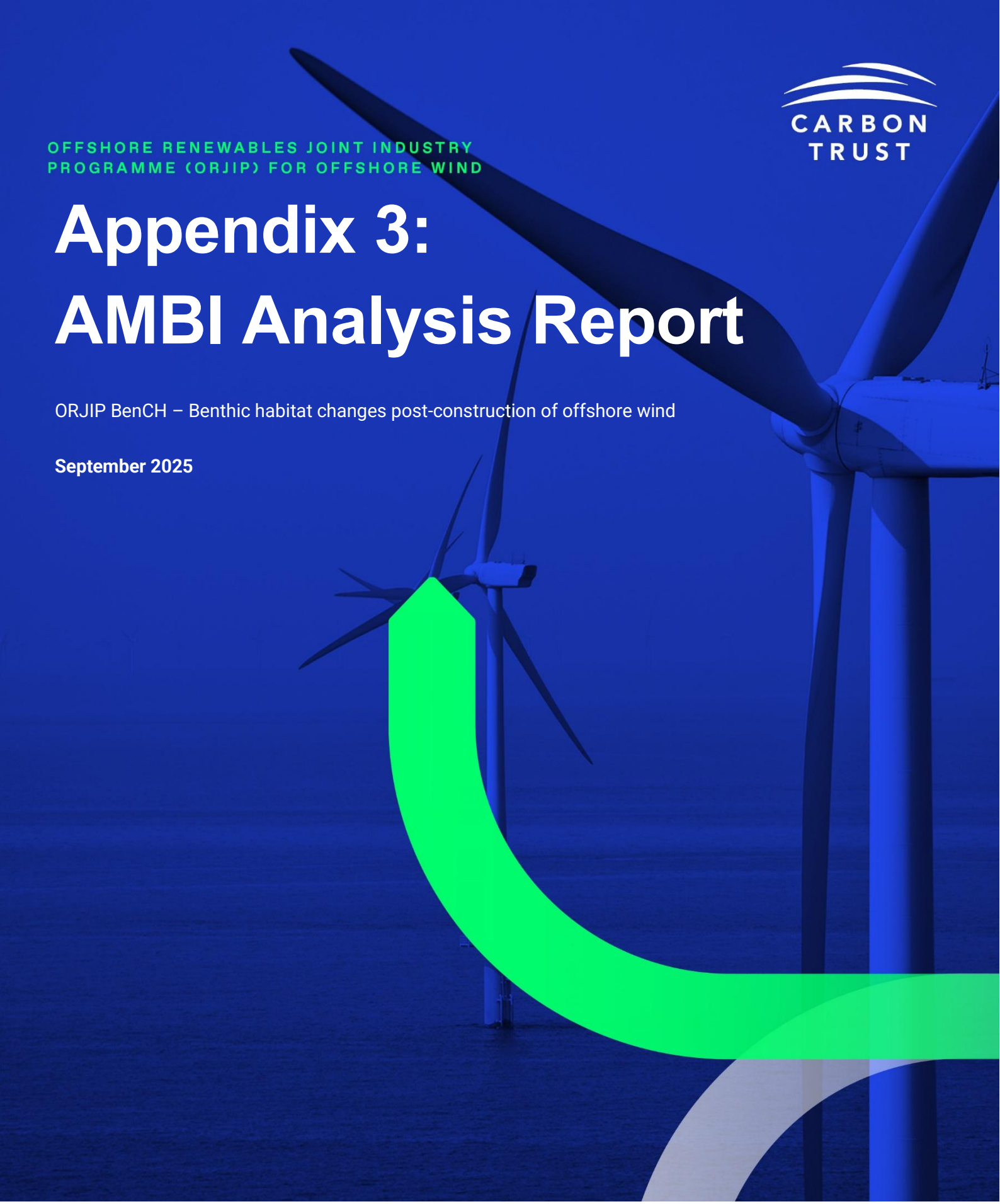

OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

Appendix 3: AMBI Analysis Report

ORJIP BenCH – Benthic habitat changes post-construction of offshore wind

September 2025

working to accelerate offshore consenting

ORJIP Offshore Wind

The Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind is a collaborative initiative that aims to:

- Fund research to improve our understanding of the effects of offshore wind on the marine environment.
- Reduce the risk of not getting, or delaying consent for, offshore wind developments.
- Reduce the risk of getting consent with conditions that reduce viability of the project.

The programme pools resources from the private sector and public sector bodies to fund projects that provide empirical data to support consenting authorities in evaluating the environmental risk of offshore wind. Projects are prioritised and informed by the ORJIP Advisory Network which includes key stakeholders, including statutory nature conservation bodies, academics, non-governmental organisations and others.

The current stage is a collaboration between the Carbon Trust, EDF Energy Renewables Limited, Ocean Winds UK Limited, Equinor ASA, Ørsted Power (UK) Limited, RWE Offshore Wind GmbH, SSE Renewables Services (UK) Limited, TotalEnergies OneTech, Crown Estate Scotland, Scottish Government (acting through the Offshore Wind Directorate and the Marine Directorate) and The Crown Estate Commissioners. For further information regarding the ORJIP Offshore Wind programme, please refer to the Carbon Trust website, or contact Ivan Savitsky (ivan.savitsky@carbontrust.com) and Žilvinas Valantiejus (zilvinas.valantiejus@carbontrust.com).

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- NatureScot
- Scottish Government's Marine Directorate

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Who we are

Our mission is to accelerate the move to a decarbonised future. We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions globally. From strategic planning and target setting to activation and communication - we are your expert guide to turn your climate ambition into impact.

We are one global network of 400 experts with offices in the UK, the Netherlands, Germany, South Africa, Singapore and Mexico. To date, we have helped set 200+ science-based targets and guided 3,000+ organisations in 70 countries on their route to Net Zero.

Contents

1. Introduction

AZTI's Marine Biotic Index (AMBI) is an ecological model that investigates the 'health' of benthic communities by classifying disturbance or pollution for a particular interest site and can detect the impact of anthropogenic pressure on the environment (Borja *et al.,* 2011). Disturbance-sensitive taxa are categorised into ecological groups according to taxon dominance along a disturbance gradient providing an insight into the ecological health of benthic communities.

AMBI was applied in the Outer Dowsing Offshore Wind Preliminary Environmental Information Report (GeoXYZ, 2023) but was not used in any of the 18 reviewed monitoring reports for OWFs. AMBI could be a useful index to apply to post-construction monitoring, noting potential localised increases in the level of deposition of organic compounds around turbine foundations addressed in APEM (2025a and b).

AMBI was proposed as a potential measure that could be investigated during WP4 to see if it could be used to detect disturbance effects from construction of OWFs and to see if any effects of organic enrichment can be detected post-construction.

2. Methodology

2.1 AMBI Analysis

The raw macrofaunal data from four OWFs using a variety of benthic sampling methods was used to apply the AMBI metric for further analysis. To perform this, the following data truncation rules were utilised (Borja and Muxika, 2005):

- Use of data restricted to soft bottom communities only; and
- Removal of the following taxa from data:
    - non-benthic invertebrates;
    - freshwater taxa;
    - In salinity >10 remove insecta;
    - Remove juveniles when the species are not identified;
    - Remove non-soft sediment taxa;
    - Remove epifaunal taxa;
    - Remove planktonic taxa;
    - Certain taxa should be grouped together (e.g. certain genus types); and
    - Never use high taxonomic levels (e.g. Bivalvia, Gastropoda), except those included in the taxon list (e.g. Nemertea etc.).

The AMBI index relies on the distribution of individual abundances of macrofaunal soft-bottom communities into five groups according to sensitivity to an increasing gradient of disturbance:

I. Disturbance sensitive species
II. Disturbance indifferent species;
III. Disturbance tolerant species;
IV. Second-order opportunistic species
V. First-order opportunistic species.

The AMBI value ranges from 0 (undisturbed) to 6 (heavily disturbed) and 7 represents azoic conditions (extremely disturbed) (WFD-UKTAG, 2014). The AMBI scores are effectively a ratio between the proportion of disturbance sensitive and tolerant taxa within a sample (Borja and Muxika, 2005), as seen in Table 1. The scores are based on the percentage of abundance of each group of one site, given by the Biotic coefficient.

$$\text{Biotic coefficient} = \left\{ \frac{(0 \times \%G_{I}) + (1.5 \times \%G_{II}) + (3 \times \%G_{III}) + (4.5 \times \%G_{IV}) + (6 \times \%G_{V})}{100} \right\}$$

Table 1. Summary of AMBI values and their equivalences

Biotic coefficient	Dominating ecological group	Benthic community health	Site disturbance classification
0.0 < AMBI ≤ 0.2	I	Normal	Undisturbed
0.2 < AMBI ≤ 1.2		Impoverished	
1.2 < AMBI ≤ 3.3	III	Unbalanced	Slightly disturbed
3.3 < AMBI ≤ 4.3	IV-V	Transitional to pollution	Moderately disturbed
4.3 < AMBI ≤ 5.0		Polluted	
5.0 < AMBI ≤ 5.5	V	Transitional to heavy pollution	Heavily disturbed
5.5 < AMBI ≤ 6.0		heavy polluted	
6.0 < AMBI ≤ 7.0	Azoic	Azoic	Extremely disturbed

*Summary table obtained from Muxika et al. (2005), modified from Borja et al. (2000)

2.2 RELATE and PERMANOVA

The RELATE function of PRIMER was utilised to find out whether there was a correlation between the following environmental metrics:

- AMBI and distance from the nearest WTG
- AMBI and total organic content (TOC (LOI%))
- TOC (LOI%) and distance from the nearest WTG

The RELATE routine uses permutation tests to estimate the likelihood of the environmental resemblance matrices sharing a similar multivariate pattern. It uses a rank correlation coefficient to measure the agreement between all the elements in the similarity matrices.

The PERMANOVA test was used to examine significant differences in AMBI scores, TOC (LOI%) and distance from the nearest WTG between sites (within array area, outside array area, export cable route (ECR), and reference), and survey phases (pre-construction, post-construction). Any significant differences would be investigated further with a pair-wise test to identify the specific site and/or survey phase where significant differences were observed.

3. Results

3.1 OWF Site 1

3.1.1 Comparison between pre- and post-construction surveys

Within Array Area

Four of the thirteen OWF stations within the array area (1c, 1e, 3a and 3d) sampled in the pre-construction survey had AMBI scores of <1.2, indicative of 'undisturbed' conditions, seven of the stations scored between 1.26 and 1.66, indicative of 'slightly disturbed' conditions, while a sample was not retrieved at two of the stations (Table 2).

Table 2. AMBI and disturbance classification summary – Site 1: within array area

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Within Array Area						
1a	1.50	1.62	1.727	Slightly disturbed	Slightly disturbed	Slightly disturbed
1b	1.39	1.58	1.691	Slightly disturbed	Slightly disturbed	Slightly disturbed
1c	1.08	1.63	1.318	Undisturbed	Slightly disturbed	Slightly disturbed
1d	1.33	1.57	1.47	Slightly disturbed	Slightly disturbed	Slightly disturbed
1e	1.12	1.53	0.639	Undisturbed	Slightly disturbed	Undisturbed
2a	1.43	1.17	1.162	Slightly disturbed	Undisturbed	Undisturbed
2b	1.66		1.089	Slightly disturbed		Undisturbed
2c	1.26	1.44	1.22	Slightly disturbed	Slightly disturbed	Slightly disturbed
2d	1.42	1.25	1.016	Slightly disturbed	Slightly disturbed	Undisturbed
3a	1.12		1.52	Undisturbed		Slightly disturbed
3b		0.91	1.761		Undisturbed	Slightly disturbed
3c		1.50*			Slightly disturbed	
3d	1.16	1.65	1.608	Undisturbed	Slightly disturbed	Slightly disturbed

*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

AMBI scores within the array area increased at seven stations between the pre-construction and first post-construction surveys. This included three of the four previously undisturbed stations (1c, 1e, 3d), which shifted to the 'slightly disturbed' classification. The remaining four stations with increased AMBI

scores remained within the ‘slightly disturbed’ category, which was consistent with their pre-construction classification.

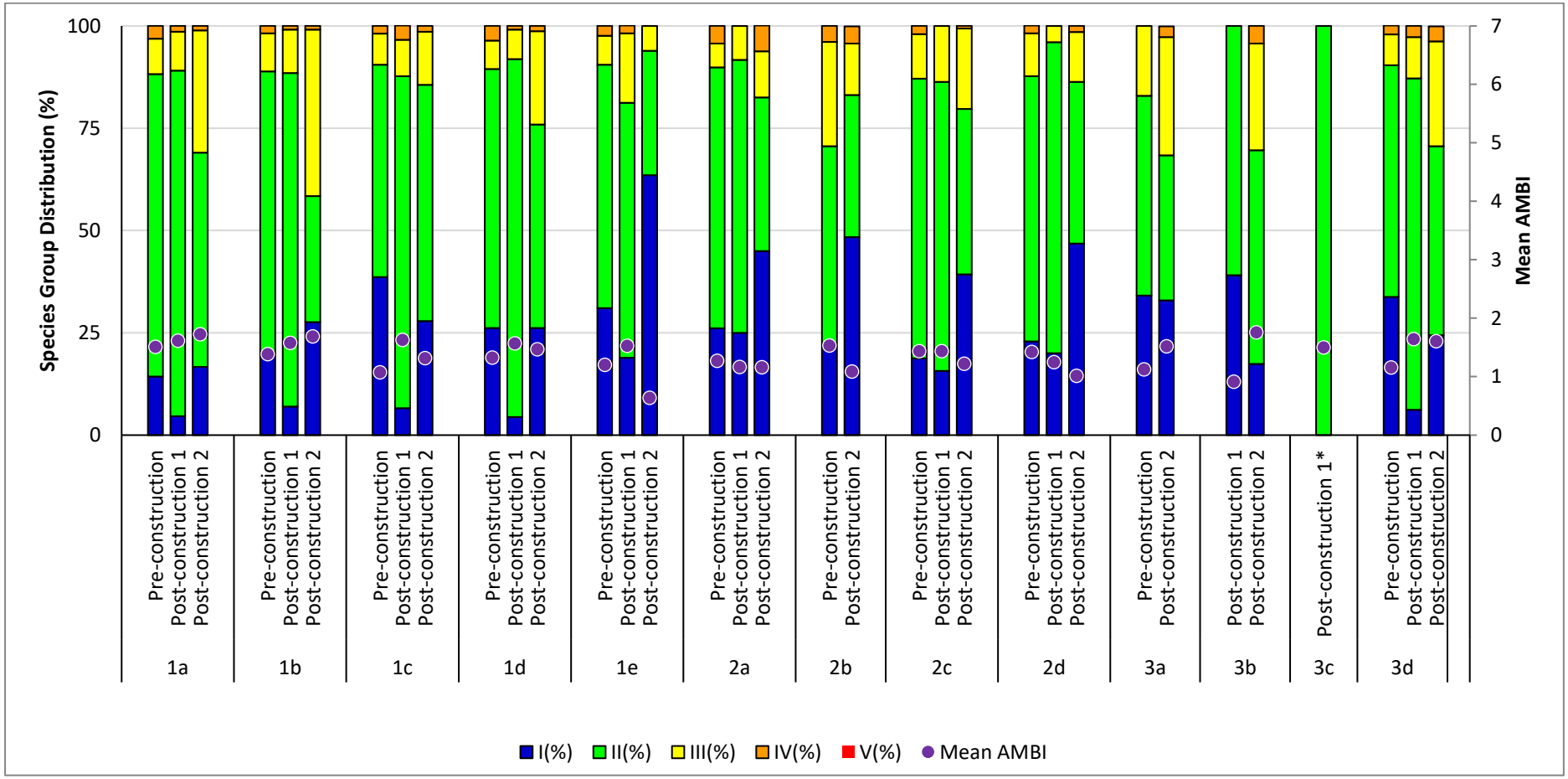
Two stations (2a and 2d) indicated decreases in AMBI scores. At one of these stations (2a), the decrease in the AMBI score was associated with a change in disturbance classification from ‘slightly disturbed’ before construction to ‘undisturbed’ in the post-construction survey.

Three stations showed increases in mean AMBI scores between the first and second post-construction surveys (stations 1a, 1b, and 3b). Stations 1a and 1b remained within the same ‘slightly disturbed’ classification, while station 3b shifted from ‘undisturbed’ to ‘slightly disturbed’ (note that this station was not sampled during the pre-construction survey). Station 3a, which was not sampled in the first post-construction survey, showed an increase in mean AMBI score between the pre-construction survey and the second post-construction survey. The remaining eight stations sampled during the second post-construction survey all showed a decrease in mean AMBI scores compared to the preceding survey—or, for those not sampled in the first post-construction survey, compared to the pre-construction survey. Of those eight stations, two showed a change in disturbance classification from ‘slightly disturbed’ to "undisturbed."

The range of AMBI scores across stations and survey periods is provided in Figure 2 and it indicates that overall, AMBI values generally remain within a narrow range, with low variability temporally and across stations. No consistent trends are apparent in the data from within the OWF array area across the construction and post-construction period (Figure 2). The consistency of AMBI scores, with only relatively minor fluctuations, along with limited changes in disturbance classification, suggests a relatively stable benthic community across the survey periods.

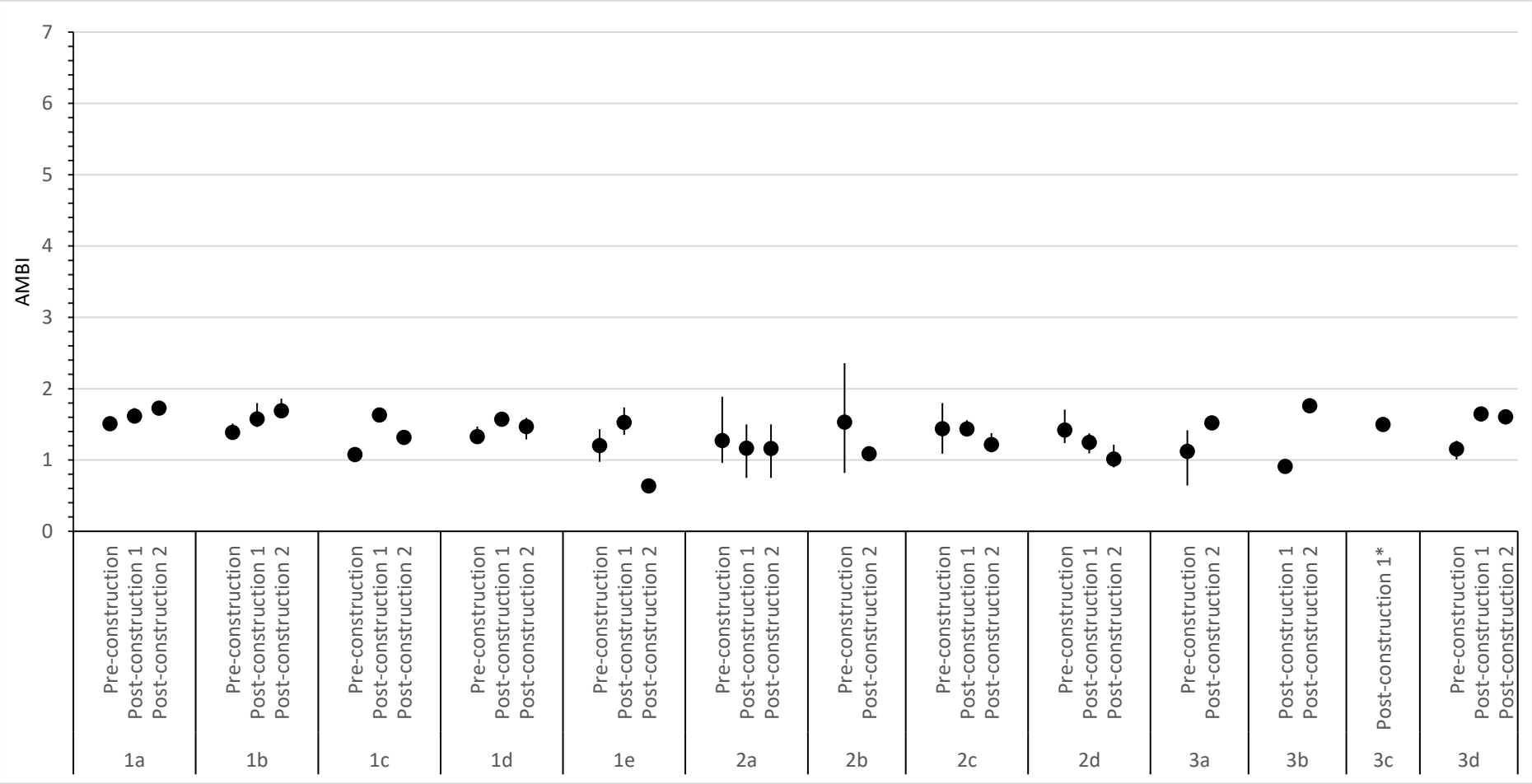
Figure 1 indicates the contribution of AMBI ecological groups at each station with group I made up of species sensitive to disturbance and group V made up of first-order opportunistic species adapted to highly disturbed environments. Within the array area the majority of stations were dominated by group II species (those indifferent to environmental disturbance) across all survey years. The contribution of group I species is variable across survey years. At 11 of the 13 stations the proportion of group I species decreased between the pre-construction and first post-construction surveys, which may reflect environmental disturbance within the array area during construction. However, the proportion of group I species increases again by the second post-construction survey to the previous levels and exceeds those levels at eight of the stations. There is generally low representation of groups III, IV and V (disturbance tolerant and opportunistic taxa) across all stations within the array area.

