		6.25 (± 6.25)	
Caulerpa geminata		12.5 (± 2.5)	
Lobospira bicuspidata		2.5 (± 2.5)	5 (± 5.0)
Halimeda cuneata			1.25 (± 1.25)
Metagonlithon			2.5 (± 2.5)
Rhodymenia			5 (± 2.89)
Amphibolis antarctica			10 (± 7.07)
Amphiroa gracilis			12.5 (± 2.5)
Pedina	8.75 (± 4.27)	15 (± 6.12)	15 (± 8.66)
Zonaria / Lobophora	13.75 (± 8.98)	21.25 (± 6.57)	46.25 (± 10.68)

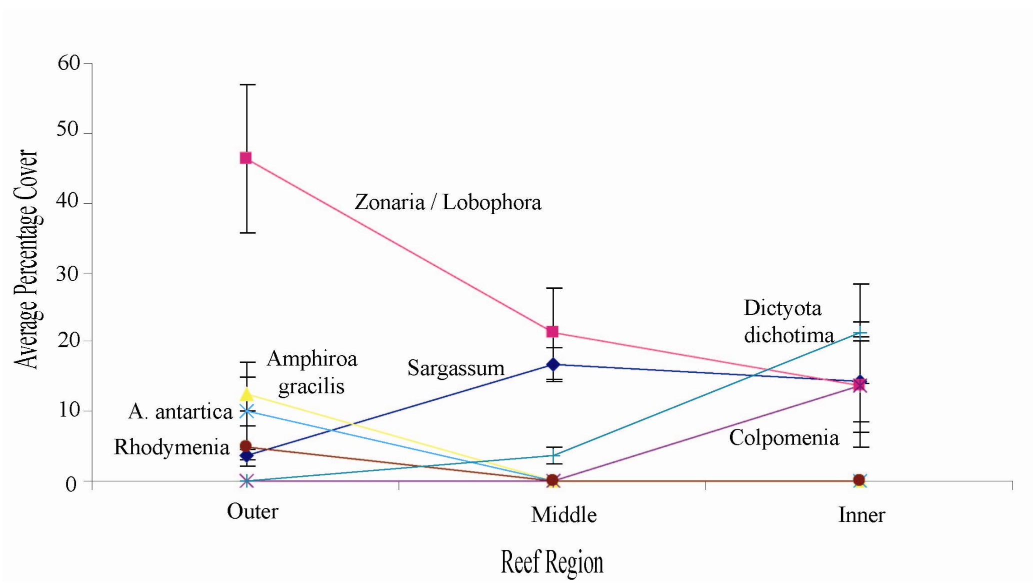

Figure 7 – Average percentage cover (with se error bars) of algal species and density of canopy species (Sargassum) for the three reef regions surveyed

The potential impacts of the pipeline construction on the reef macroalgae assemblage would be from an increase in total suspended solids (TSS) associated with laying of the pipe. Smothering or associated light reduction from increased TSS may cause the loss of some species from the area.

Sediment loading may also have ramifications in terms of algal recruitment (see review by Airoldi 2003) and associated recovery of affected areas. Some taxa, such as *Sargassum*, where dispersal is limited and recruits often come from parent populations located within a few meters (Kendrick and Walker 1991, 1995), may recovery slowly from disturbance.

The significant difference in algal assemblage on the reef from the outer to the inner sections should be accounted for when assessing any impacts of the pipeline construction on the reef.

Fish

Fish species richness and abundance were relatively low in the easement habitats (sand and seagrass; Figures 8 & 9). Only one species was recorded on the bare sand habitat and nine species being recorded across all seagrass habitats. In comparison, a total of 13 species were recorded in reef habitat (Figure 8). It should be noted that there is large degree of variation in the species richness for the seagrass habitat.