Figure 1. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period– Site 1: within array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 2. AMBI score range observed during the survey period – Site 1: within array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Outside Array Area

Of the eight stations located outside the OWF array area, one station (4a) had an AMBI score of <1.2 ('undisturbed') during the pre-construction survey. The remaining seven stations had AMBI scores between 1.26 and 2.12, falling within the 'slightly disturbed' classification (Table 3).

Five stations indicated an increase in AMBI score during the first post-construction survey. Two of these (4a ['undisturbed' to 'slightly disturbed'] and 5c ['slightly disturbed' to 'moderately disturbed']) were associated with changes in disturbance classification. At two stations there was a decrease in AMBI score between pre- and post-construction surveys (4e and 5b) with station 5b also showing an associated change in classification from 'slightly disturbed' to 'undisturbed'.

For three stations there was an increase in AMBI score between the first and second post-construction surveys, with one of these (4b) changing disturbance classification (from 'slightly disturbed' to 'moderately disturbed'). Station 5a was not sampled during the first post-construction survey, but had an increase in AMBI score between the pre-construction survey and the second post-construction survey, but no change in disturbance classification. The remaining four stations all had a decrease in AMBI score between the first and second post-construction surveys with two of these also moving from a 'slightly disturbed' classification to an 'undisturbed' classification (4e) or from 'moderately disturbed' to 'slightly disturbed'(5c). Figure 6 indicates the range of AMBI scores across stations outside the array area and the reference stations for different survey periods and indicates the range of scores was generally more variable than those within the array area, with no consistent trends evident.

Overall, the mean temporal change and fluctuations in AMBI scores and disturbance classification at the stations outside of the array area were generally comparable to those within the OWF array area.

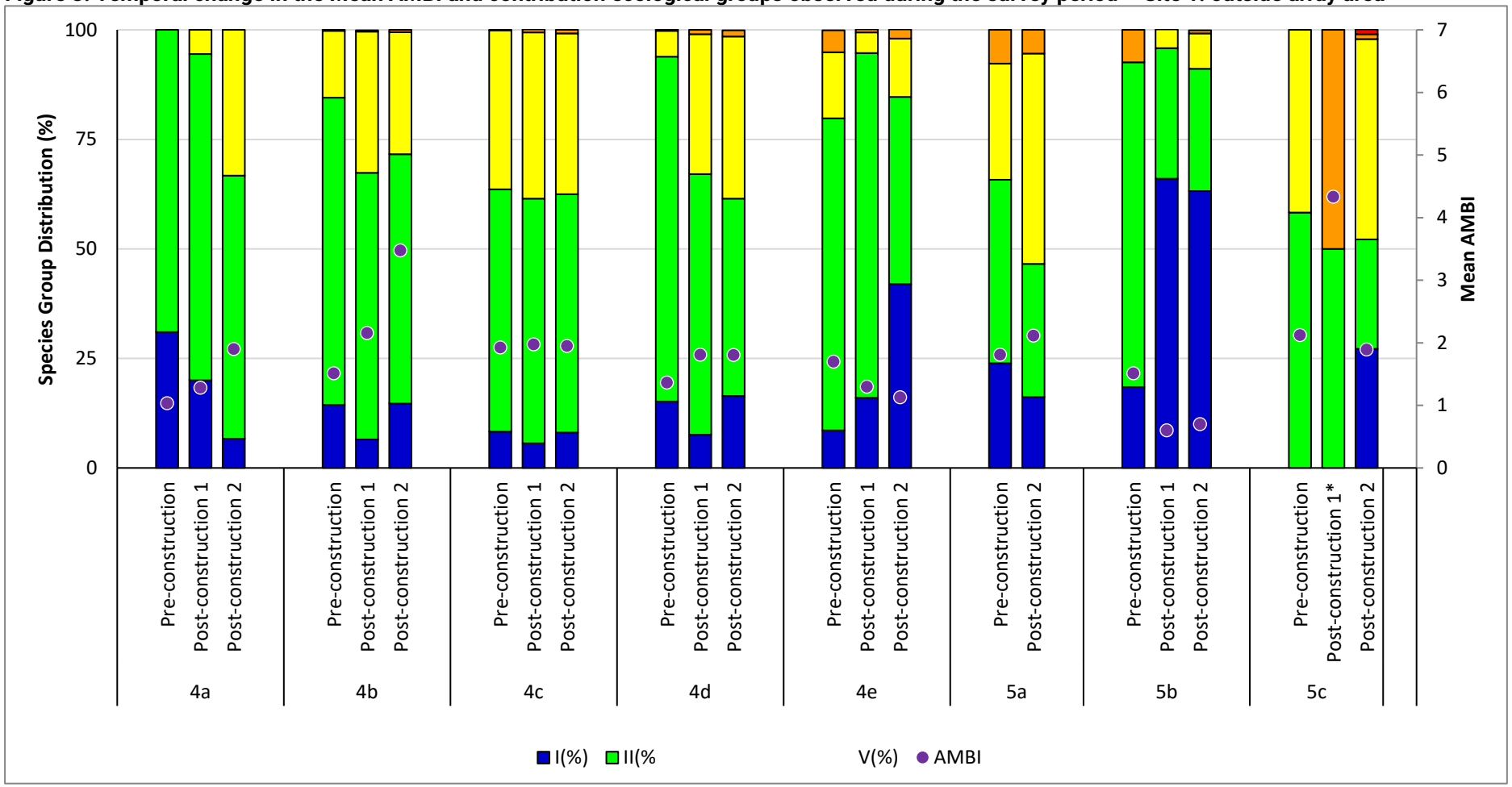
Fluctuations in the contribution of AMBI ecological groups I to IV were observed in between surveys, but no consistent trends were evident (Figure 3). Similar to the stations within the array area, the majority of stations were dominated by group II species (those indifferent to environmental disturbance) across all survey years, although the proportion of group III species (tolerant to disturbance) was greater in these stations than in the stations within the array area. The contribution of group I species fluctuated between survey years with only two stations (4a and 5a) showing a lower proportion of this group between the pre-construction survey and the second post-construction survey.

Table 3. AMBI and disturbance classification summary – Site 1: outside array area

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Outside Array Area						
4a	1.12	1.28	1.9	Undisturbed	Slightly disturbed	Slightly disturbed
4b	1.61	2.15	3.476	Slightly disturbed	Slightly disturbed	Moderately disturbed
4c	1.93	1.97	1.949	Slightly disturbed	Slightly disturbed	Slightly disturbed
4d	1.36	1.81	1.804	Slightly disturbed	Slightly disturbed	Slightly disturbed
4e	1.70	1.30	1.126	Slightly disturbed	Slightly disturbed	Undisturbed
5a	1.81		2.115	Slightly disturbed		Slightly disturbed
5b	1.51	0.60	0.701	Slightly disturbed	Undisturbed	Undisturbed
5c	2.12	4.33*	1.892	Slightly disturbed	Moderately disturbed	Slightly disturbed

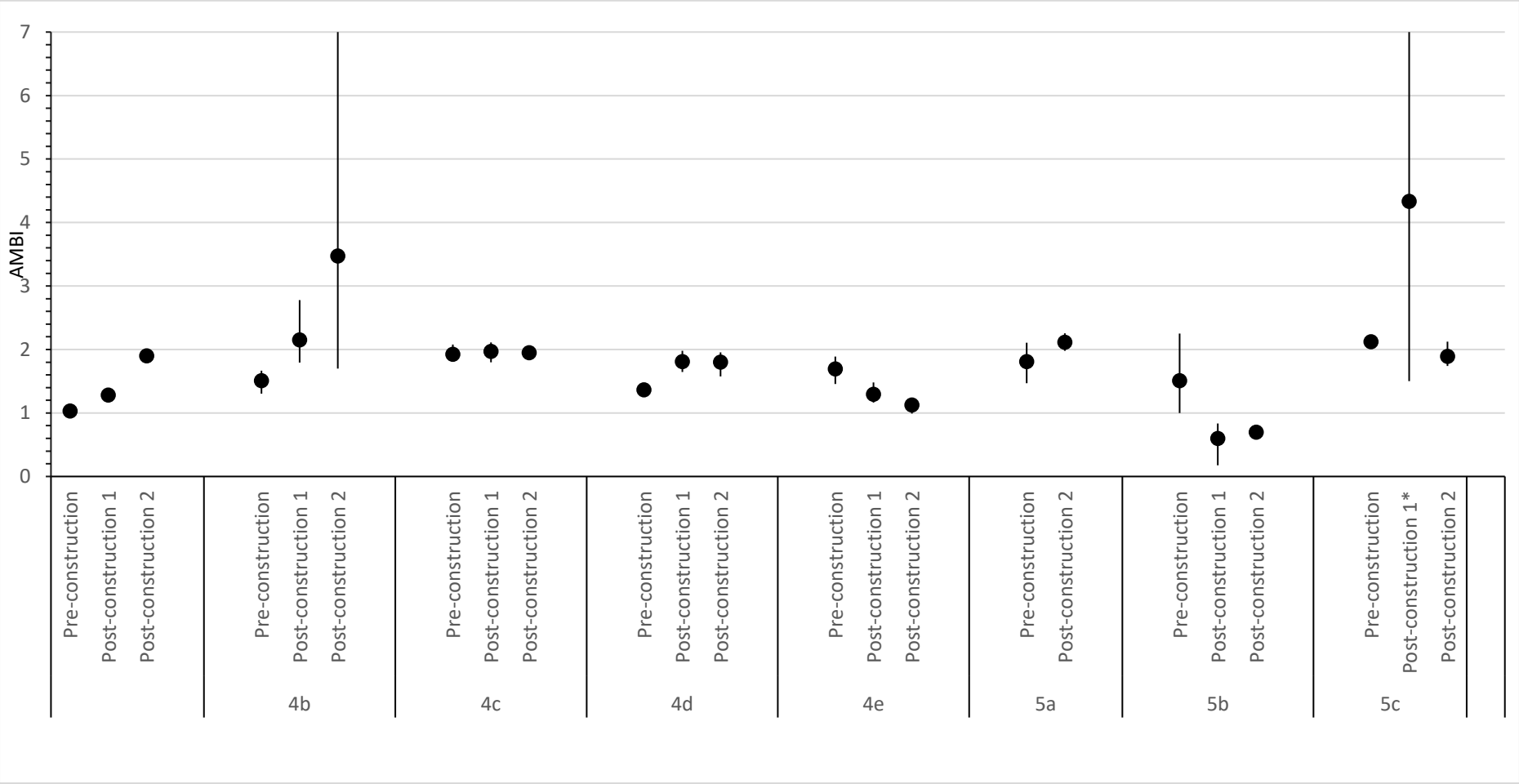
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 3. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 1: outside array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 4. AMBI score range observed during the survey period – Site 1: outside array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Reference Stations

All reference stations were classified as 'slightly disturbed' during the pre-construction survey with the exception of station 6c, which was 'undisturbed' (Table 4). At all reference stations there was an increase in mean AMBI scores during the first post-construction survey, however these increases were relatively minor and did not correspond to a change in disturbance classification at any of the stations.

The AMBI scores slightly decreased at two stations during the second post-construction survey, and slightly increased at the other two stations, none of which corresponded to a change in disturbance classifications, which remained stable at all stations across the monitoring period.

Similar to stations within and outside the array area, group II taxa dominated the ecological group composition with the exception of station 6c at which group I taxa dominated across the survey years (Figure 5). The proportion of group I taxa increased between the pre-construction survey and the second post-construction survey at all of the reference stations with the exception of station 6c where the proportion of group I taxa remained relatively stable.

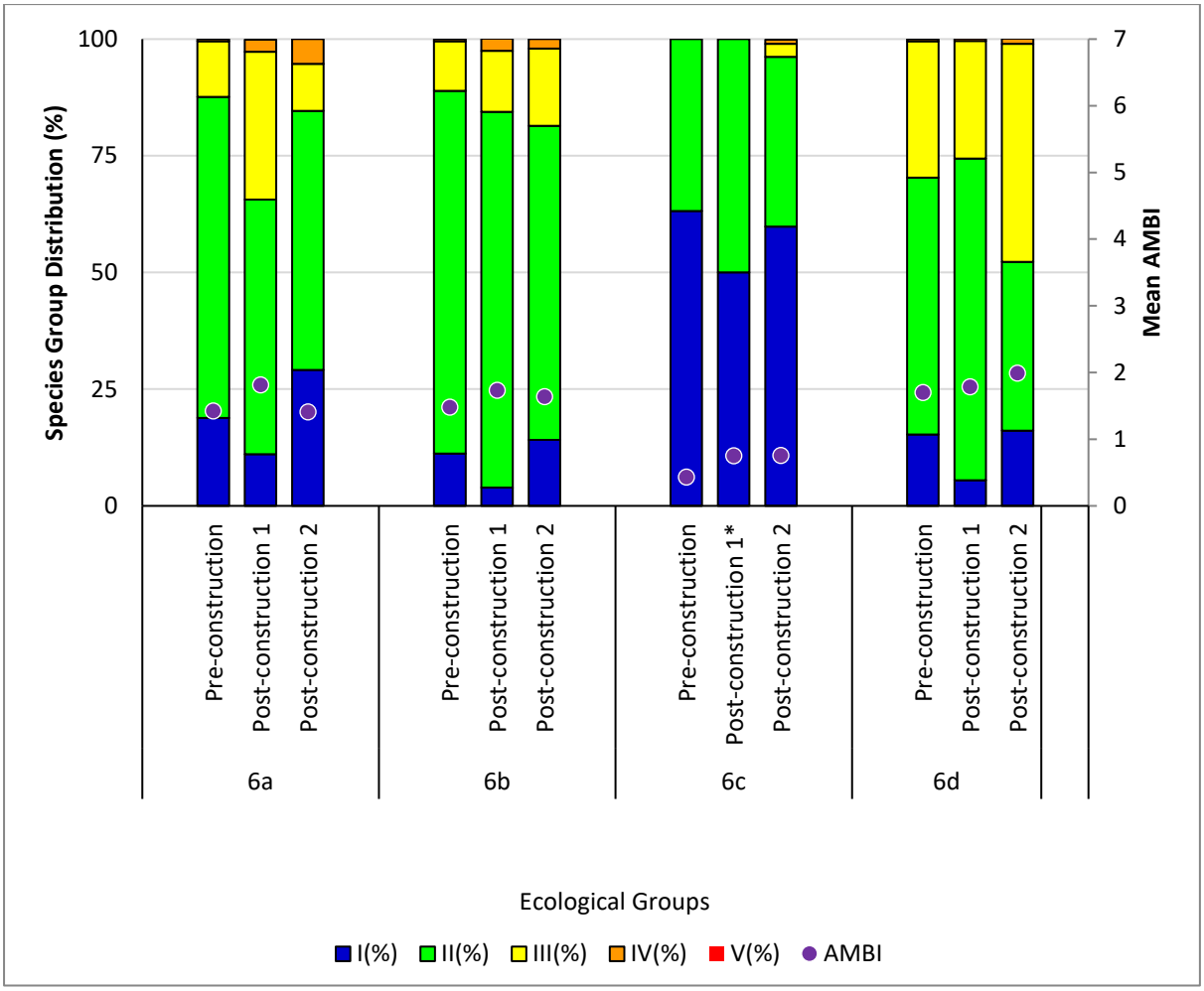
In general, AMBI scores and the composition of ecological groups across all stations, including the reference stations indicated minor changes across survey years, with disturbance classifications remaining relatively stable. There were no consistent trends in the AMBI data, across all three site areas and no clear spatial patterns.

Table 4. AMBI and disturbance classification summary – Site 1: reference

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Reference						
6a	1.42	1.81	1.41	Slightly disturbed	Slightly disturbed	Slightly disturbed
6b	1.48	1.73	1.639	Slightly disturbed	Slightly disturbed	Slightly disturbed
6c	0.43	0.75*	0.754	Undisturbed	Undisturbed	Undisturbed
6d	1.70	1.79	1.992	Slightly disturbed	Slightly disturbed	Slightly disturbed

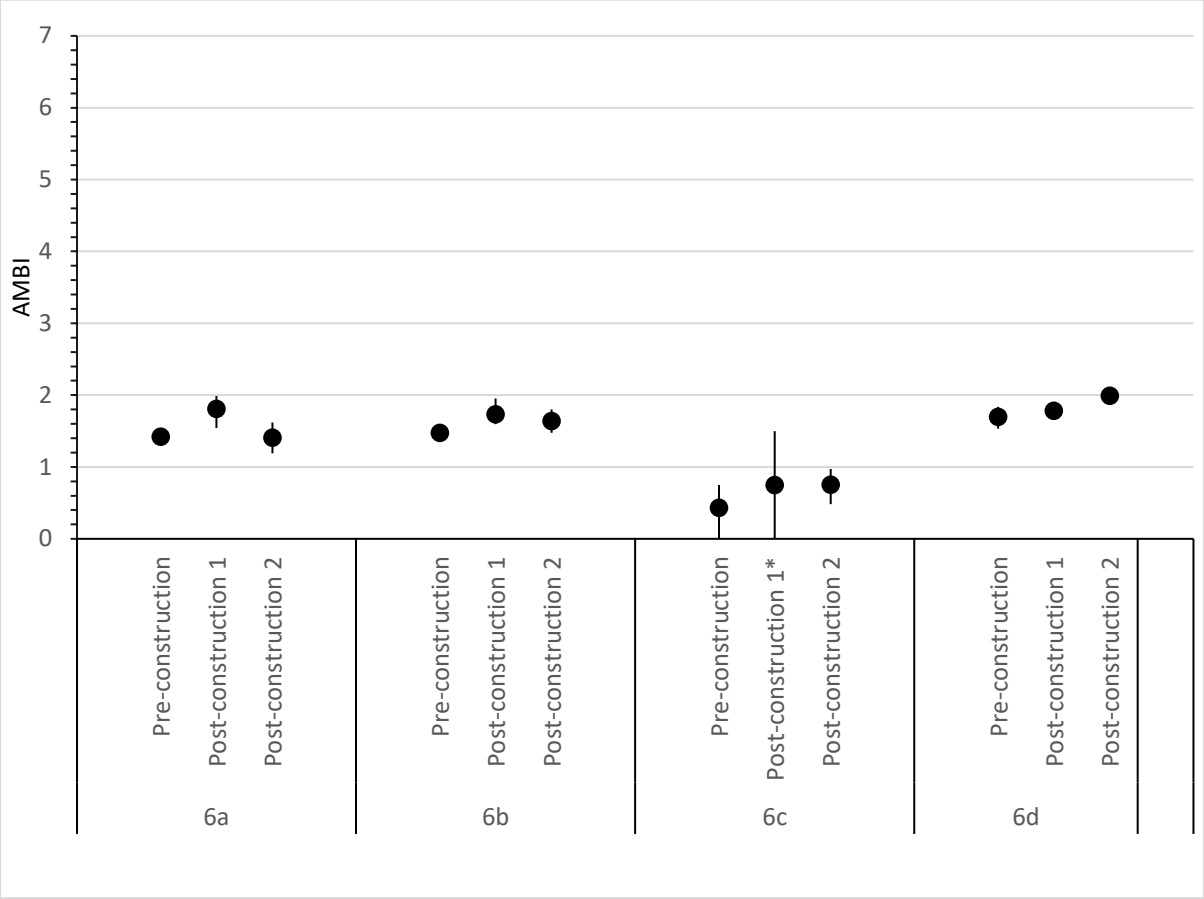
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 5. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 1: reference



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 6. AMBI score range observed during the survey period – Site 1: reference



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

3.1.2 Statistical Analysis and Comparison

The RELATE function of PRIMER identified a significant correlation between AMBI scores and the distance of stations from the nearest wind turbine generator (WTG) within the array area and outside the array area (Table 5). However, this correlation was observed for the first post-construction survey only. AMBI scores increased at seven of the 11 stations within the array area between the pre- and first post-construction survey (Table 2), indicating that there is some potential that the installation of the turbines may have influenced the AMBI scores at these stations during this period although changes were generally small scale. At three of these sites, the disturbance classification changed from 'undisturbed' pre-construction to 'slightly disturbed' for the first post construction survey, however, it should be noted that the majority of stations were already classed as 'slightly disturbed' during the pre-construction survey.

No correlation was identified between AMBI scores and TOC across the array area and across all survey years suggesting that TOC has not affected the AMBI scores at this OWF. Similarly, within the array area, there was no correlation between distance of a station from nearest WTG and TOC.

Table 5. RELATE analyses output comparing correlations between AMBI, TOC (LOI%) and distance from nearest wind turbine generator (WTG)

Groups	Survey Phase	Sample statistic (Rho):	Significance level of sample statistic:
Within Array Area			
AMBI vs Distance from WTG	Pre – construction[1]	-0.012	47%
	Post – construction 1	0.298	4.7%
	Post – construction 2	0.183	16%
AMBI vs TOC (LOI%)	Pre – construction	-0.021	49.6%
	Post – construction 1	0.15	17.3%
	Post – construction 2	-0.131	79.1%
Distance from WTG vs TOC (LOI%)	Pre – construction	0.215	9..6%
	Post – construction 1	0.067	23.2%
	Post – construction 2	0.008	44.2%
Outside Array Area			
AMBI vs Distance from WTG	Pre – construction	0.304	7.7%
	Post – construction 1	0.693	4.3%
	Post – construction 2	-0.233	91.7%
AMBI vs TOC (LOI%)	Pre – construction	-0.215	85.5%
	Post – construction 1	-0.147	58.4%
	Post – construction 2	0.041	38.6%
Distance from WTG vs TOC (LOI%)	Pre – construction	0.077	31.3%
	Post – construction 1	-0.075	51.5%
	Post – construction 2	-0.263	95.8%
Reference			
AMBI vs Distance from WTG	Pre – construction	0.278	30.1%
	Post – construction 1	0.309	26%
	Post – construction 2	0.278	30.2%
AMBI vs TOC (LOI%)	Pre – construction	-0.086	51.2%
	Post – construction 1	0.771	21.1%
	Post – construction 2	0.714	16.7%
Distance from WTG vs TOC (LOI%)	Pre – construction	-0.37	83.1%
	Post – construction 1	0.123	50.1%
	Post – construction 2	0.123	49.7%

A PERMANOVA test examining significant differences in AMBI scores between survey phases and site location (within array area, outside array area and reference) indicated an overall significant effect of site location (Pseudo-F = 4.4586; P (perm) = 0.013) but not survey phase (Pseudo-F = 0.74251; P(perm) = 0.475). Pairwise PERMANOVA models and raw data confirmed that the only significant difference

[1] For pre-construction the distance is relative to where the WTG was planned to be constructed, so there would be no influence of WTGs.

was between the AMBI scores within the array area and outside the array area (Table 6), with AMBI scores generally slightly higher outside the array area during the pre-construction survey (Table 2).

There was no significant difference in AMBI scores between the array area and reference sites, or between the reference area and outside the array during the pre-construction phase. Additionally, there was no significant difference in AMBI scores between sites in either of the post-construction surveys, suggesting that construction of the OWF did not result in significant changes to AMBI scores within the array area relative to the reference stations.

Table 6. PERMANOVA output comparing AMBI scores for stations at different site locations for pre-construction and post-construction surveys.

Groups	t value*	p value
Pre-construction		
Within Array vs Outside Array Area	2.8665	0.007
Within Array Area vs Reference	0.3088	0.764
Outside Array Area vs Reference	1.5544	0.153
Post-construction 1		
Within Array vs Outside Array Area	1.3157	0.224
Within Array Area vs Reference	0.51209	0.633
Outside Array Area vs Reference	0.63154	0.617
Post-construction 2		
Within Array vs Outside Array Area	1.8273	0.086
Within Array Area vs Reference	0.318	0.767
Outside Array Area vs Reference	0.93809	0.378

* a lower t-value indicates the between-group variation is smaller compared to within-group variation when compared to a higher t-value.

A PERMANOVA test examining significant differences in TOC (LOI) between survey phases and sites indicated an overall significant effect of site location (Pseudo-F = 4.4849; P (perm) = 0.013) and survey phase (Pseudo-F = 31.073; P(perm) = 0.001). The Pairwise PERMANOVA test (Table 7, Table 8) and raw data identified the following trends:

- **Post-construction surveys 1 and 2:** TOC (LOI%) at the reference stations was significantly higher than stations within the array area
- **Post-construction 2:** TOC (LOI%) at the reference stations was significantly higher than at the stations outside the array area
- **Within Array Area:**
  - TOC (LOI%) in the pre-construction survey was significantly higher than the post-construction surveys
  - TOC (LOI%) in the first post-construction survey was significantly higher than the second post-construction survey
- **Outside Array Area**: TOC (LOI%) in the pre-construction survey was significantly higher than the post-construction surveys

There was no significant difference in TOC (LOI%) between site locations during the pre-construction phase (Table 7).

Overall, the PERMANOVA output and consideration of associated data suggests a decrease in TOC (LOI%) within the array area during the survey period. No significant difference in TOC (LOI%) was observed between surveys at the reference stations (Table 8).

Table 7. PERMANOVA output comparing OWF and Reference station TOC (LOI%) for pre-construction and post-construction surveys

Groups	t value*	p value
Pre-construction		
Within Array vs Outside Array Area	1.0701	0.322
Within Array Area vs Reference	0.89717	0.384
Outside Array Area vs Reference	1.4644	0.163
Post-construction 1		
Within Array vs Outside Array Area	0.13597	0.899
Within Array Area vs Reference	2.2879	0.034
Outside Array Area vs Reference	1.5463	0.177
Post-construction 2		
Within Array vs Outside Array Area	1.8575	0.051
Within Array Area vs Reference	4.4423	0.004
Outside Array Area vs Reference	2.3319	0.035

* a lower t-value indicates the between-group variation is smaller compared to within-group variation when compared to a higher t-value.

Table 8. PERMANOVA output comparing TOC (LOI%) within the array area, outside the array area and reference stations for pre-construction and post-construction surveys

Groups	t value*	p value
Within Array Area		
Pre-construction vs post-construction 1	5.0127	0.001
Pre-construction vs post-construction 2	6.2429	0.001
Post-construction 1 vs post-construction 2	3.8504	0.002
Outside Array Area		
Pre-construction vs post-construction 1	3.6036	0.009
Pre-construction vs post-construction 2	4.3566	0.002
Post-construction 1 vs post-construction 2	0.59963	0.561
Reference		
Pre-construction vs post-construction 1	1.743	0.114
Pre-construction vs post-construction 2	1.7227	0.096
Post-construction 1 vs post-construction 2	0.056633	0.889

* a lower t-value indicates the between-group variation is smaller compared to within-group variation when compared to a higher t-value.

3.2 OWF Site 2

3.2.1 Comparison between pre and post construction surveys

Within Array Area

Fourteen of the 15 stations within the array area scored <1.2 in the pre-construction survey, indicative of 'undisturbed' conditions. The exception was Station 17 with an AMBI score 2.14, indicative of 'slightly disturbed' conditions (Table 9).

Eight stations with 'undisturbed' conditions in the pre-construction survey remained 'undisturbed' in all post-construction surveys, while Station 17 remained 'Slightly disturbed'.

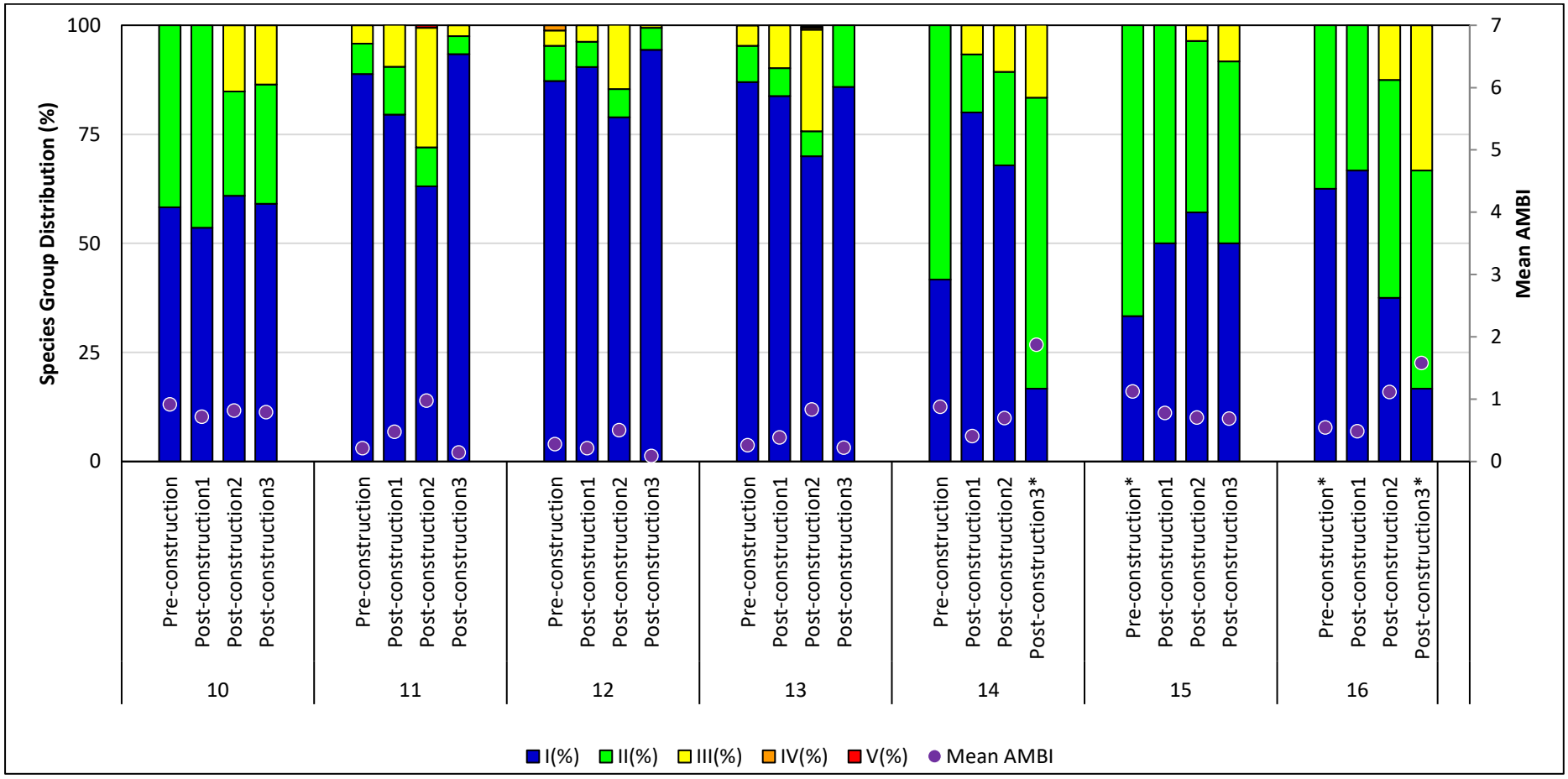
Three stations (18, 19 and 20) went from 'undisturbed' in the pre-construction phase to 'slightly disturbed' in all post-construction surveys. Two Stations (14 and 16) were 'undisturbed' for the majority of the survey period until the final post-construction survey (slightly disturbed), while Station 24 went from 'undisturbed' (pre-construction) to 'slightly disturbed (first post-construction) before returning to 'undisturbed' conditions for the remaining two survey periods. There was some variability in AMBI scores across replicate samples at most stations, which was more evident at Stations 16 to 19 (Figure 8).

Figure 7 shows the contribution of AMBI ecological groups at each station. Stations 10-14 and 21-24 are dominated by group I (disturbance sensitive species) with little variability between pre- and post-construction survey periods. Stations 15 and 16 show ecological group contributions are more balanced between groups I and II with little variability between survey periods. Stations 17 to 20 are generally dominated by group III (disturbance tolerant species). Of note is a shift from group I dominance at stations 18-20 during the pre-construction survey to group III dominance across the post-construction surveys. As described above, this change in ecological group dominance was reflected in a change in AMBI disturbance classification from 'undisturbed' to 'slightly disturbed' at these stations. This may reflect some localised influence of the OWF infrastructure at these stations.

Table 9. AMBI and disturbance classification summary – Site 2: within array area

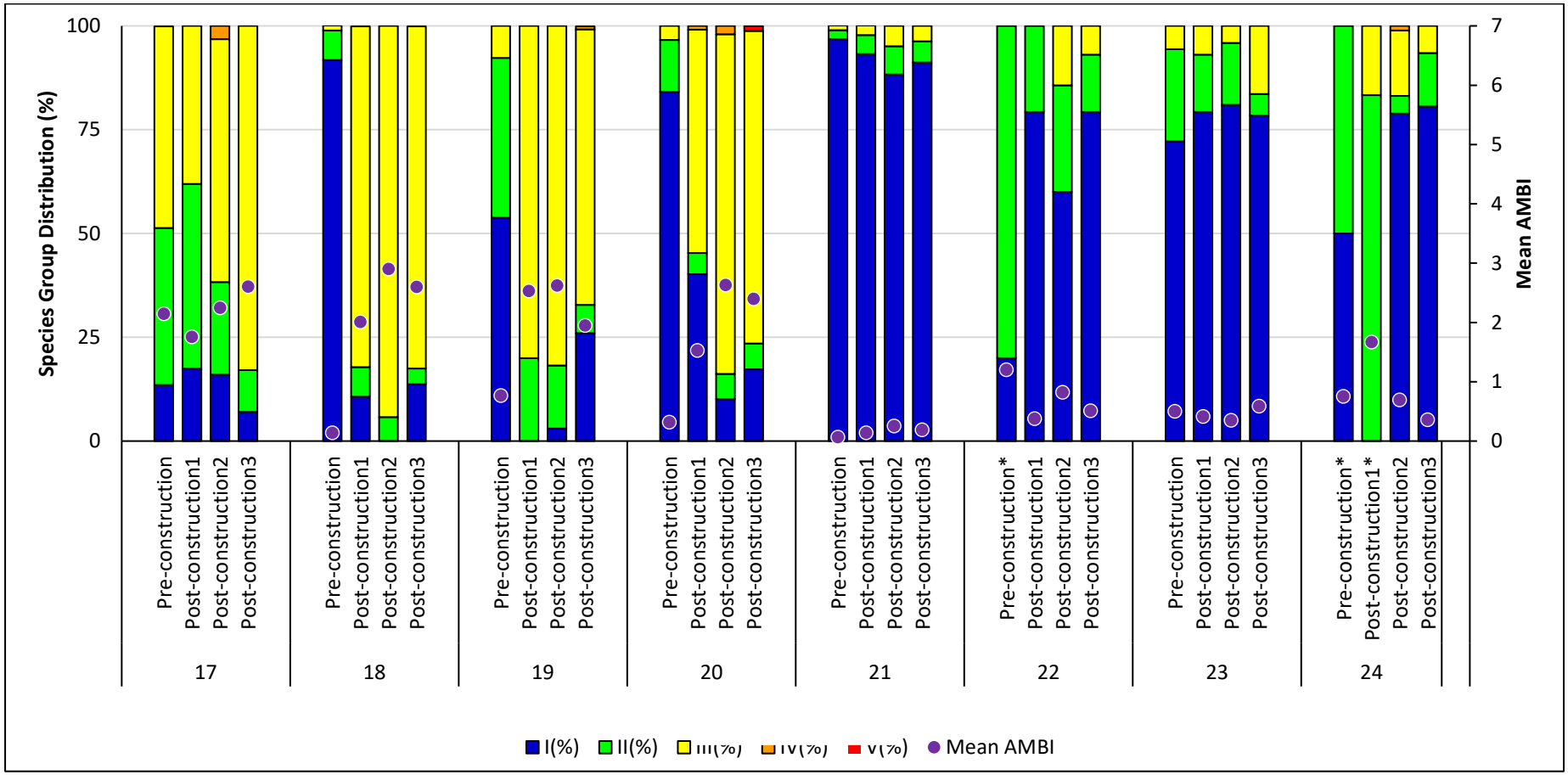
Station	Average AMBI score				Disturbance classification			
	Pre	Post1	Post2	Post3	Pre	Post1	Post2	Post3
Within Array Area								
10	0.92	0.72	0.82	0.79	Undisturbed	Undisturbed	Undisturbed	Undisturbed
11	0.22	0.48	0.98	0.15	Undisturbed	Undisturbed	Undisturbed	Undisturbed
12	0.28	0.22	0.50	0.09	Undisturbed	Undisturbed	Undisturbed	Undisturbed
13	0.26	0.39	0.84	0.22	Undisturbed	Undisturbed	Undisturbed	Undisturbed
14	0.88	0.41	0.70	1.88	Undisturbed	Undisturbed	Undisturbed	Slightly disturbed
15	1.13	0.78	0.71	0.69	Undisturbed	Undisturbed	Undisturbed	Undisturbed
16	0.55	0.49	1.12	1.58	Undisturbed	Undisturbed	Undisturbed	Slightly disturbed
17	2.14	1.75	2.25	2.61	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
18	0.14	2.01	2.90	2.60	Undisturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
19	0.77	2.53	2.62	1.95	Undisturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
20	0.32	1.53	2.63	2.40	Undisturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
21	0.07	0.14	0.25	0.19	Undisturbed	Undisturbed	Undisturbed	Undisturbed
22	1.20	0.38	0.82	0.51	Undisturbed	Undisturbed	Undisturbed	Undisturbed
23	0.50	0.42	0.35	0.59	Undisturbed	Undisturbed	Undisturbed	Undisturbed
24	0.75	1.67	0.69	0.36	Undisturbed	Slightly disturbed	Undisturbed	Undisturbed