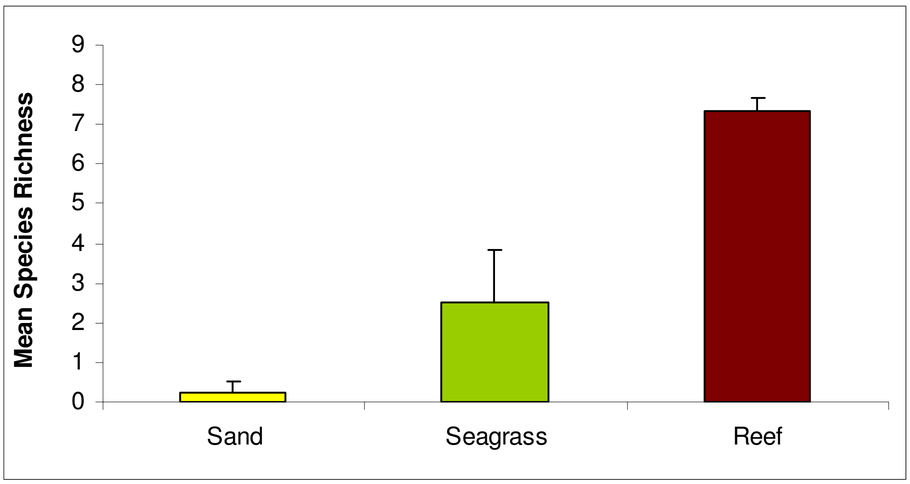

Figure 8 – Mean species richness of fish from the three habitats on, or adjacent to the easement (error bars represent standard error)

The mean abundance of fish was low in sand habitat (Figure 9). Seagrass and reef habitats having similar and higher abundances (Figure 9), though abundances were highly variable in the seagrass habitat.

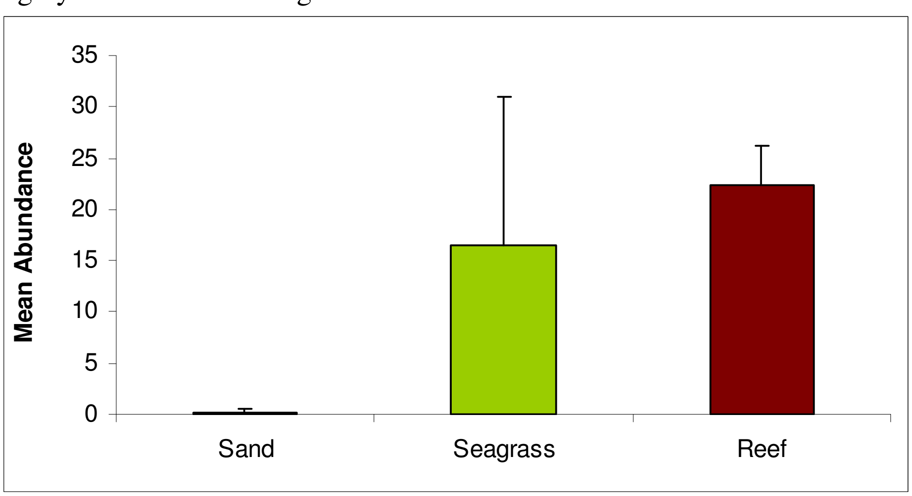

Figure 9 – Mean abundance of fish from the three habitats on or adjacent to the easement (error bars represent standard error)

The low visibility during the reef survey would have resulted in an underestimate of the both the number of species on the reef and their abundances, and clearer conditions may have yielded an even greater difference between this and the other habitats. This differences in richness and abundance among habitats is expected and consistent with other studies of fish fauna on the mid west coast of Western Australia (Vanderklift and How unpublished data); reefs provide a more complex habitat and greater niche-provision. In this instance the reef area's richness and abundance was further enhanced from seagrass abutting the reef. All four seagrass species recorded in the easement meadows were present immediately adjacent to the reef, further increasing niche provision that could be exploited by a number of reef and seagrass species.

The variation in species richness and abundance of fish within seagrass habitat is related to the variation of the habitat itself. The lack of replication of *Amphibolis* on the easement prevents definitive statements regarding the differences in richness or abundance between the two seagrass meadow types. However it does appear that there is a higher richness and abundance in the *Amphibolis* meadow. The three samples taken from the structurally simple *Halophila* spp meadows showed an average richness of 1.3 species per sample compared with the 6 species recorded on the one *Amphibolis* transect. This was also the case for abundance, with a mean abundance of 2 fish on the *Halophila* transects and 60 individuals on the one *Amphibolis* transect. *Amphibolis* has a complex canopy and is higher above the substrate providing more sheltered areas for fish to seek refuge. More complex and dense seagrass meadows contain significantly more fish than those which are more open and simple in their meadow structure (Hyndes et al. 2003).

The differences in the richness and abundance of fish in the two seagrass habitats has consequences for potential impacts of the construction and operations in the easement. The majority of seagrass cover in the easement consists of *Halophila* meadows (Figure 4). As a result, any impacts from the laying of the pipeline and subsequent loss of *Halophila* habitat would have an impact on a small number of species with limited abundances in those areas, than would be the case if *Amphibolis* was the dominant species of the easement.

Macro invertebrates

No large epi-benthic macro invertebrates were recorded in sand or seagrass transects, though a sea hare (Mollusca: Anaspidea) was noted whilst swimming between transects over bare sand. Although none were noted here, exposed bare sand areas can support colonies of sand dollars (Echinodermata: Clypeasteroids) or some large predatory molluscs. The sighting of a sea hare (Mollusca: Anaspidea) was not unexpected as this area is known to have large numbers of sea hares washed ashore seasonally (Geraldton City Council).

In the reef habitat, the survey revealed no urchins but high levels of the Western Rock Lobster (*Panulirus cygnus*; mean 85.3 ± 38.4 SE $transect^{-1}$). The reef adjacent to the easement is an area of high western rock lobster densities. These inshore reefs appear to be preferred habitat for juvenile western rock lobster before moving offshore as they mature (L. MacArthur pers com).The western rock lobster on the Separation Point reef appear to be predominantly under the legal size of 76 mm, though no size estimates were made. The two transects conducted in the Outer and Middle regions had similar and higher number of Western Rock Lobsters than that in the Inner reef region (Figure 10). While the lack replication prevents any significance being ascribed to this observation the inshore site did have fewer ledges than the more outer two sites and may have been a less suitable lobster habitat.

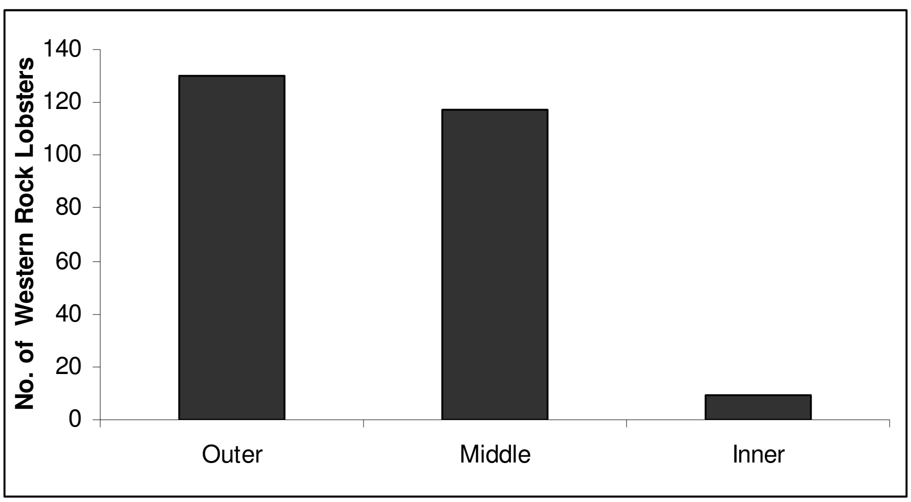

Figure 10 – Number of Western Rock Lobster recorded on transects at each one of the three reef zones.