Figure 7. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 2: within array area



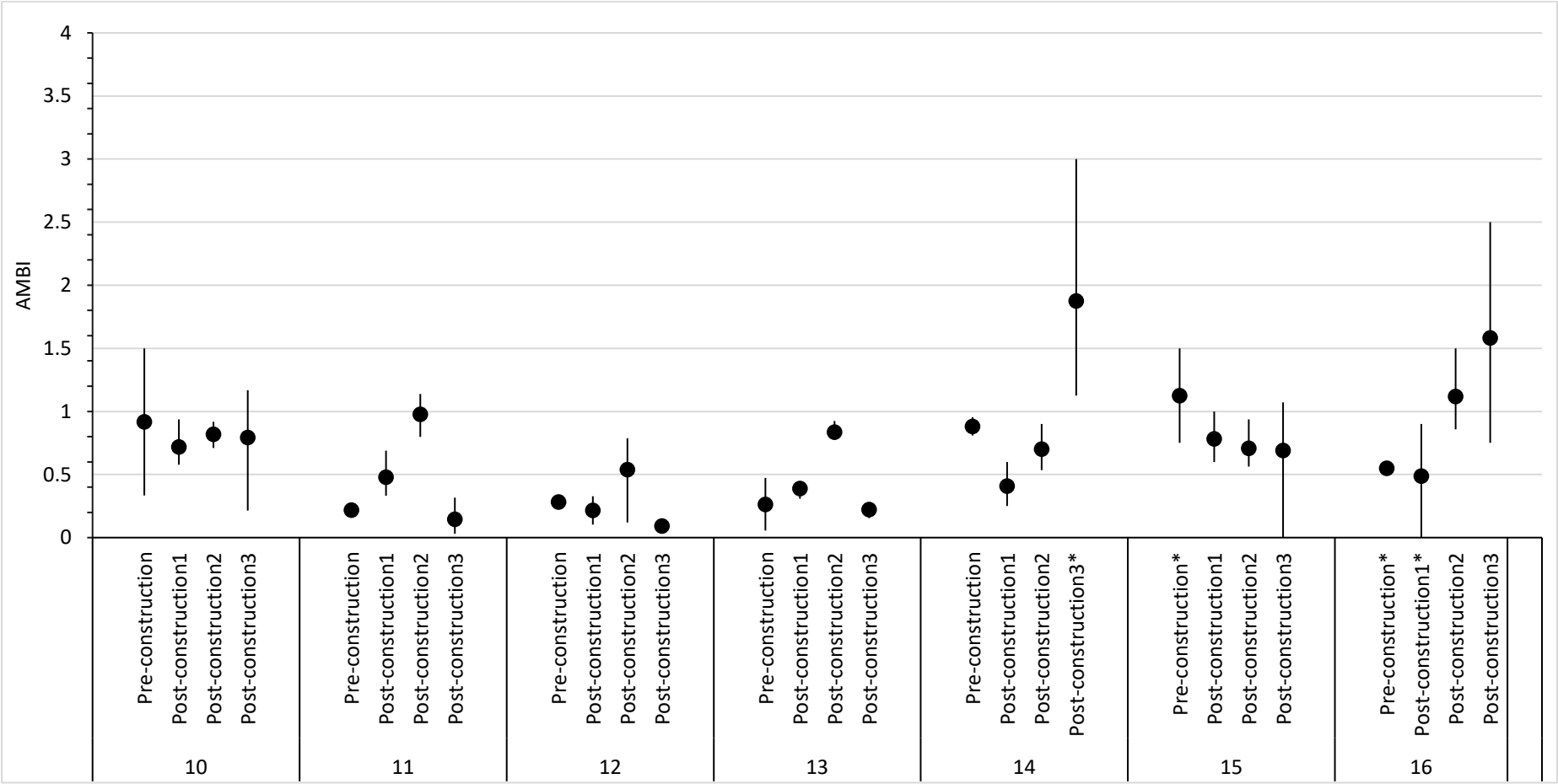
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 7. (cont.) Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 2: within array area



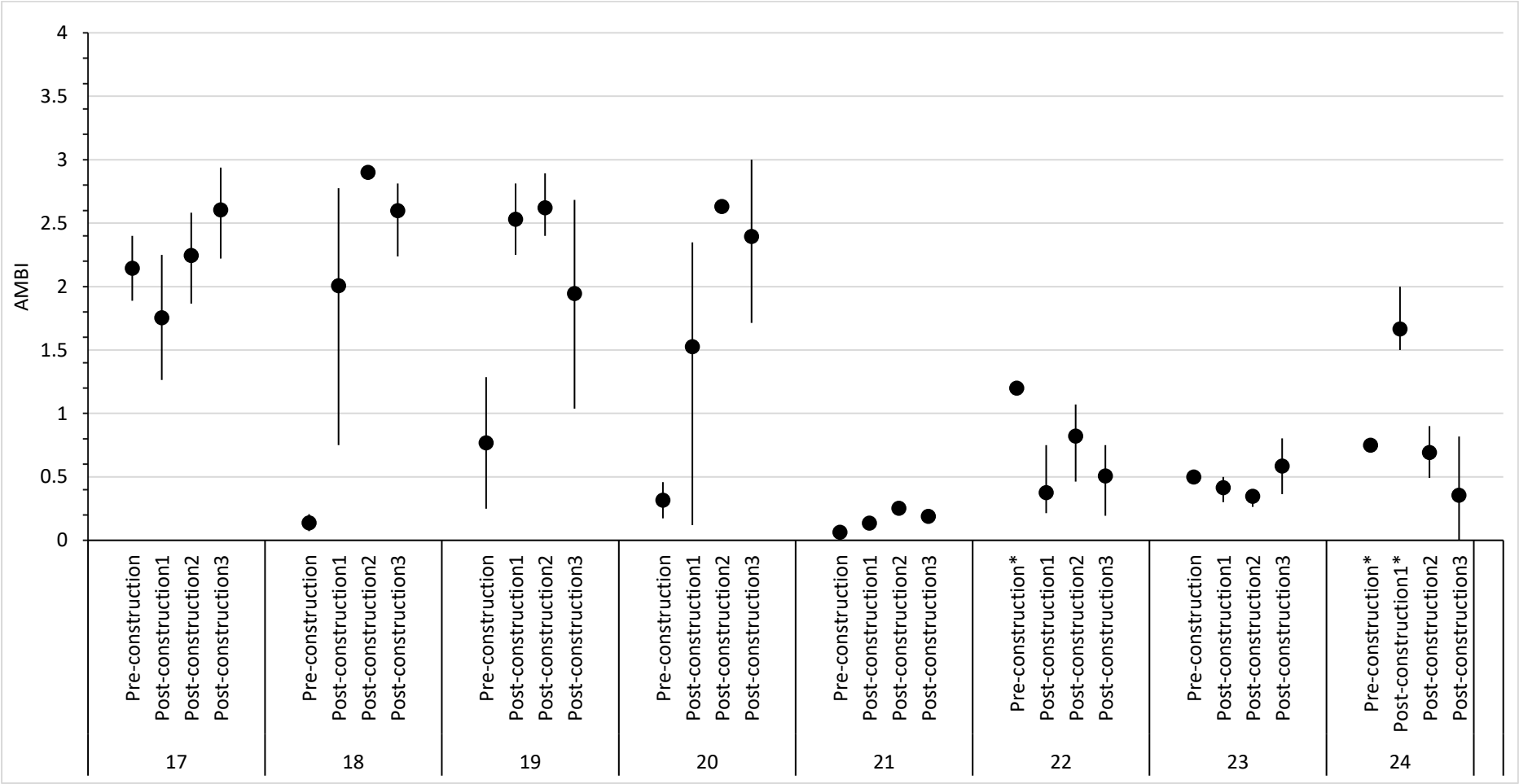
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 8. AMBI score range observed during the survey period – Site 2: within array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 8. (Cont.) AMBI score range observed during the survey period – Site 2: within array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Export Cable Route

Two of the five stations located along the export cable route (stations 6 and 7) had AMBI scores ≤1.2 during the pre-construction survey, indicating 'undisturbed' conditions. Three stations were classified as 'slightly disturbed' (stations 5, 8 and 9) (Table 10).

Only one station had a classification change during the first post-construction survey with station 7 shifting from 'undisturbed' to 'slightly disturbed'. The AMBI score at station 5 increased while the AMBI scores at the three remaining stations all decreased during the first post-construction survey. These changes in AMBI scores did not result in changes in the pre-construction disturbance classifications.

No classification changes occurred between the first and second post-construction surveys, with all stations maintaining their status from the previous period. During the third post-construction survey, station 6 shifted from 'undisturbed' to 'slightly disturbed'. All other stations maintained their disturbance classifications from the previous survey, with stations 5, 7, 8, and 9 remaining 'slightly disturbed' throughout the final three monitoring periods.

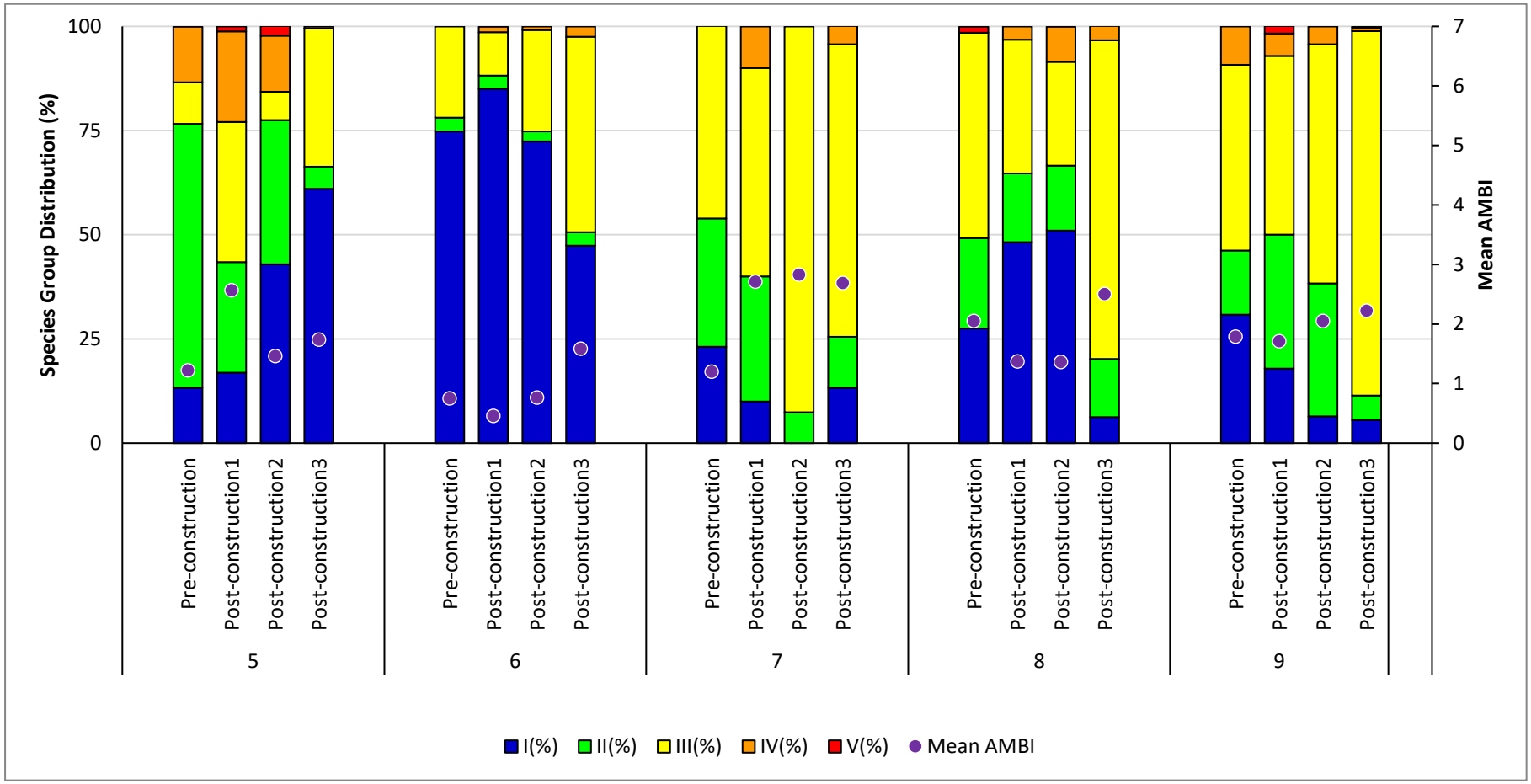
In comparison to the stations within the array (Figure 8), there was generally a greater degree of variability in AMBI scores across replicate samples at the ECR (Figure 10).

AMBI ecological groups I to III were the largest contributors to the benthic ecological communities (Figure 9). Groups I to III contributed similarly at station 5 with small contributions from group IV and V also evident. Notably, the contribution of group I (disturbance sensitive species) increased with each passing survey period. Group I species dominated at station 6 whereas group III (disturbance tolerant) species generally dominated at stations 7, 8 and 9. The contribution of ecological group IV (second-order opportunistic species) was notably higher compared to the stations within the array area. Fluctuations in the contribution of each AMBI ecological group were also observed in between surveys, but generally no consistent patterns were visible.

Table 10. AMBI and disturbance classification summary – Site 2 – ECR

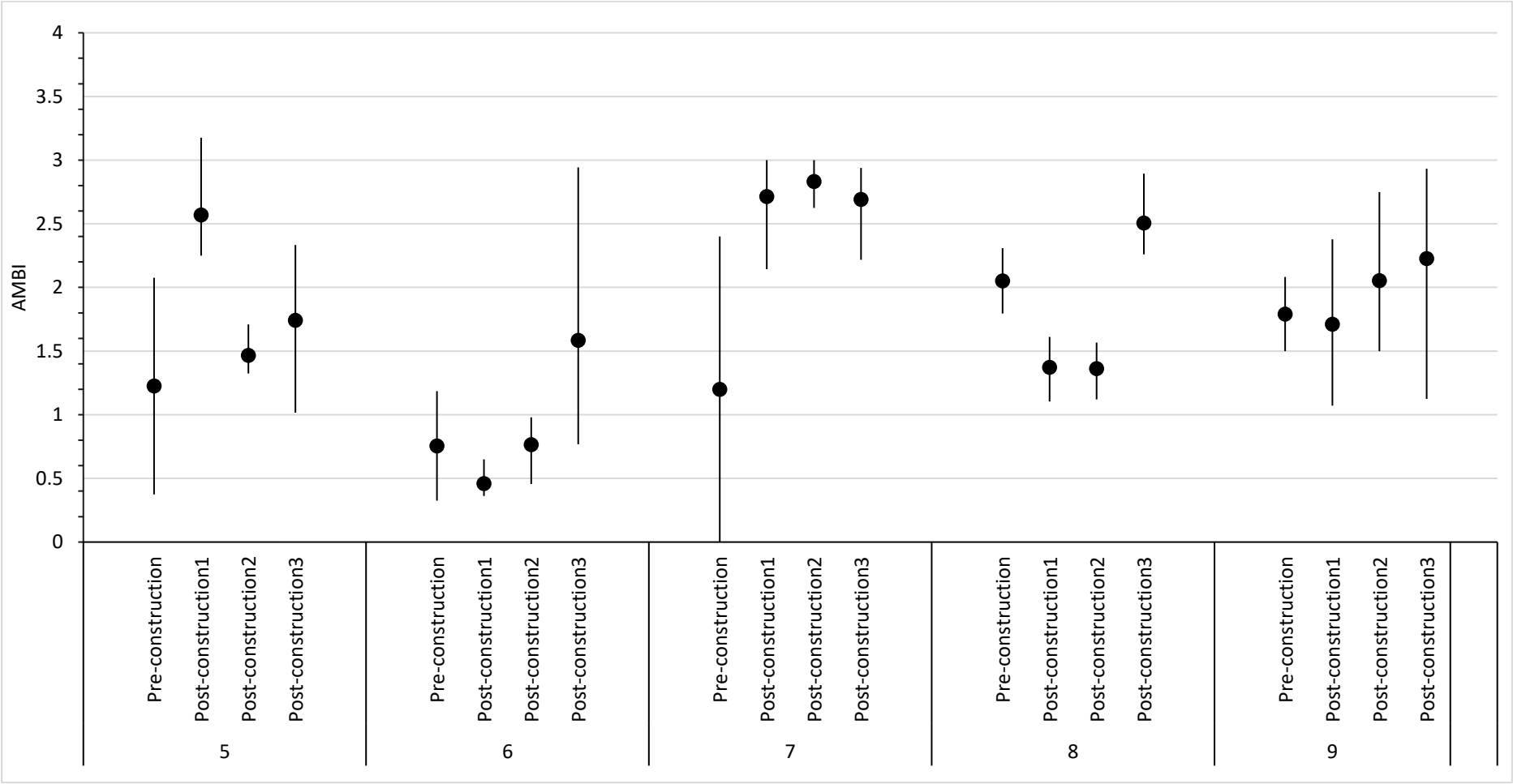
Station	Average AMBI score				Disturbance classification			
	Pre	Post1	Post2	Post3	Pre	Post1	Post2	Post3
Export Cable Route								
5	1.23	2.57	1.47	1.74	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
6	0.76	0.46	0.77	1.59	Undisturbed	Undisturbed	Undisturbed	Slightly disturbed
7	1.20	2.71	2.83	2.69	Undisturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
8	2.05	1.37	1.36	2.51	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
9	1.79	1.71	2.05	2.23	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed

Figure 9. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 2: ECR



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 10. AMBI score range observed during the survey period – Site 2: ECR



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Reference

Of the nine reference stations, five stations (1, 2, 26, 27, and 29) had AMBI scores ≤1.2 during the pre-construction survey, indicating 'undisturbed' conditions (Table 11). The remaining four stations were classified as 'slightly disturbed' during the pre-construction survey. Stations 26, 27 and 29 remained 'undisturbed' for the entire survey period, while stations 4, 25 and 28 remained 'slightly disturbed' throughout. The only change in disturbance classification between the pre-construction survey and the first post-construction survey was at station 3, which shifted from 'slightly disturbed' in pre-construction to 'undisturbed' in the first post-construction survey. Generally, AMBI scores and classifications remained very stable throughout the survey period. The degree of variability in AMBI scores across replicate samples at the reference stations (Figure 12) was generally comparable to the variability observed within the array area (Figure 8).