Densities of lobsters have been measured off the mid west coast however have often focused on the more cryptic post-puerulus form (Jernakoff 1990, Jernakoff et al. 1994). Work on juvenile lobster abundance and distribution is currently being undertaken at the Jurien Bay Marine Park (MacArthur unpublished data). Smaller undersized lobsters are being found in high abundances on near-shore reefs. Using the same transect method of estimating juvenile rock lobsters densities, this research has found that shallow inshore reefs with adjacent seagrass meadows have lobster densities of 16.25 lobsters per transect. This is considerably less than densities of found at Separation Point which averaged 85 lobsters per transect over the three transects conducted on the reef. A maximum of 47 lobsters were found on one transect in the Jurien Bay survey which is almost a third of the 130 lobsters recorded on the outer portion of the Separation Point reef. This indicates that this near-shore reef adjacent to the pipeline easement is a suitable and potentially important area for juvenile rock lobster

Summary

1. The easement habitats encompassed a near-shore wrack accumulation area, seagrass meadows and areas of bare sand.

2. Five species of seagrass were recorded in the easement but it is dominated by *Halophila* meadows, predominantly *H. ovalis*. This is a coloniser species known to inhabit a wide range of environmental conditions.

3. The macro-algal assemblage on the adjacent reef varied between the offshore, middle and inshore sections. This variation would need to be incorporated into any future sampling of the reef adjacent to the pipeline easement.

4. The adjacent reef demonstrated a high level of fish numbers and taxa and is a very important juvenile rock lobster habitat. The numbers of western rock lobsters at this site is far in excess of previously recorded densities from sites further south.

5. The *Halophila* spp meadows and bare sand of the easement had a low abundance and species richness of fish with no epi-benthic macro invertebrates recorded.

The information contained in this reports provides a baseline of habitat map of the easement area and the adjacent reef habitat. It also contains qualitative and quantitative descriptions of the habitats with replicated sample data. The data in this survey provides a quantitative baseline against which future surveys of the easement area can be compared. As always, any future comparisons should be made with caution as benthic habitat characteristics vary at seasonal or shorter timescales. Seagrass meadows and reefs are patchy in time and space and the data contained in this report relate to only one sampling time. Future surveys should, as much as practicable, be undertaken at comparable times of year.

Appendix 1 – Habitat Mapping Data

Distance	**Habitat**	**Category**	**Dense / Sparse**	**Depth**
0	Beach	0		-2
10	Beach	0		-2
20	Beach	0		-1
30	Beach	0		-1
40	Wash	0		0
50	Wrack	1	Dense	0.3
60	Wrack	1	Dense	
70	Wrack	1	Dense	1
80	Wrack	1	Dense	
90	Wrack	1	Dense	
100	Wrack	1	Dense	1
110	Wrack	1	Dense	1
120	Wrack	1	Dense	1.1
130	Sand	0		1.4
140	Sand	0		1.6
150	Sand	0		1.7
160	Wrack	1		2
170	Wrack	1		2.1
180	Sand	0		2.3
190	Wrack	1	Sparse	2.5
200	Wrack	1	Sparse	2.7
210	Wrack	1	Sparse	
215	Sand	0		
220	Wrack	1	Sparse	3
230	Wrack	1	Sparse	3.3
240	Sand	0		3.2
250	Sand	0		3.4
260	Wrack	1	Sparse	3.9
270	Sand	0		4.1
280	Sand	0		4.4
290	Sand	0		4.3
296	*H. ovalis*	5	Dense	
300	H. *spinulosa*	5	Dense	4.3
310	*H. spinulosa*	5	Dense	4.2
320	*H. ovalis* and *H. spinulosa*	5	Sparse	4.3
330	Sand	0		4.5
340	Sand	0		4.5
350	Sand	0		4.8
360	*H. ovalis*	5		4.9
370	*H. ovalis*	5		4.7
380	Sand	0		4.8
386	*H. spinulosa*	5	Dense	
390	*H. spinulosa*	5	Dense	5
400	*H. ovalis*	5	Dense	4.9
410	*H. ovalis*	5	Sparse	4.9
420	*H. ovalis*	5	Dense	4.7
422	Sand	0		