Stations 26, 27 and 29 were dominated by group I species and remained relatively stable throughout the survey period. Stations four and 28 also remained relatively stable across the survey periods but had a greater contribution of group II and III species. The remaining reference stations fluctuated in the contribution of each AMBI ecological group between surveys no consistent patterns visible (Figure 11).

Table 11 AMBI and disturbance classification summary – Site 2: reference

Station	Average AMBI score				Disturbance classification			
	Pre	Post1	Post2	Post3	Pre	Post1	Post2	Post3
Reference								
1	1.01	0.22	1.28	0.70	Undisturbed	Undisturbed	Slightly disturbed	Undisturbed
2	0.75*	1.05	2.46	1.29	Undisturbed	Undisturbed	Slightly disturbed	Slightly disturbed
3	1.88	0.51	1.37	1.53	Slightly disturbed	Undisturbed	Slightly disturbed	Slightly disturbed
4	1.35	1.49	1.64	1.91	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
25	1.46	2.12	2.49	2.45	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
26	0.19	0.14	0.22	0.24	Undisturbed	Undisturbed	Undisturbed	Undisturbed
27	0.14	0.95	0.22	0.43	Undisturbed	Undisturbed	Undisturbed	Undisturbed
28	1.37	1.93	1.93	1.76	Slightly disturbed	Slightly disturbed	Slightly disturbed	Slightly disturbed
29	1.01	0.29	0.46	0.62	Undisturbed	Undisturbed	Undisturbed	Undisturbed

*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 11 Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 2: reference

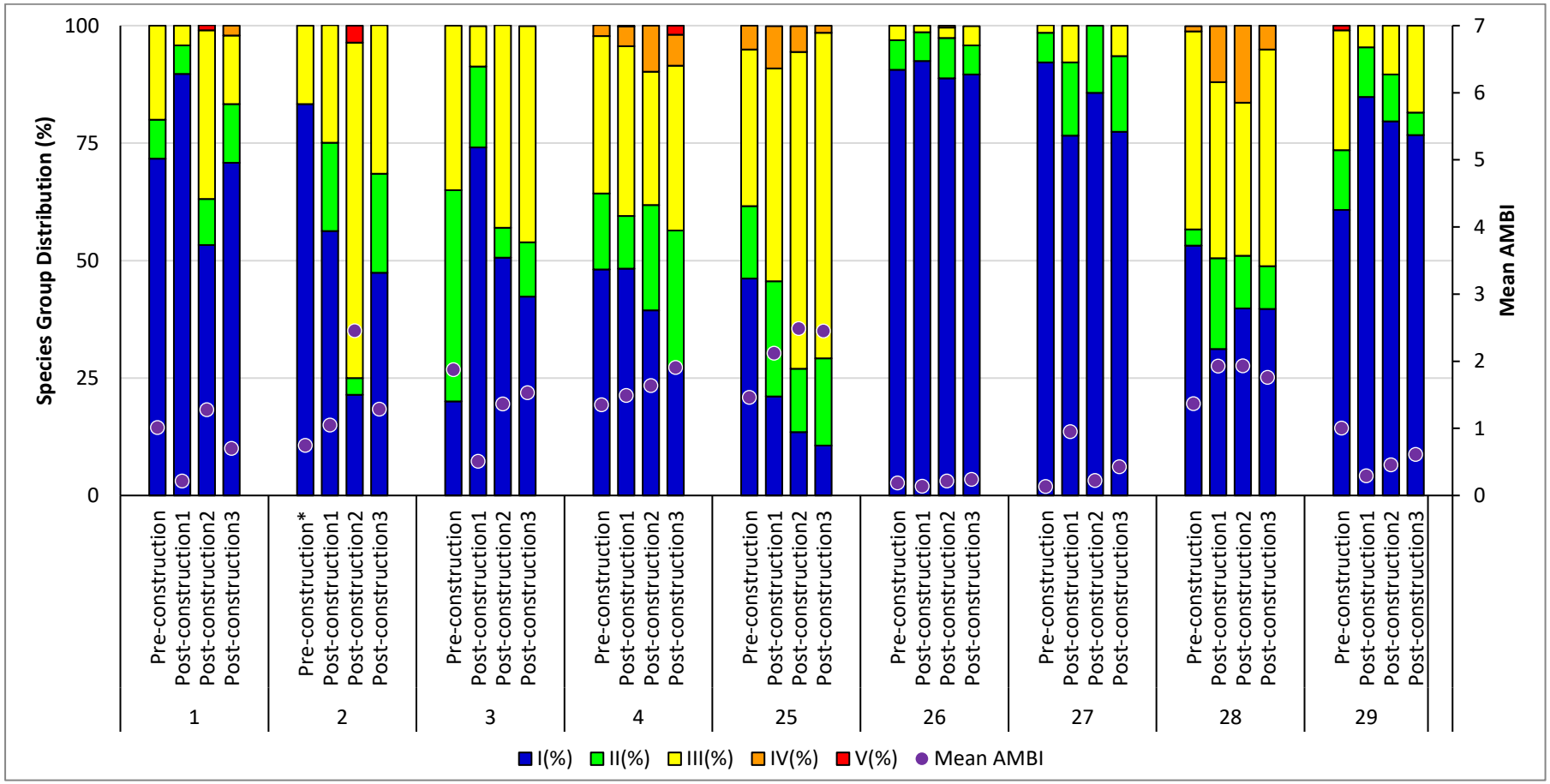
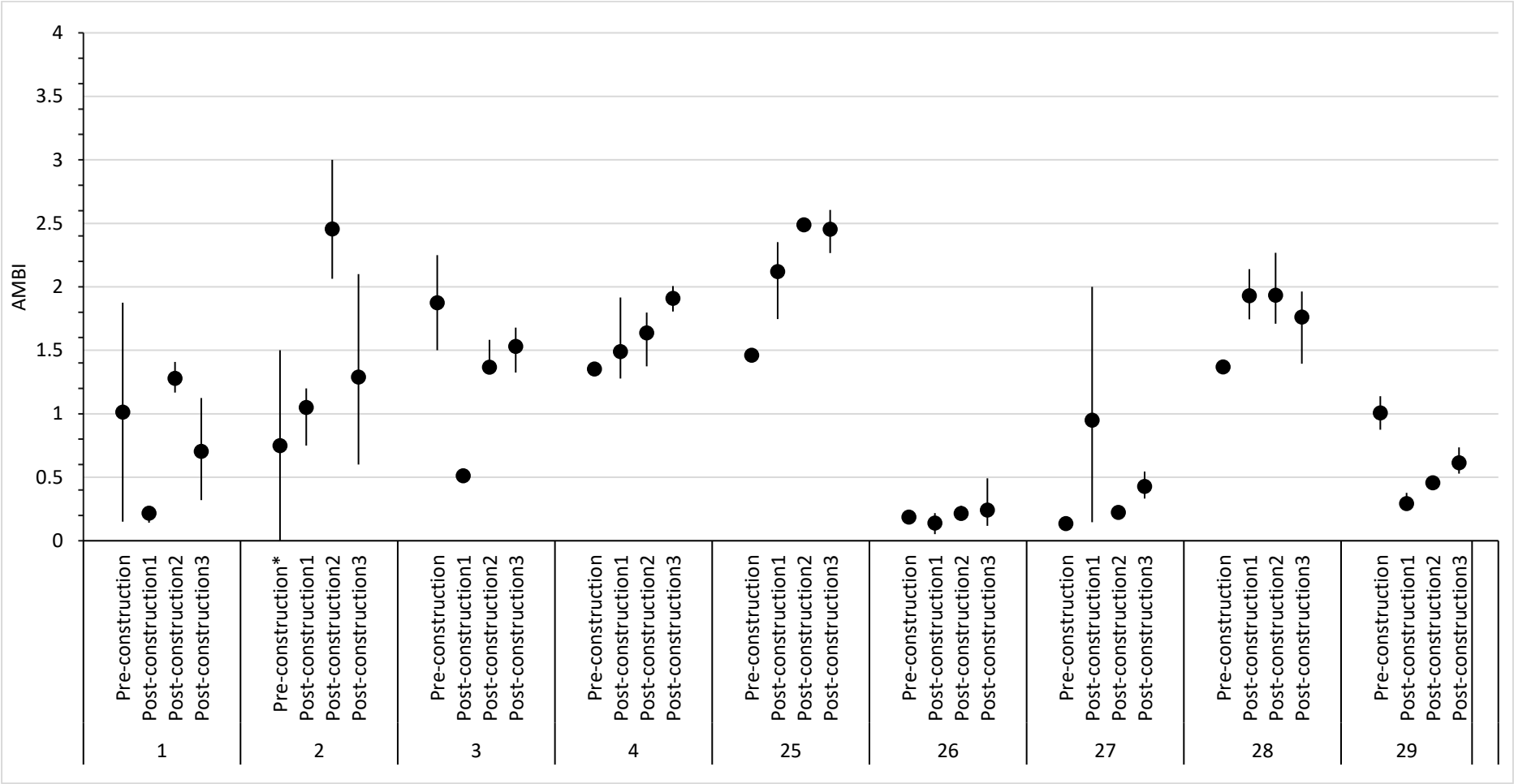


Figure 12. AMBI score range observed during the survey period – Site 2: reference



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

3.2.2 *Statistical Analysis and Comparison*

The RELATE function of PRIMER identified a correlation between AMBI scores and TOC (LOI%) within the array area for the entire survey period (Table 12). In general, the raw data suggest that fluctuations in TOC are associated with similar fluctuations in AMBI scores (i.e. where TOC increases, AMBI scores also increase and vice versa). This correlation was also observed within the ECR for the last two post-construction surveys, and within the reference stations for the last post-construction survey. A correlation between AMBI scores and distance from the nearest WTG was observed within the reference stations for the first and last post-construction survey. No correlation was observed between TOC (LOI%) and distance from the nearest WTG.

Table 12. RELATE analyses output comparing correlations between AMBI, TOC (LOI%) and distance from nearest WTG

Groups	Survey Phase	Sample statistic (Rho):	Significance level of sample statistic:
Within Array Area			
AMBI vs Distance from WTG	Pre – construction	-0.04	60.90%
	Post – construction 1	-0.035	65.00%
	Post – construction 2	0.019	31.10%
	Post – construction 3	0.085	9%
AMBI vs TOC (LOI%)	Pre – construction	0.347	1.00%
	Post – construction 1	0.385	0.10%
	Post – construction 2	0.44	0.10%
	Post – construction 3	0.473	0.10%
Distance from WTG vs TOC (LOI%)	Pre – construction	-0.061	68
	Post – construction 1	0.012	38.1
	Post – construction 2	-0.031	58.70%
	Post – construction 3	-0.02	57.10%
ECR			
AMBI vs Distance from WTG	Pre – construction	0.024	35.60%
	Post – construction 1	-0.084	77.80%
	Post – construction 2	-0.001	44.50%
	Post – construction 3	0.061	26.70%
AMBI vs TOC (LOI%)	Pre – construction	0.25	7.80%
	Post – construction 1	0.05	24.90%
	Post – construction 2	0.268	2.20%
	Post – construction 3	0.242	3.60%
Distance from WTG vs TOC (LOI%)	Pre – construction	0.116	27.70%
	Post – construction 1	0.164	8.30%
	Post – construction 2	0.007	40.30%
	Post – construction 3	-0.041	59.70%
Reference			
AMBI vs Distance from WTG	Pre – construction	-0.004	40.50%
	Post – construction 1	0.169	2%
	Post – construction 2	0.102	10%
	Post – construction 3	0.196	0.80%

Groups	Survey Phase	Sample statistic (Rho):	Significance level of sample statistic:
AMBI vs TOC (LOI%)	Pre – construction	-0.071	71.70%
	Post – construction 1	0.124	5.10%
	Post – construction 2	-0.06	81.30%
	Post – construction 3	0.43	0.10%
Distance from WTG vs TOC (LOI%)	Pre – construction	-0.071	62.90%
	Post – construction 1	-0.037	69.70%
	Post – construction 2	0.014	34.90%
	Post – construction 3	-0.042	75.20%

A PERMANOVA test examining significant differences in AMBI scores between survey phases and sites (within array area, ECR and reference) indicated an overall significant effect of site location (Pseudo-F = 7.5589; P (perm) = 0.003) but not survey phase (Pseudo-F = 0.29478; P(perm) = 0.941):

- **Pre-construction and post-construction 3:** AMBI scores within the ECR were generally higher than within the array area
- **Post-construction 3:** AMBI scores within the ECR were generally higher than the reference area

Overall, there was no significant difference in AMBI scores between the array area and reference area for the entire survey period (Table 13) suggesting that construction of the OWF did not result in significant changes to AMBI scores within the array area relative to the reference stations. Additionally, there was no significant difference in AMBI scores between the ECR and reference stations until post-construction 3.

Table 13. PERMANOVA output comparing AMBI scores for pre-construction and post-construction surveys – Site 2

Groups	t value*	p value
Pre-construction		
Within Array vs Export Cable Route	2.6355	0.021
Within Array Area vs Reference	1.4582	0.18
Export Cable Route vs Reference	1.2396	0.242
Post-construction 1		
Within Array vs Export Cable Route	2.037	0.076
Within Array Area vs Reference	0.12734	0.9
Export Cable Route vs Reference	1.7695	0.122
Post-construction 2		
Within Array vs Export Cable Route	1.0688	0.287
Within Array Area vs Reference	0.33819	0.739
Export Cable Route vs Reference	0.74712	0.451
Post-construction 3		
Within Array vs Export Cable Route	2.3264	0.031
Within Array Area vs Reference	0.29199	0.78
Export Cable Route vs Reference	2.4737	0.031

* a lower t-value indicates the between-group variation is smaller compared to within-group variation when compared to a higher t-value.

Additionally a PERMANOVA test examining significant differences in TOC (LOI%) between surveys phases and sites indicated an overall significant effect of site location (Pseudo-F = 179.47; P (perm) = 0.001) and survey phase (Pseudo-F = 8.6736; P(perm) = 0.001) (Table 14, Table 15). The results of the PERMANOVA test and assessment of the raw data identified the following trends:

- **All surveys:** TOC (LOI%) at the ECR stations were significantly higher than the array and reference stations
- **All surveys:** TOC (LOI%) at the reference stations were significantly higher than the array stations
- **Export Cable Route:** TOC (LOI%) in the post-construction surveys were significantly higher than the pre-construction survey

While PERMANOVA for OWF Site 1 indicated TOC (LOI%) significantly decreasing between surveys within the array area, the PERMONVA output for OWF Site 2 found no significant difference in TOC (LOI%) within the array area (Table 15) between surveys.

Table 14. PERMANOVA output comparing Array, ECR and Reference station TOC (LOI%) for pre-construction and post-construction surveys

Groups	t value*	p value
Pre-construction		
Within Array vs Export Cable Route	5.1567	0.001
Within Array Area vs Reference	2.0796	0.047
Export Cable Route vs Reference	2.4017	0.032
Post-construction 1		
Within Array vs Export Cable Route	16.159	0.001
Within Array Area vs Reference	4.5453	0.001
Export Cable Route vs Reference	7.6623	0.001
Post-construction 2		
Within Array vs Export Cable Route	12.437	0.001
Within Array Area vs Reference	4.0724	0.003
Export Cable Route vs Reference	6.3409	0.001
Post-construction 3		
Within Array vs Export Cable Route	10.186	0.001
Within Array Area vs Reference	3.5606	0.001
Export Cable Route vs Reference	5.48	0.001

* a lower t-value indicates the between-group variation is smaller compared to within-group variation when compared to a higher t-value.

Table 15. PERMANOVA output comparing Array, ECR and Reference station TOC (LOI%) for pre-construction and post-construction surveys

Groups	t value*	p value
Within Array Area		
Pre-construction vs post-construction 1	0.73172	0.516
Pre-construction vs post-construction 2	1.0173	0.33
Pre-construction vs post-construction 3	0.39644	0.688
Post-construction 1 vs post-construction 2	0.61979	0.576
Post-construction 1 vs post-construction 3	0.25551	0.784
Post-construction 2 vs post-construction 3	0.72131	0.455
Export Cable Route		
Pre-construction vs post-construction 1	3.5646	0.003
Pre-construction vs post-construction 2	3.6023	0.001
Pre-construction vs post-construction 3	2.4809	0.024
Post-construction 1 vs post-construction 2	1.094	0.296
Post-construction 1 vs post-construction 3	0.15756	0.885
Post-construction 2 vs post-construction 3	1.0572	0.317
Reference		
Pre-construction vs post-construction 1	0.75609	0.444
Pre-construction vs post-construction 2	1.2979	0.21
Pre-construction vs post-construction 3	0.70366	0.492
Post-construction 1 vs post-construction 2	0.79802	0.425
Post-construction 1 vs post-construction 3	0.034009	0.967
Post-construction 2 vs post-construction 3	0.70605	0.461

3.3 OWF Site 3

3.3.1 Comparison between pre-and post-construction surveys

Within Array Area

Four of the six OWF stations within the array area sampled in the pre-construction survey had AMBI scores of ≤1.2, indicative of 'undisturbed' conditions (stations 3, 4, 5 and 6. The remaining two stations (stations 1 and 2) were classified as 'slightly disturbed' (Table 16).

Station 5 remained ‘undisturbed’ for the entire survey period, while Stations 1 and 2 went from ‘slightly disturbed’ in the pre-construction survey to ‘undisturbed’ by the second post-construction survey. More notable changes in AMBI classification were observed at stations 3, 4 and 6 which shifted from ‘undisturbed’ in the pre-construction survey, to ‘moderately disturbed’ (stations and 3 and 6) or ‘extremely disturbed’ (station 4) in the first post-construction survey. However, all three stations had returned to ‘undisturbed’ by the second post-construction survey. It should be noted that no countable taxa were recorded at station 4, resulting in a maximum AMBI score 7, (Figure 13) and the ‘extremely disturbed’ classification. The shift from ‘undisturbed’ to disturbed conditions at these stations between the pre- and first post-construction monitoring survey may suggest a temporary localised impact from the construction of the OWF.

However, low abundance (<6) and/or species richness (<3) was recorded at most of the post-construction stations. Therefore, the AMBI scores and disturbance classifications should be treated with caution.

Variability in AMBI scores across replicate samples was minimal at most stations, except for Stations 3 and 6 during the first post-construction survey (Figure 14).