430	Sand	0		5.2
440	Sand	0		5.2
443	*H. ovalis*	5		
447	*H. ovalis*	5		
450	Sand	0		5.4
460	Sand	0		5.4
470	Sand	0		5.6
480	*H. ovalis*	5	Sparse	5.8
490	*H. ovalis*	5	Dense	5.8
500	*H. ovalis, H. spinulosa* and *S. isoetifolium*	5	Dense	5.8
510	*H. ovalis, H. spinulosa* and *S. isoetifolium*	5	Sparse	6
520	*H. ovalis, H. spinulosa* and *S. isoetifolium*	5	Dense	6.4
530	*A. antarctica*	10	Dense	6.5

Appendix 2 – Seagrass densities and heights

Transect	Seagrass species	Quadrat Distance	Leaf / Shoot density	Max. height	Avg. height	% cover
T1	*Amphibolis antarctica*	0.1	25	59	45	30
T1	*Amphibolis antarctica*	2	26	63	46	15
T1	*Amphibolis antarctica*	3	3	81	45	5
T1	*Amphibolis antarctica*	4.8	0	0	0	0
T1	*Amphibolis antarctica*	6.6	18	60	70	70
T1	*Amphibolis antarctica*	9.4	0	0	0	0
T2	*Amphibolis antarctica*	1	14	67	38	50
T2	*Amphibolis antarctica*	1.8	20	69	54	80
T2	*Amphibolis antarctica*	3.6	9	60	30	45
T2	*Amphibolis antarctica*	8.1	15	70	60	75
T2	*Amphibolis antarctica*	9	5	57	35	20
T2	*Amphibolis antarctica*	9.5	7	67	55	30
510	*Halophila ovalis*	1	29			35
510	*Halophila spinulosa*	1	15			20
510	*Halophila ovalis*	2.7	18			20
510	*Halophila ovalis*	7	14			35
510	*Halophila spinulosa*	7	20			40
510	*Halophila ovalis*	7.7	12			25
510	*Halophila spinulosa*	7.7	30			40
510	*Syringodium isoetifolium*	7.7	10			10
510	*Halophila ovalis*	9.5	10			10
510	*Halophila spinulosa*	9.5	5			5
510	*Syringodium isoetifolium*	9.5	40			50
500	*Halophila spinulosa*	1.2	5			5
500	*Halophila ovalis*	1.2	25			30
500	*Halophila spinulosa*	3	5			10
500	*Halophila ovalis*	3	45			60
500	*Halophila spinulosa*	8.8	18			20
500	*Halophila spinulosa*	9.3	26			60
500	*Halophila ovalis*	9.3	10			20
500	*Halophila spinulosa*	9.5	12			30
500	*Halophila ovalis*	9.5	13			20
500	*Halophila spinulosa*	9.9	9			30
500	*Halophila ovalis*	9.9	15			25
446	*Halophila ovalis*	1.6	72			80
446	*Halophila ovalis*	1.9	60			60
446	*Halophila ovalis*	2.5	16			30
446	*Halophila ovalis*	3.2	50			65
446		7	0			0
446		9	0			0
390	*Halophila spinulosa*	0.5	16			50
390	*Halophila spinulosa*	0.7	30			30
390	*Halophila spinulosa*	1.8	29			65
390	*Halophila spinulosa*	4.4	24			40
390	*Halophila ovalis*	7	13			25
390	*Halophila spinulosa*	7	15			40

390	*Halophila ovalis*	8.5	32			50
320		0.3	0			0
320		1.3	0			0
320	*Halophila ovalis*	3.3	44			70
320	*Halophila ovalis*	4	60			80
320	*Halophila spinulosa*	5.7	15			20
320	*Halophila ovalis*	5.7	28			40
320	*Halophila spinulosa*	7.1	9			15
300	*Halophila ovalis*	7.6	33			65
300	*Zostra tasmanica*	7.6	30			10
300	*Halophila ovalis*	4.2	21			20
300	*Halophila ovalis*	7.4	30			40
300	*Halophila ovalis*	8.8	21			25
300		9.2	0			0
300		9.8	0			0

Appendix 3 – Fish abundances on transects over sand, seagrass (*Amphibolis antarctica* T1 and *Halophila* spp T2 - 4) and reef

Habitat	Transect	Starting	Scientific Name	Name	Count
Sand	1	130		NO FISH	
Sand	2	200	*Upeneus tragula*	Bar-tailed Goatfish	1
Sand	3	340		NO FISH	
Sand	4	440		NO FISH	
Seagrass	1	530	*Siphamia cephalotes*	Wood's Siphonfish	26
Seagrass	1	530	*Apogon rueppellii*	Gobbleguts	1
Seagrass	1	530	*Haliochoeres brownfieldi*	Brownfield's Wrasse	1
Seagrass	1	530	*Odax acroptilus*	Rainbow Cale	1
Seagrass	1	530	*Siganus spp*	Spinefoot	30
Seagrass	1	530	*Caesioscorpis theagenes*	Fusilier Sweep	1
Seagrass	2	420	*Torguigener pleurogramma*	Banded Toadfish	1
Seagrass	3	370	*Pentapodus vitta*	Butterfish	1
Seagrass	3	370	*Pseudolabrus parilus*	Brown Spotted Wrasse	3
Seagrass	3	370	*Haliochoeres brownfieldi*	Brownfield's Wrasse	1
Seagrass	4	300		NO FISH	
Reef	1	Outside	*Coris auricularis*	Western King Wrasse	14
Reef	1	Outside	*Pseudolabrus parilus*	Brown Spotted Wrasse	5
Reef	1	Outside	*Haliochoeres brownfieldi*	Brownfield's Wrasse	4
Reef	1	Outside	*Parma occidentalis*	Western Scalyfin	1
Reef	1	Outside	*Parma mccullochi*	McCulloch's Scalyfin	2
Reef	1	Outside	*Torguigener pleurogramma*	Banded Toadfish	1
Reef	1	Outside	*Cheilodactylus rubrolabiatus*	Red-lipped Morwong	1
Reef	2	Middle	*Agogon victoriae*	Red Stripped Cardinalfish	2
Reef	2	Middle	*Pseudolabrus parilus*	Brown Spotted Wrasse	2
Reef	2	Middle	*Haliochoeres brownfieldi*	Brownfield's Wrasse	3
Reef	2	Middle	*Coris auricularis*	Western King Wrasse	8
Reef	2	Middle	*Parupeneus signatus*	Black Spotted Goatfish	4
Reef	2	Middle	*Kyphosus cornelii*	Western Buffalo Bream	4
Reef	2	Middle	*Parma mccullochi*	McCulloch's Scalyfin	1
Reef	3	Inner	*Torguigener pleurogramma*	Banded Toadfish	1
Reef	3	Inner	*Pseudolabrus parilus*	Brown Spotted Wrasse	1
Reef	3	Inner	*Haliochoeres brownfieldi*	Brownfield's Wrasse	2
Reef	3	Inner	*Parma mccullochi*	McCulloch's Scalyfin	5
Reef	3	Inner	*Parapercis haackei*	Wavy Grubfish	2
Reef	3	Inner	*Microcanthus strigatus*	Stripy	2
Reef	3	Inner	*Thalassoma septemfasciata*	Seven Banded Wrasse	1
Reef	3	Inner	*Coris auricularis*	Western King Wrasse	1

Appendix 4 – Species list of fish recorded on the transects or sighted on the easement at Separation Point

Common Name	Scientific Name
Fish recorded on transects	
Banded Toadfish	*Torguigener pleurogramma*
Bar-tailed Goatfish	*Upeneus tragula*
Black Spotted Goatfish	*Parupeneus signatus*
Brown Spotted Wrasse	*Pseudolabrus parilus*
Brownfield's Wrasse	*Haliochoeres brownfieldi*
Butterfish	*Pentapodus vitta*
Fusilier Sweep	*Caesioscorpis theagenes*
Gobbleguts	*Apogon rueppellii*
McCulloch's Scalyfin	*Parma mccullochi*
Rainbow Cale	*Odax acroptilus*
Red Stripped Cardinalfish	*Agogon victoriae*
Red-lipped Morwong	*Cheilodactylus rubrolabiatus*
Seven Banded Wrasse	*Thalassoma septemfasciata*
Spinefoot	*Siganus spp*
Stripy	*Microcanthus strigatus*
Wavy Grubfish	*Parapercis haackei*
Western Buffalo Bream	*Kyphosus cornelii*
Western King Wrasse	*Coris auricularis*
Western Scalyfin	*Parma occidentalis*
Wood's Siphonfish	*Siphamia cephalotes*
Other species seen on the easement	
Sand Whiting	*Sillago spp.*
Skippy	*Pseudocaranx spp*
Fanbellied Leatherjacket	*Monacanthus chinensus*