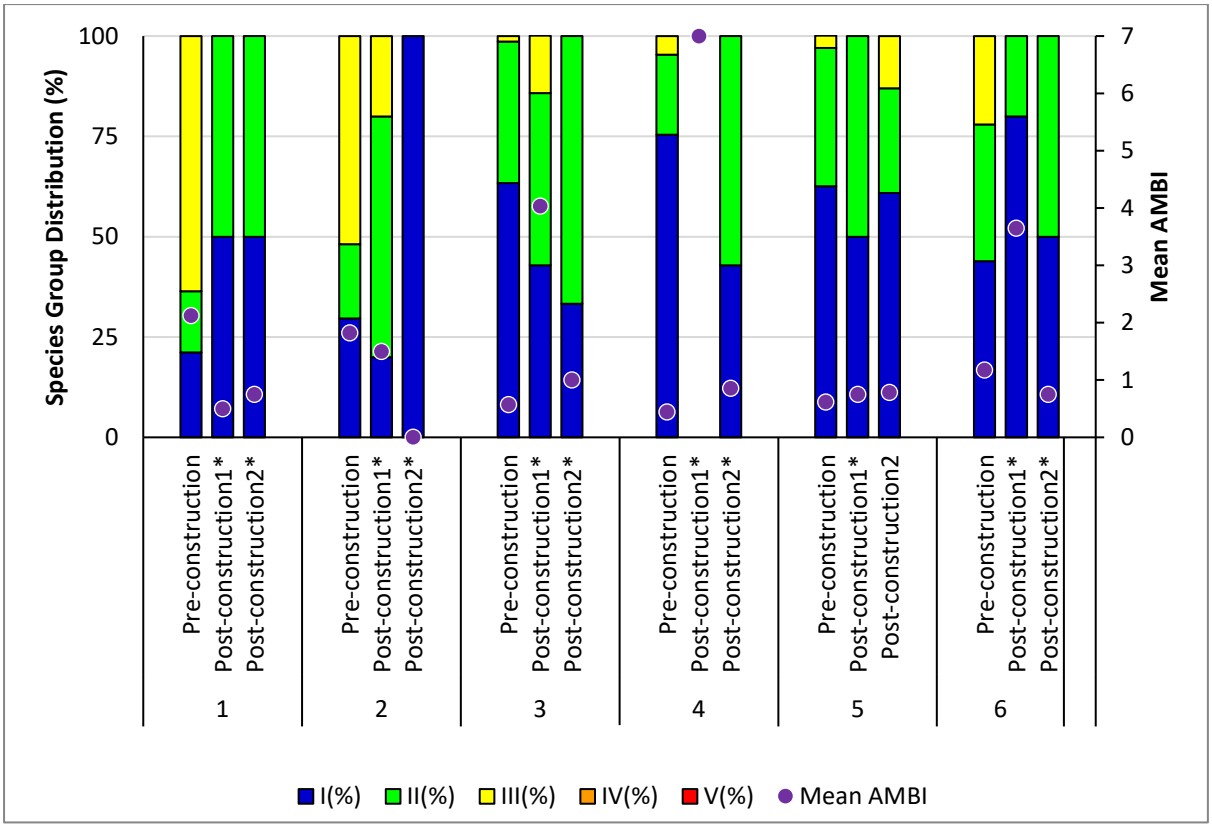
Groups I and II were the dominant ecological groups across most stations and surveys. Fluctuations in the contribution of each AMBI ecological group was observed across stations and between surveys, but no consistent pattern was visible (Figure 13).

Table 16. AMBI and disturbance classification summary – Site 3: within array area

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Within Array Area						
1	2.12	0.50*	0.75*	Slightly disturbed	Undisturbed	Undisturbed
2	1.82	1.50*	0.00*	Slightly disturbed	Slightly disturbed	Undisturbed
3	0.57	4.04*	1.00*	Undisturbed	Moderately disturbed	Undisturbed
4	0.44	7.00*	0.86*	Undisturbed	Extremely disturbed	Undisturbed
5	0.62	0.75*	0.78	Undisturbed	Undisturbed	Undisturbed
6	1.17	3.65*	0.75*	Undisturbed	Moderately disturbed	Undisturbed

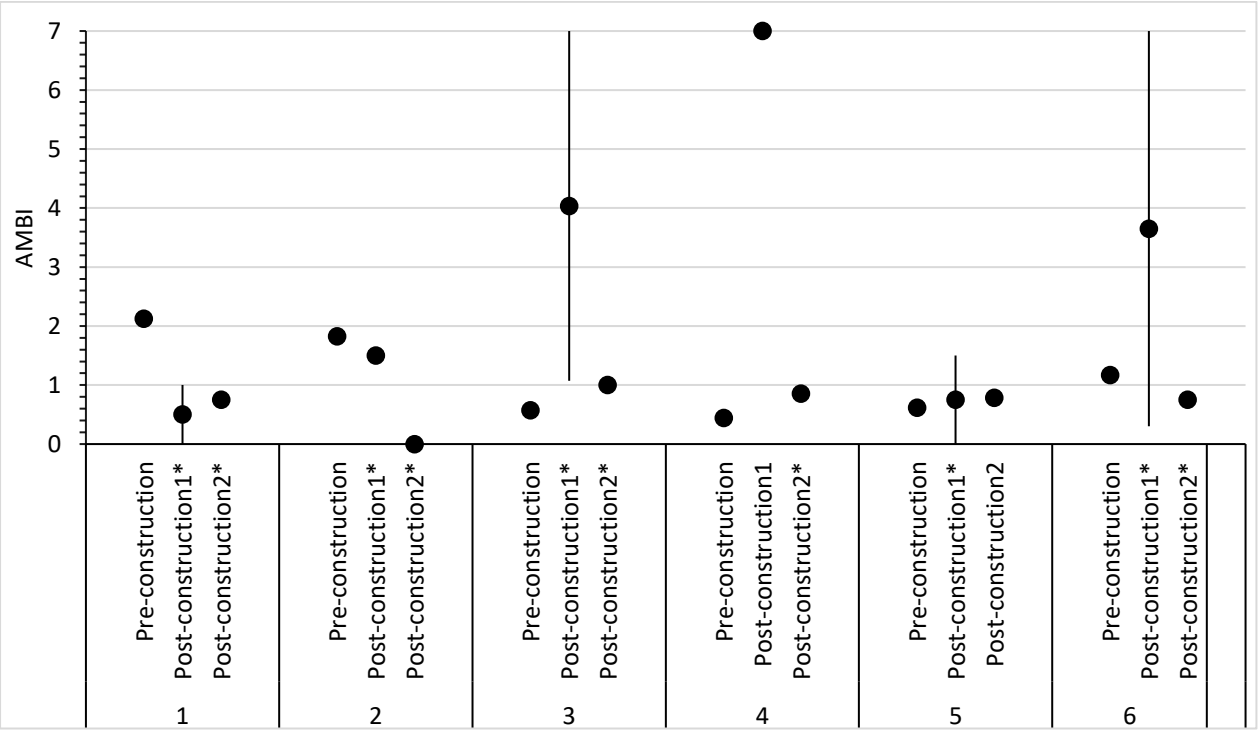
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 13. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 3: within array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 14. AMBI score range observed during the survey period – Site 3: within array area



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Export Cable Route

Five of the eight stations located along the export cable route had AMBI scores ≤1.2 during the pre-construction survey, indicating 'undisturbed' conditions (stations 9, 10, 11, 12 and 13. The remaining three stations were classified as 'slightly disturbed' (stations 7, 8 and 14) (Table 17).

In the first post-construction survey, the three 'slightly disturbed' stations all shifted to an 'undisturbed' disturbance classification and only one station (station 9) went from 'undisturbed' to 'slightly disturbed'. Only very minor changes were seen between the first and second post-construction surveys suggesting the communities in this area remained relatively stable across the survey period. There was low variability in AMBI scores across replicate samples at the export cable route (Figure 16).

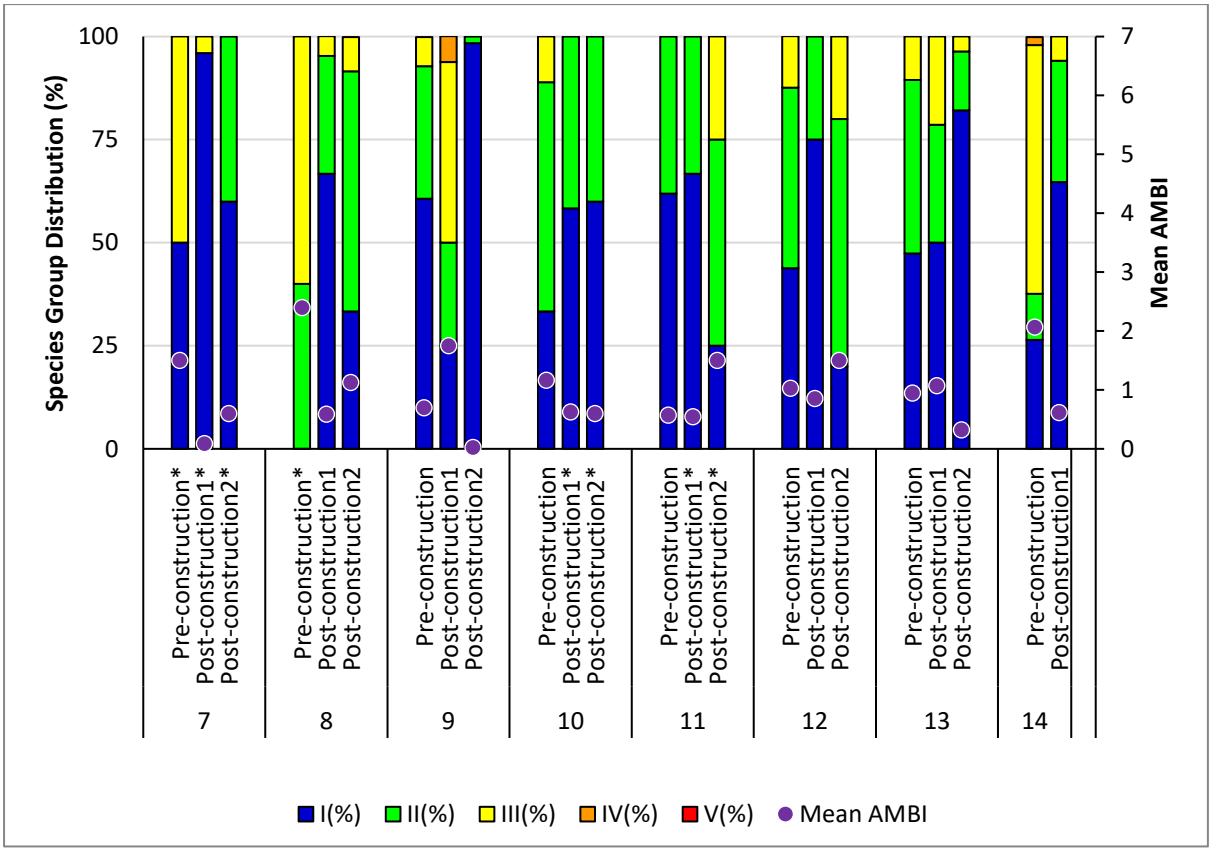
Groups I and II were the dominant ecological groups across most stations and surveys. Fluctuations in the contribution of each AMBI ecological group was observed across stations and between surveys, but no consistent pattern was visible (Figure 15).

Table 17. AMBI and disturbance classification summary – Site 3: ECR

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Export Cable Route						
7	1.50*	0.09*	0.60*	Slightly disturbed	Undisturbed	Undisturbed
8	2.40*	0.59	1.13	Slightly disturbed	Undisturbed	Undisturbed
9	0.70	1.75	0.02	Undisturbed	Slightly disturbed	Undisturbed
10	1.17	0.63*	0.60*	Undisturbed	Undisturbed	Undisturbed
11	0.57	0.54*	1.50*	Undisturbed	Undisturbed	Slightly disturbed
12	1.03	0.86	1.50	Undisturbed	Undisturbed	Slightly disturbed
13	0.95	1.07	0.32	Undisturbed	Undisturbed	Undisturbed
14	2.07	0.61		Slightly disturbed	Undisturbed	

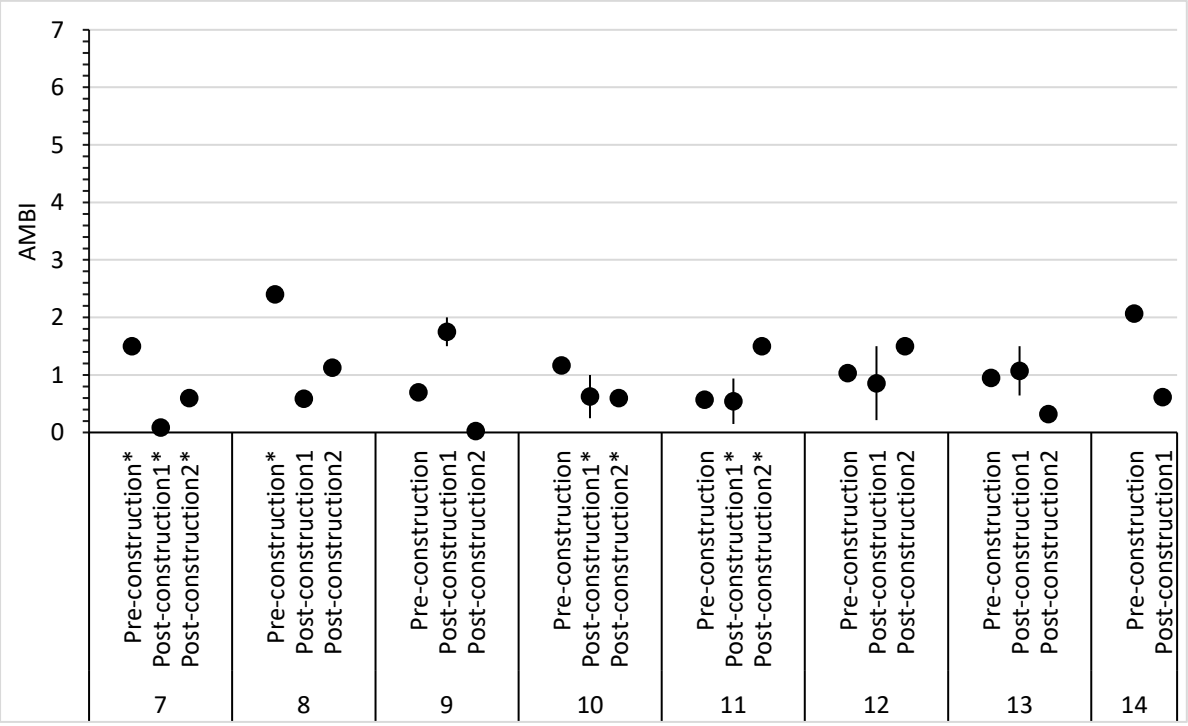
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 15. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 3: ECR



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 16. AMBI score range observed during the survey period – Site 3: ECR



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Reference

All three reference stations (15, 16, and 17) were classified as 'undisturbed' during the pre-construction survey (Table 18). The reference stations showed very little variability across the pre- and post-construction survey periods. During the first post-construction survey, all reference stations maintained their 'undisturbed' classifications, with stations 15 and 16 showing slight decreases in AMBI scores and station 17 showing a minor increase but remaining within the 'undisturbed' classification.

During the second post-construction survey station 17 shifted to 'slightly disturbed', which was the only classification change observed at the reference stations across the survey period.

The degree of variability in AMBI scores across replicate samples at the reference stations (Figure 18) was generally comparable to the variability observed within the export cable route (Figure 16).

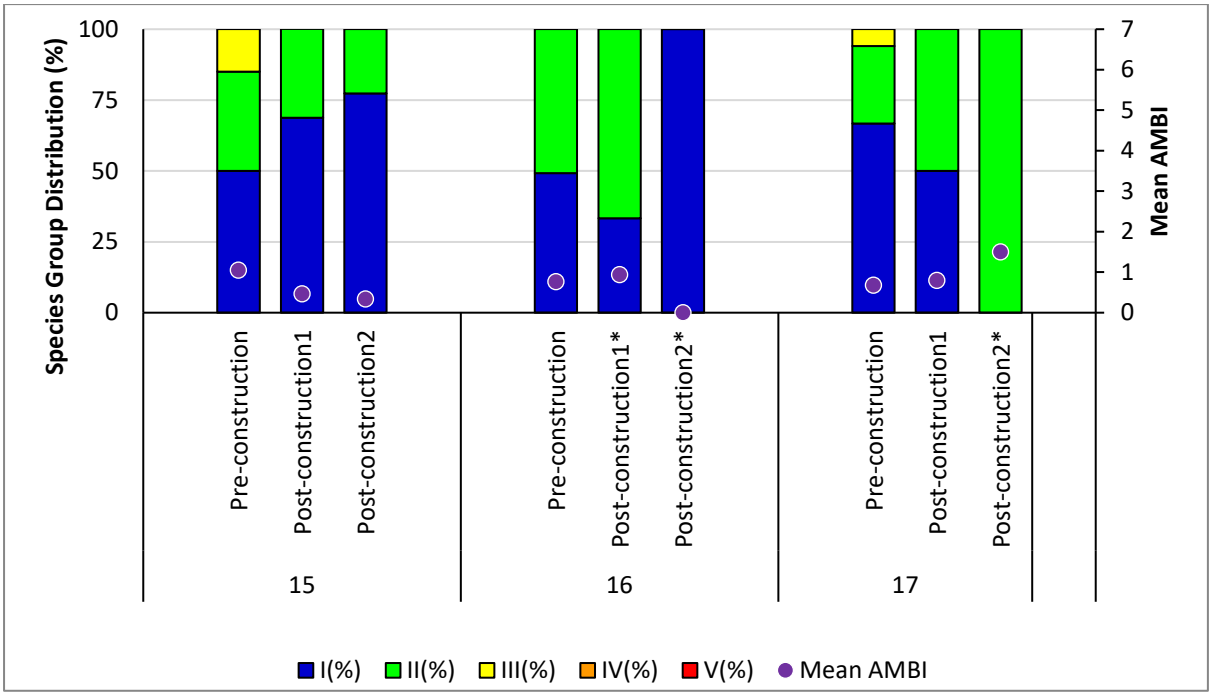
AMBI ecological groups I and II were the largest contributors to the benthic ecological communities at the reference stations. There was little variability between groups during the pre- and first post-construction survey across all three reference stations. At station 16, during the second post-construction survey, group I contributed 100% however, this is due to the truncated benthic community consisting of only three group I individuals. Similarly, at station 17, group II dominated 100% during the second post-construction survey, which is reflected in the change in disturbance classification to 'slightly disturbed' (Figure 13).

Table 18. AMBI and Disturbance classification summary – Site 3: reference

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Reference						
15	1.05	0.47	0.34	Undisturbed	Undisturbed	Undisturbed
16	0.77	0.94*	0.00*	Undisturbed	Undisturbed	Undisturbed
17	0.68	0.80	1.50*	Undisturbed	Undisturbed	Slightly disturbed

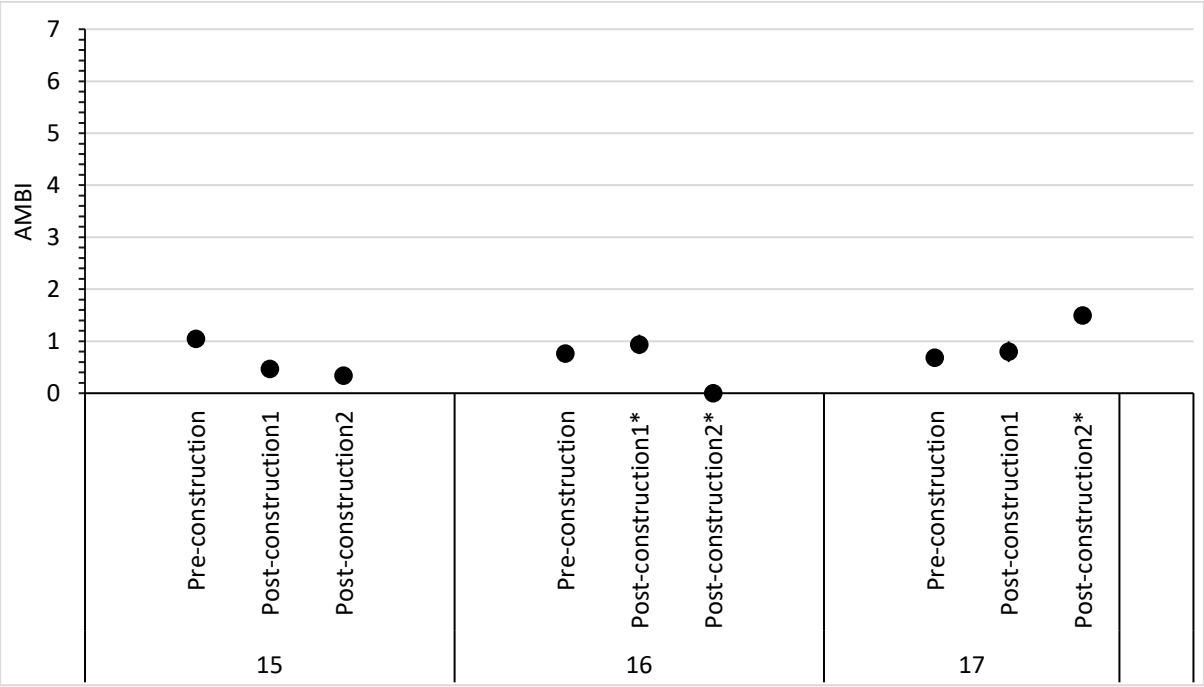
*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 17. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 3: reference



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

Figure 18. AMBI score range observed during the survey period – Site 3: reference



*Result to be treated with caution due to low abundance (<6) and/or no. of species (<3)

3.3.2 *Statistical Analysis and Comparison*

The RELATE function of PRIMER identified no correlation between AMBI scores and distance from the nearest WTG (Table 19). The RELATE function could not be applied to TOC (LOI%) due to most concentrations being below the limit of detection.