Appendix 5 – Western Rock Lobster densities for transects at different zones of the reef

Location	Distance	Den 1	Den 2	Den 3	Total	Transect Total
Outer	5	8	11		19	
	10	1	4		5	
	15	15			15	
	20	33	16	26	75	
	25	7			7	
	30	9			9	130
Middle	5	11	4		15	
	10	1	8		9	
	15	35	3	1	39	
	20	2			2	
	25	16	8		24	
	30	23	5		28	117
Inner	5	5			5	
	10				0	
	15				0	
	20	4			4	
	25				0	
	30				0	9

Appendix 5 – Reef algal species and their associated percentage cover or densities

Area	Quadrat	Species	% Cover
Outer	1	*Zonaria / Lobophora*	50
Outer	1	*Pedina*	30
Outer	1	*Metagonlithon*	10
Outer	1	*Amphiroa gracilis*	10
Outer	2	*Zonaria / Lobophora*	75
Outer	2	*Amphiroa gracilis*	20
Outer	2	*Lobospira bicuspidata*	20
Outer	3	*Zonaria / Lobophora*	30
Outer	3	*Amphiroa gracilis*	10
Outer	3	*Amphibolis antarctica*	30
Outer	3	*Halimeda cuneata*	5
Outer	3	*Rhodymenia*	10
Outer	4	*Zonaria / Lobophora*	30
Outer	4	*Pedina*	30
Outer	4	*Amphiroa gracilis*	10
Outer	4	*Amphibolis antarctica*	10
Outer	4	*Rhodymenia*	10
Middle	1	*Pedina*	15
Middle	1	*Zonaria / Lobophora*	15
Middle	1	*Caulerpa gemiata*	5
Middle	1	*Plocamium mertensii*	25
Middle	1	*Dictyota dichotima*	5
Middle	2	*Pedina*	30
Middle	2	*Zonaria / Lobophora*	10
Middle	2	*Caulerpa gemiata*	15
Middle	2	*Dictyota dichotima*	5
Middle	2	*Lobospira bicuspidata*	10
Middle	3	*Pedina*	15
Middle	3	*Zonaria / Lobophora*	20
Middle	3	*Caulerpa gemiata*	15
Middle	4	*Zonaria / Lobophora*	40
Middle	4	*Caulerpa gemiata*	15
Middle	4	*Dictyota dichotima*	5
Middle	4	*Peysonnelia*	5
Inner	1	*Dictyota dichotima*	40
Inner	1	*Colpomenia*	20
Inner	1	*Zonaria / Lobophora*	5
Inner	2	*Dictyota dichotima*	20
Inner	2	*Colpomenia*	30
Inner	2	*Caulerpa racemosa*	5
Inner	2	*Pedina*	5
Inner	3	*Dictyota dichotima*	5
Inner	3	*Zonaria / Lobophora*	10
Inner	3	*Pedina*	10
Inner	4	*Dictyota dichotima*	20
Inner	4	*Zonaria / Lobophora*	40
Inner	4	*Pedina*	20
Inner	4	*Colpomenia*	5

Area	Quadrat	Species	Density
Outer	1	*Sargassum*	4
Outer	2	*Sargassum*	2
Outer	3	*Sargassum*	6
Outer	4	*Sargassum*	3
Middle	1	*Sargassum*	10
Middle	2	*Sargassum*	18
Middle	3	*Sargassum*	20
Middle	4	*Sargassum*	19
Middle	4	*Caulocystis uvifera*	1
Inner	1	*Sargassum*	10
Inner	2	*Sargassum*	22
Inner	3	*Sargassum*	0
Inner	4	*Sargassum*	25

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