A PERMANOVA test examining significant differences in AMBI scores between survey phases and sites (within array area, export cable route and reference) indicated no effect of site location (Pseudo-F = 2.7614; P (perm) = 0.076) or survey phase (Pseudo-F = 2.0215; P(perm) = 0.155). The PERMANOVA test could not be applied to TOC (LOI%) due to the majority of concentrations being below the limit of detection.

Table 19. RELATE analyses output comparing correlations between AMBI and distance from nearest WTG

Groups	Survey Phase	Sample statistic (Rho):	Significance level of sample statistic:
Within Array Area			
AMBI vs Distance from WTG	Pre-construction	-0.028	45.3
	Post – construction 1	-0.138	59.50%
	Post – construction 2	-0.271	68%
Export Cable Route			
AMBI vs Distance from WTG	Pre-construction	0.331	8.90%
	Post – construction 1	-0.023	51.00%
	Post – construction 2	-0.257	90.30%
Reference			
AMBI vs Distance from WTG	Pre-construction	NA	undefined
	Post – construction 1	NA	undefined
	Post – construction 2	-0.5	82.20%

3.4 OWF Site 4

3.4.1 Comparison between pre-and post-construction surveys

Within Array Area

Only one of the nine OWF stations within the array area (Station 5) sampled in the pre-construction survey had mean AMBI scores of <1.2, indicative of 'undisturbed' conditions. Two stations (13 and 14) scored 3.40 and 3.69, indicative of 'moderately disturbed' conditions while the six remaining stations scored between 1.50 and 3.11, indicative of 'slightly disturbed' conditions (Table 20).

AMBI scores at the six 'slightly disturbed' stations increased between the pre-construction and first post-construction surveys. Two of the six previously 'slightly disturbed' stations (9 and 11) shifted to 'moderately disturbed' classification. The remaining four stations with increased AMBI scores remained within the 'slightly disturbed' category, which was consistent with their pre-construction classification.

By comparison, mean AMBI scores decreased at Stations 1 and 14 ('undisturbed' and 'moderately disturbed'). The decrease in AMBI score at Station 14 was associated with a change in disturbance classification from 'moderately disturbed' before construction to 'slightly disturbed' in the first post-construction survey. The mean AMBI score at Station 14 continued to decrease in the second post-construction survey, however the disturbance classification remained consistent with the first post-construction survey ('slightly disturbed').

Station 5 showed an increase in mean AMBI score between the first and second post-construction survey but remained 'undisturbed'. Six stations showed a decrease in mean AMBI scores between the first and second post-construction survey while Station 13 showed a decrease between the pre-construction and the second post-construction (not sampled during the first post-construction survey). Three stations (10, 11 and 13) showed no change in disturbance classification ('slightly disturbed' and 'moderately disturbed'). Three stations shifted from 'slightly disturbed' to "disturbed" while stations 9 and 13 changed from 'moderately disturbed' in the preceding survey to 'slightly disturbed' in the second post-construction survey

The range of AMBI scores across stations and survey periods is provided in Figure 20. Most stations generally showed in increase in AMBI score followed by a decrease, with low variability between replicates. Overall, the change in disturbance classification was minor, despite the fluctuations in AMBI scores across the survey period, suggesting a relatively stable benthic community

Temporal change in the contribution of AMBI ecological groups are provided in Figure 19. Most stations show a low contribution of group I species in the pre-construction phase, with varying proportions of group II, III and IV species contributing to the 'slightly disturbed' and 'moderately disturbed' classifications. The exception was Station 5, which was dominated by group I species. Overall, most stations showed a general decrease in group I species and increase in group III and/or IV species from the pre-construction to the first post-construction survey. This was followed by an increase in group I species and decrease in group III and/or IV species. The exceptions were Stations 5, 13 and 14, which showed a general increase in group I species and decrease in group III or IV species.

Table 20. AMBI and disturbance classification summary – Site 4: within array area

Station	Average AMBI score			Disturbance classification		
	Pre	Post 1	Post 2	Pre	Post1	Post2
Within Array Area						
5	1.0	0.08	0.26	Undisturbed	Undisturbed	Undisturbed
6	1.8	3.08	0.96	Slightly disturbed	Slightly disturbed	Undisturbed
7	1.5	3.16	0.79	Slightly disturbed	Slightly disturbed	Undisturbed
8	1.7	2.89	1.04	Slightly disturbed	Slightly disturbed	Undisturbed
9	3.1	3.76	1.82	Slightly disturbed	Moderately disturbed	Slightly disturbed
10	1.5	3.17	2.51	Slightly disturbed	Slightly disturbed	Slightly disturbed
11	2.2	4.05	3.38	Slightly disturbed	Moderately disturbed	Moderately disturbed
13	3.4		2.39	Moderately disturbed		Slightly disturbed
14	3.6	1.68	1.57	Moderately disturbed	Slightly disturbed	Slightly disturbed

Figure 19. Temporal change in the Mean AMBI and contribution of ecological groups observed during the survey period – Site 4: within array area

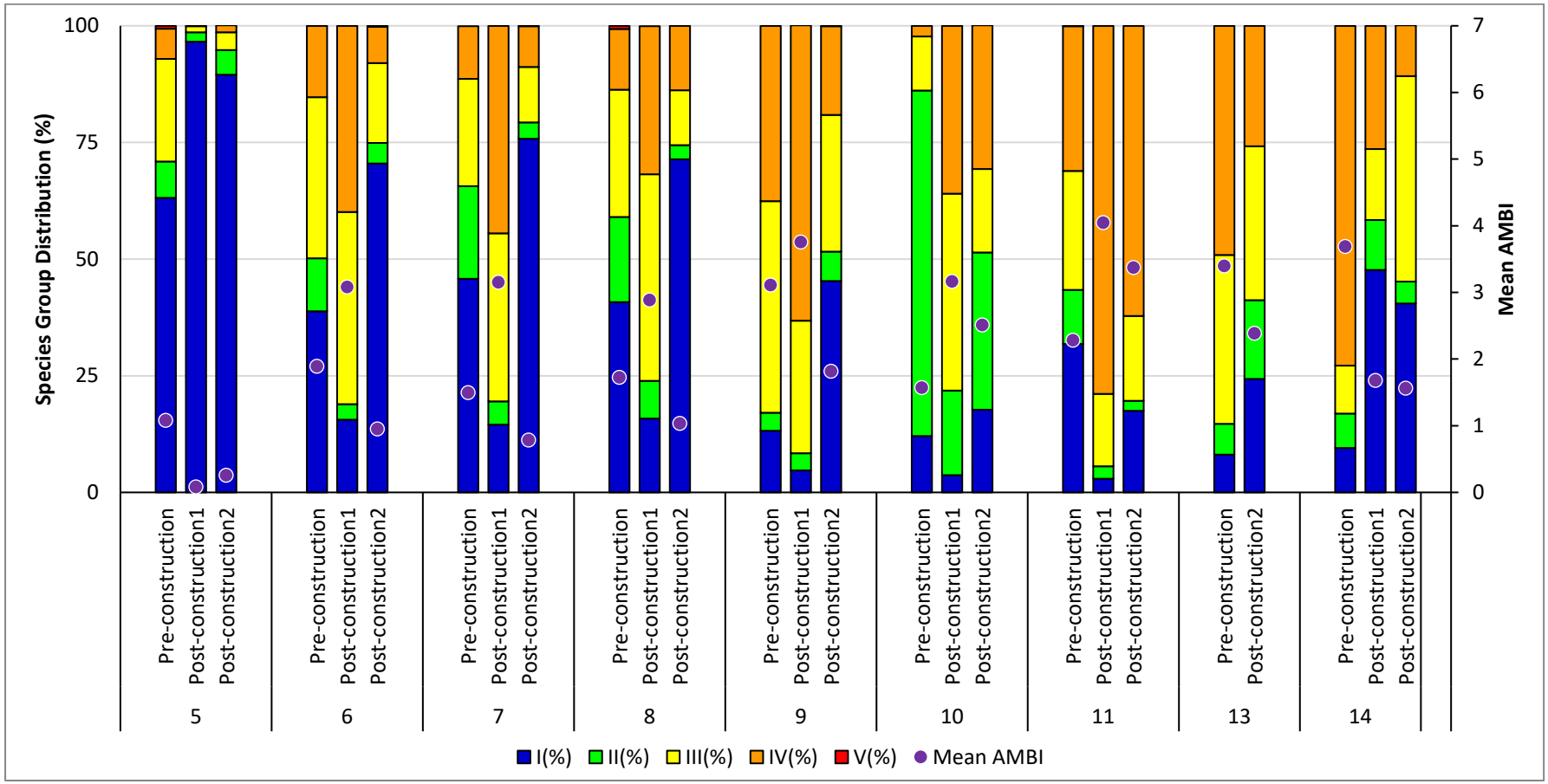
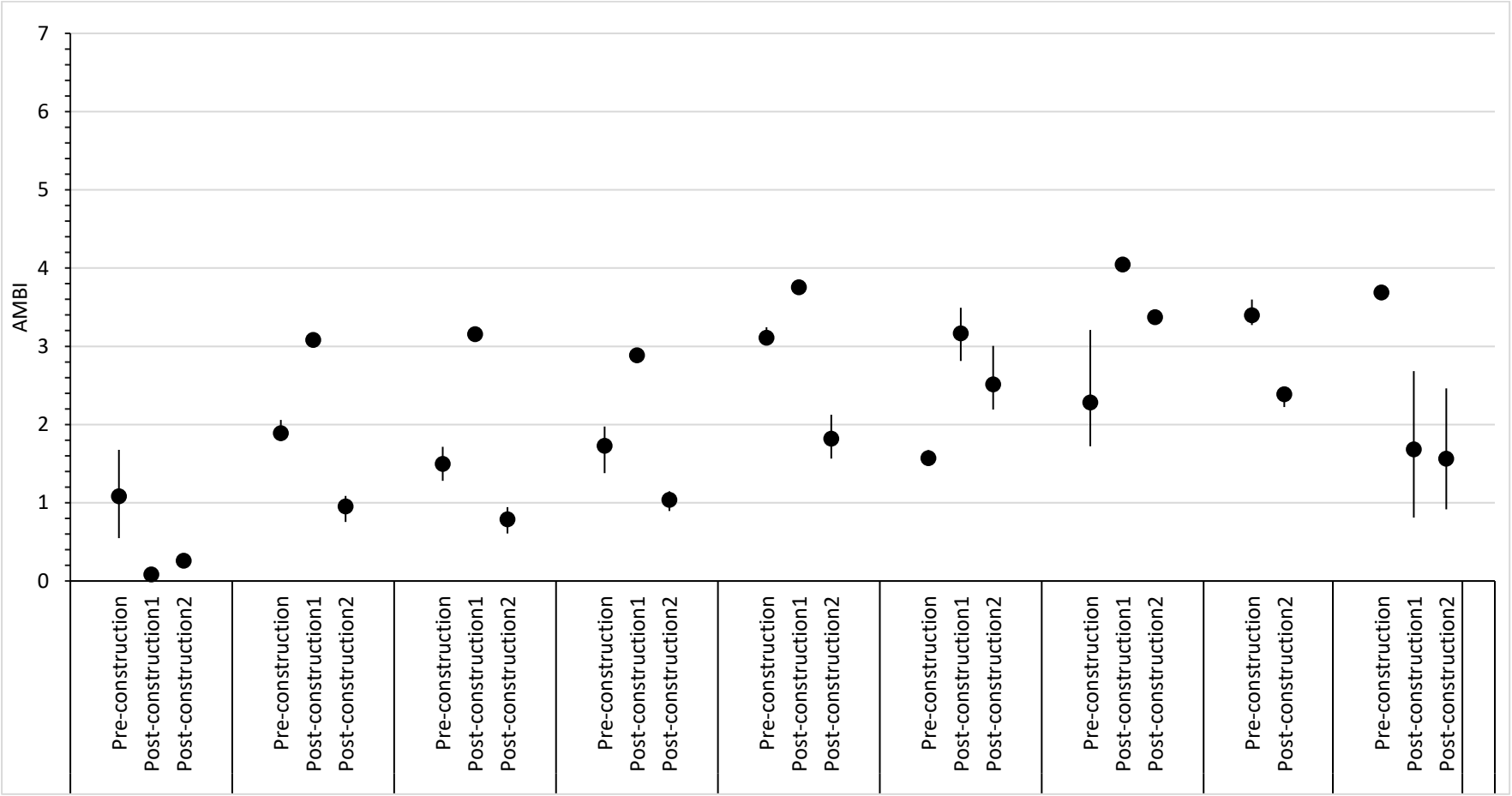


Figure 20. AMBI score range observed during the survey period – Site 4: within array area



Outside Array Area

Only one of the five OWF stations within the array area (Station 15) sampled in the pre-construction survey had mean AMBI scores of <1.2, indicative of 'undisturbed' conditions. Station 4 scored 3.47, indicative of 'moderately disturbed' conditions while the three remaining stations scored between 1.33 and 2.66, indicative of 'slightly disturbed' conditions (Table 21).

Mean AMBI scores increased at three stations between the pre-construction and first post-construction surveys. This included Stations 4 and 15 and which remained 'moderately disturbed' and 'undisturbed' respectively while Station 12 shifted from 'slightly disturbed' to 'moderately disturbed'. The two remaining stations indicated decreases in AMBI scores; Station 2 shifted to "undisturbed while Station 3 remained 'slightly disturbed'.

Two stations (4 and 12) indicated decreases in mean AMBI scores at the second post-construction survey. At Station 12, the decrease in the AMBI score was associated with a change in disturbance classification from 'moderately disturbed' (first post-construction) to 'slightly disturbed' (preconstruction and second post-construction) while Station 4 remained 'moderately disturbed'. Station 2 showed an increase in mean AMBI score, resulting in a shift from 'undisturbed' to 'slightly disturbed'.

The mean AMBI score continued to increase at Station 15, resulting in the disturbance classification changing from 'undisturbed' (first post-construction) to 'slightly disturbed' (second post construction) while the mean AMBI score at Station 3 continued to decrease, the disturbance classification remained 'slightly disturbed' for the entire survey period.

The range of AMBI scores across stations and survey periods is provided in Figure 22 indicating low variability between sample replicates. Additionally, the variability in mean AMBI scores was generally comparable to stations within the array area (Figure 20) with no clear trend.

The contribution of AMBI ecological groups at each station is presented in Figure 21. The majority of stations outside the array area showed a low contribution of group I species and variable contributions of group II, III and IV, except for Station 15 which generally shows group I to be the main contributor. Overall, there is no clear trend on the representation of groups I to IV at Stations 2, 3, 4 and 12 while Station 15 shows a general decrease in group I contribution and increase in groups II, III and IV between the pre-construction and post-construction surveys.

Table 21. AMBI and disturbance classification summary – Site 4: outside array area

Station	Average AMBI score			Disturbance classification		
	Pre	Post 1	Post 2	Pre	Post1	Post2
Outside Array Area						
2	1.4	1.19	1.54	Slightly disturbed	Undisturbed	Slightly disturbed
3	2.6	2.54	1.62	Slightly disturbed	Slightly disturbed	Slightly disturbed
4	3.4	3.69	3.36	Moderately	Moderately	Moderately
12	1.3	3.40	1.89	Slightly disturbed	Moderately	Slightly disturbed
15	0.3	0.97	2.11	Undisturbed	Undisturbed	Slightly disturbed

Figure 21. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 4: outside area array

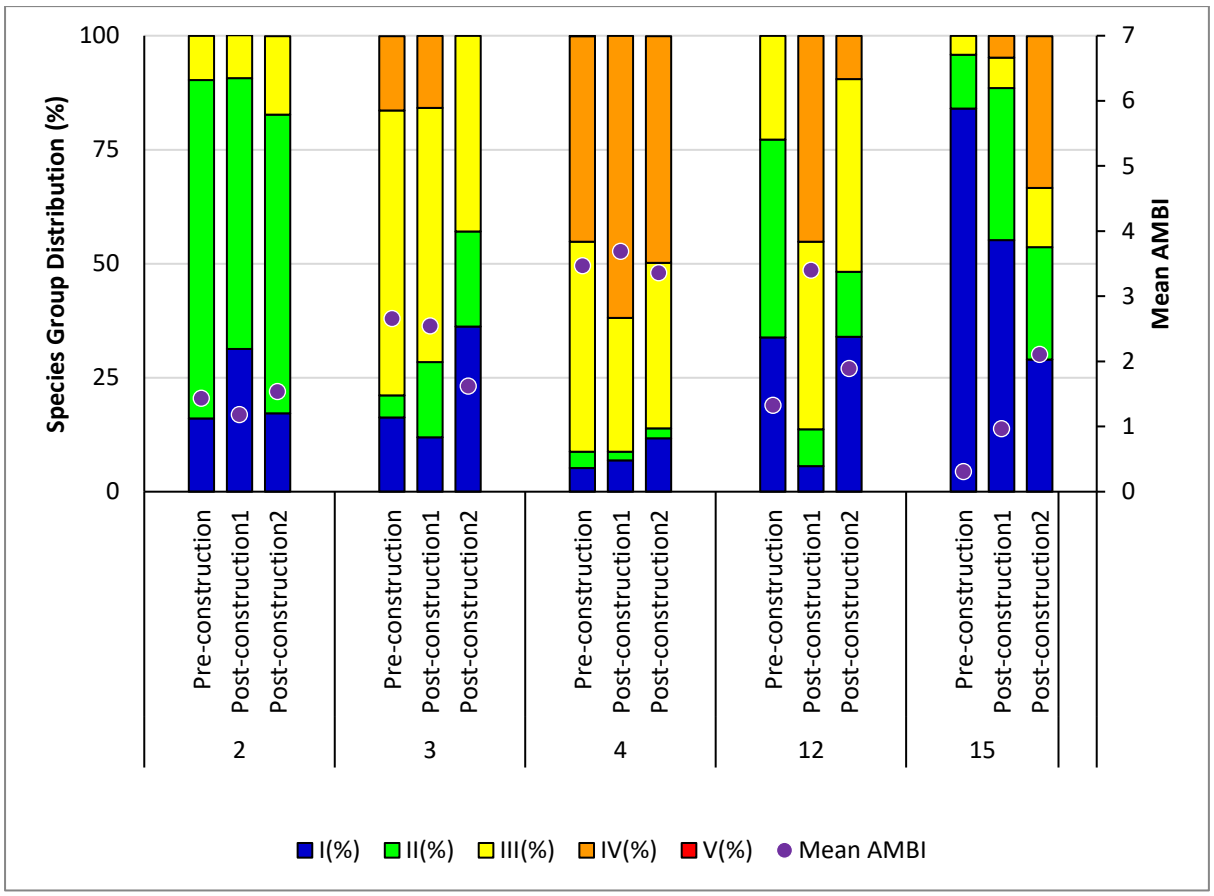
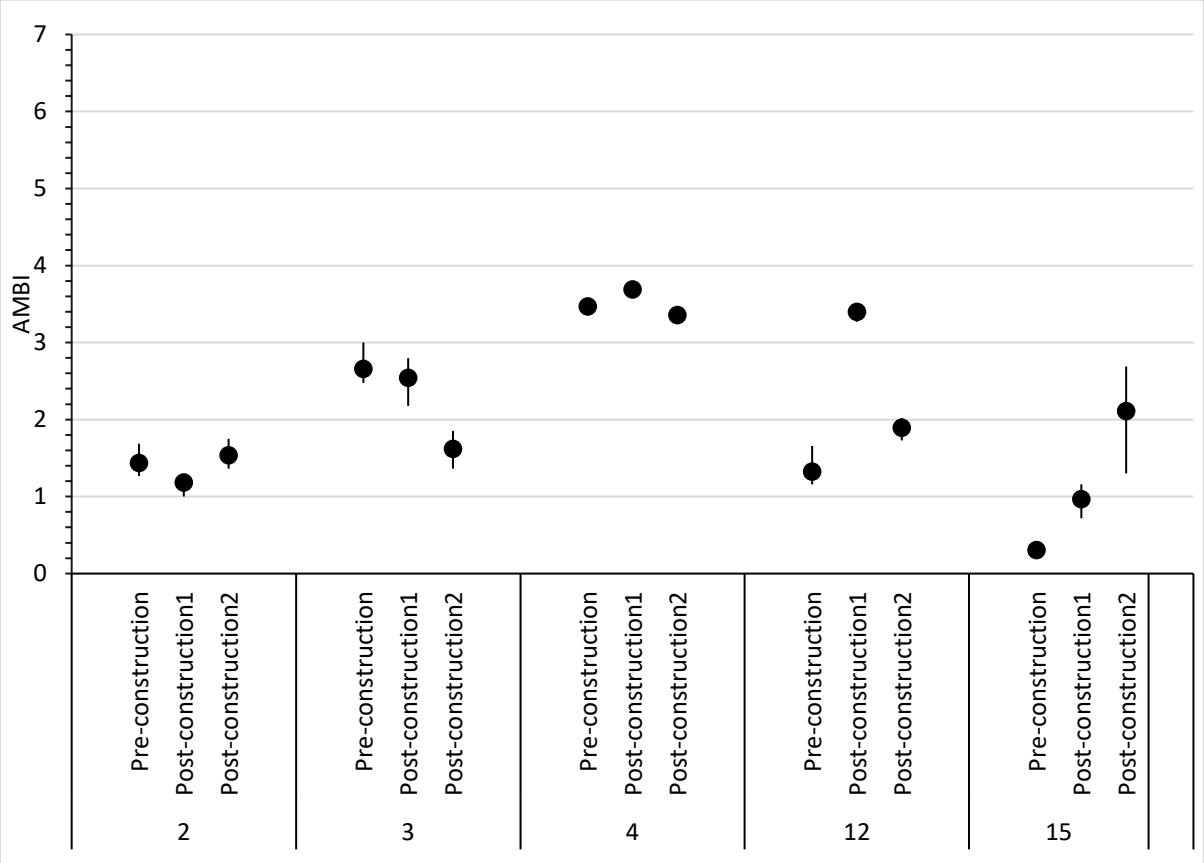


Figure 22. AMBI score range observed during the survey period – Site 4: outside array area



Export Cable Route

Stations 16 and 19 had mean AMBI scores of 0.49 and 0.02 in the pre-construction survey, indicative of 'undisturbed' conditions, while Station 17 scored 2.22, indicative of 'slightly disturbed' conditions (Table 22).

Mean AMBI scores increased at all three stations between the pre-construction and first post-construction surveys. The disturbance classification remained unchanged at Stations 16 and 17 ('undisturbed' and 'slightly disturbed'), while Station 19 shifted from 'undisturbed' to 'slightly disturbed'.

The Mean AMBI scores at Stations 16 and 17 also increased in the second post-construction survey. At Station 16, the increase in the AMBI score was associated with a change in disturbance classification from 'undisturbed' (first post-construction) to 'slightly disturbed' (second post-construction) while Station 17 remained 'slightly disturbed'. Station 19 showed a decrease in mean AMBI score, resulting in a shift from 'slightly disturbed' back to the 'undisturbed' classification observed in the pre-construction survey.

The range of AMBI scores across stations and survey periods is provided in Figure 24 and it indicates that overall, AMBI values generally remain within a narrow range, with low variability between replicates, temporally and across stations. Stations 16 and 17 generally show a trend of increasing AMBI scores across the pre-construction and post-construction period. Overall, the minor the relatively minor fluctuations in AMBI scores, along with minor changes in disturbance classification, suggests a relatively stable benthic community across the survey periods.

The contribution of AMBI ecological groups at each station is presented in Figure 23. All three stations showed group I species to be the main contributor in the pre-construction phase, with varying contributions of group II, III and IV. Overall, there is no clear trend on the representation of groups I to IV at Stations 17 and 19 while Station 16 shows a general decrease in group I contribution and increase in groups II, III and IV between the pre-construction and post-construction surveys.

Table 22. AMBI and disturbance classification summary – Site 4: ECR

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Export Cable Route						
16	0.49	0.74	1.38	Undisturbed	Undisturbed	Slightly disturbed
17	2.22	2.45	2.55	Slightly disturbed	Slightly disturbed	Slightly disturbed
19	0.02	1.27	0.04	Undisturbed	Slightly disturbed	Undisturbed

Figure 23. Temporal change in the Mean AMBI and contribution of ecological groups observed during the survey period – Site 4: ECR

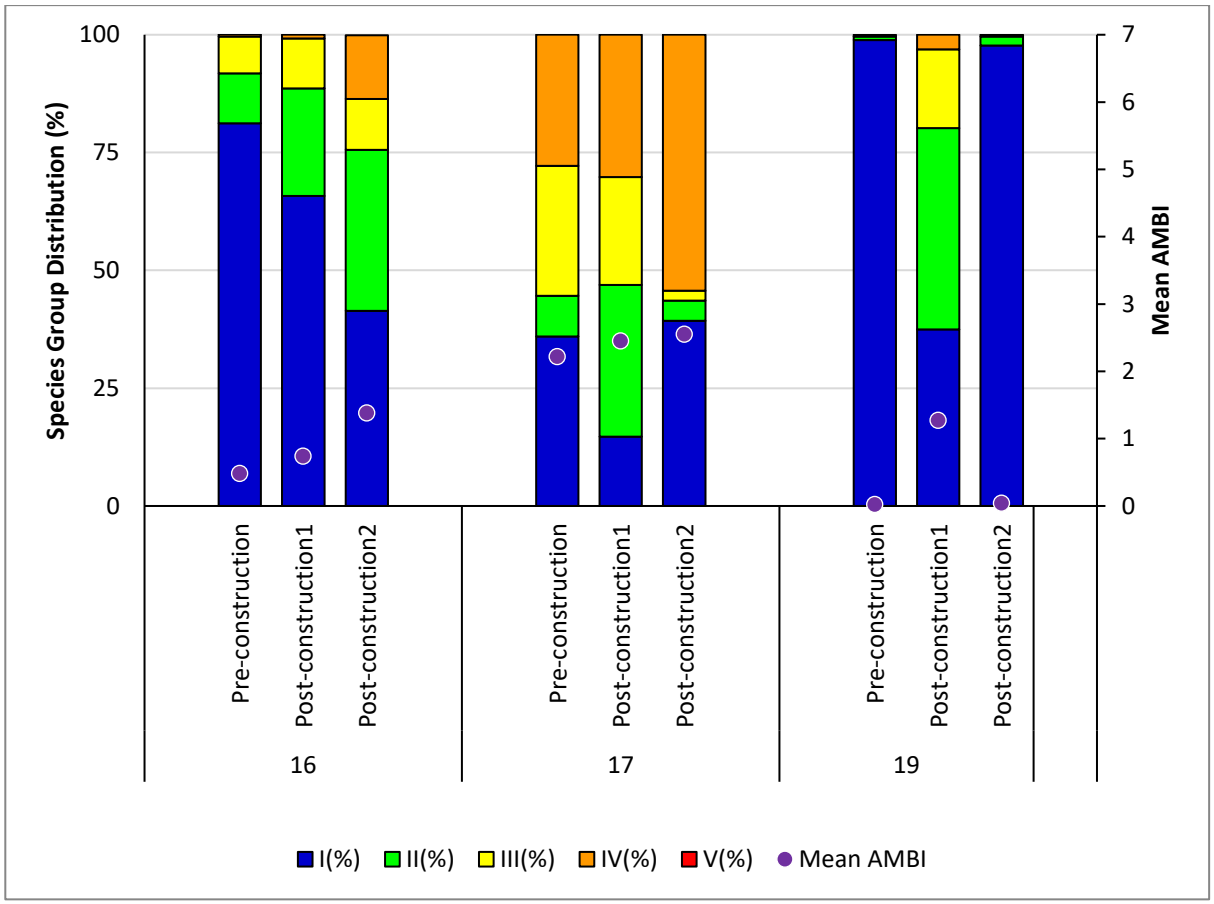
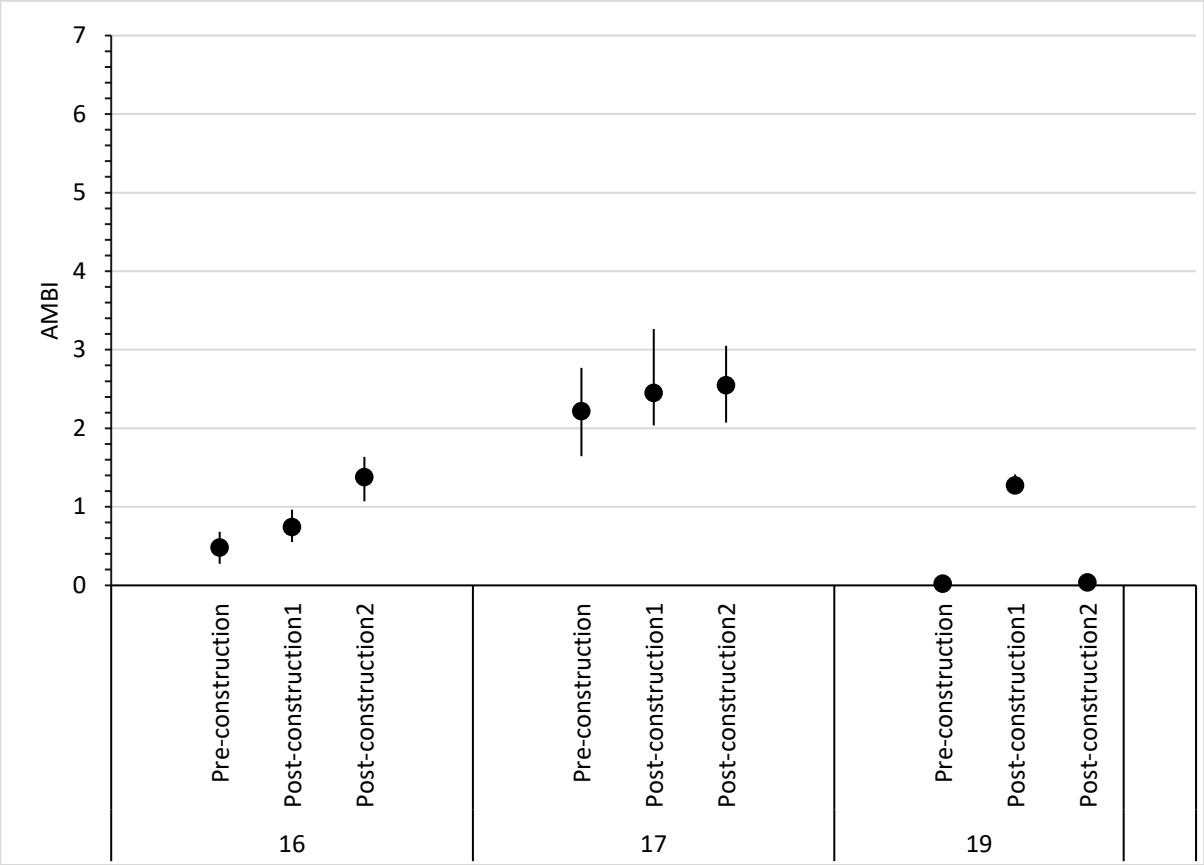


Figure 24. AMBI score range observed during the survey period – Site 4: ECR



Reference Stations

Two of the three reference stations (1 and 18) sampled in the pre-construction survey had mean AMBI scores of 1.42 and 1.94, indicative of 'slightly disturbed' conditions, while Station 20 scored 1.0, indicative of 'undisturbed' conditions (Figure 23).

Although the mean AMBI scores at Stations 1 and 18 decreased between the pre-construction and first post-construction survey, the disturbance classification remained 'slightly disturbed'. By comparison, Station 20 showed an increase in mean AMBI score, resulting in a shift from 'undisturbed' to 'slightly disturbed'.

Mean AMBI scores at Stations 18 and 20 decreased between the first and second post-construction survey. The decrease at Station 18 resulted in a shift from 'slightly disturbed' (pre-construction and first post-construction) to 'undisturbed', while the disturbance classification at Station 20 remained 'slightly disturbed'. Station 1 remained "slightly undisturbed", despite the increase in mean AMBI score.

The range of AMBI scores across stations and survey periods is provided in Figure 25. No clear trend was visible and variability between sample replicates and temporal variation was generally low with the exception of Station 20. Overall, the change in disturbance classification was minor, despite the fluctuations in AMBI scores across the survey period, suggesting a relatively stable benthic community

Temporal change in the contribution of AMBI ecological groups are provided in Figure 25. The contribution of group I species was relatively low at Stations 1 and 18 during the pre-construction phase, with groups II and III contributing to the "slightly disturbed classification. By comparison, Station 20 had

a higher group I species contribution during pre-construction, resulting in an 'undisturbed' classification. No clear trend was visible at Station 1 while Station 18 indicated a general increase in group I and II contribution and a decrease in group III contribution, resulting in a shift from 'slightly disturbed' to 'undisturbed'. Station 20 showed a general decrease in group I species and general increase in group III and IV contribution, resulting in a shift from 'undisturbed' to 'slightly disturbed'.

Table 23. AMBI and disturbance classification summary – Site 4: reference

Station	Average AMBI score			Disturbance classification		
	Pre	Post1	Post2	Pre	Post1	Post2
Reference						
1	1.42	1.29	1.78	Slightly disturbed	Slightly disturbed	Slightly disturbed
18	1.94	1.68	1.12	Slightly disturbed	Slightly disturbed	Undisturbed
20	1.00	3.17	2.73	Undisturbed	Slightly disturbed	Slightly disturbed

Figure 25. Temporal change in the Mean AMBI and contribution ecological groups observed during the survey period – Site 4: reference

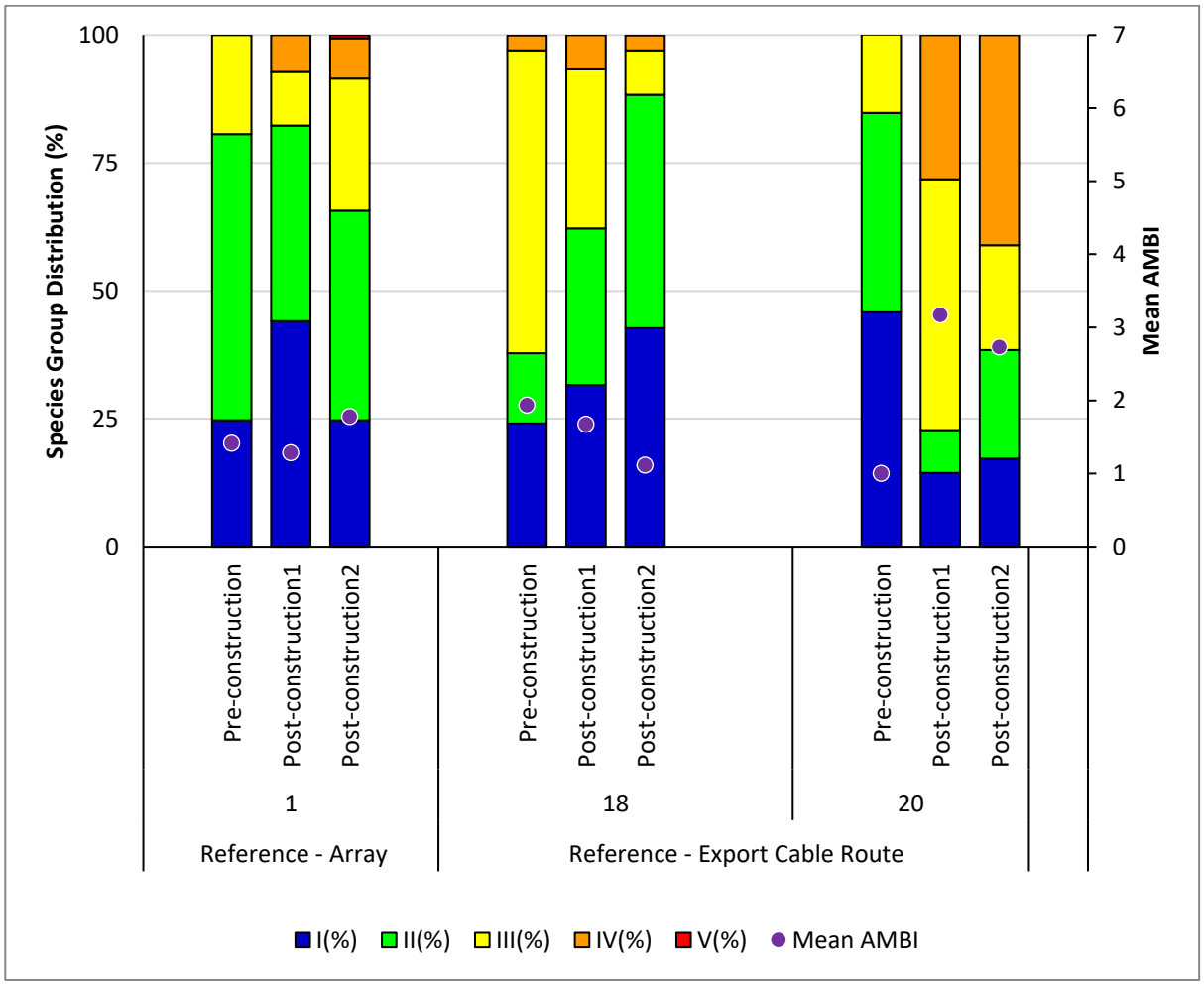
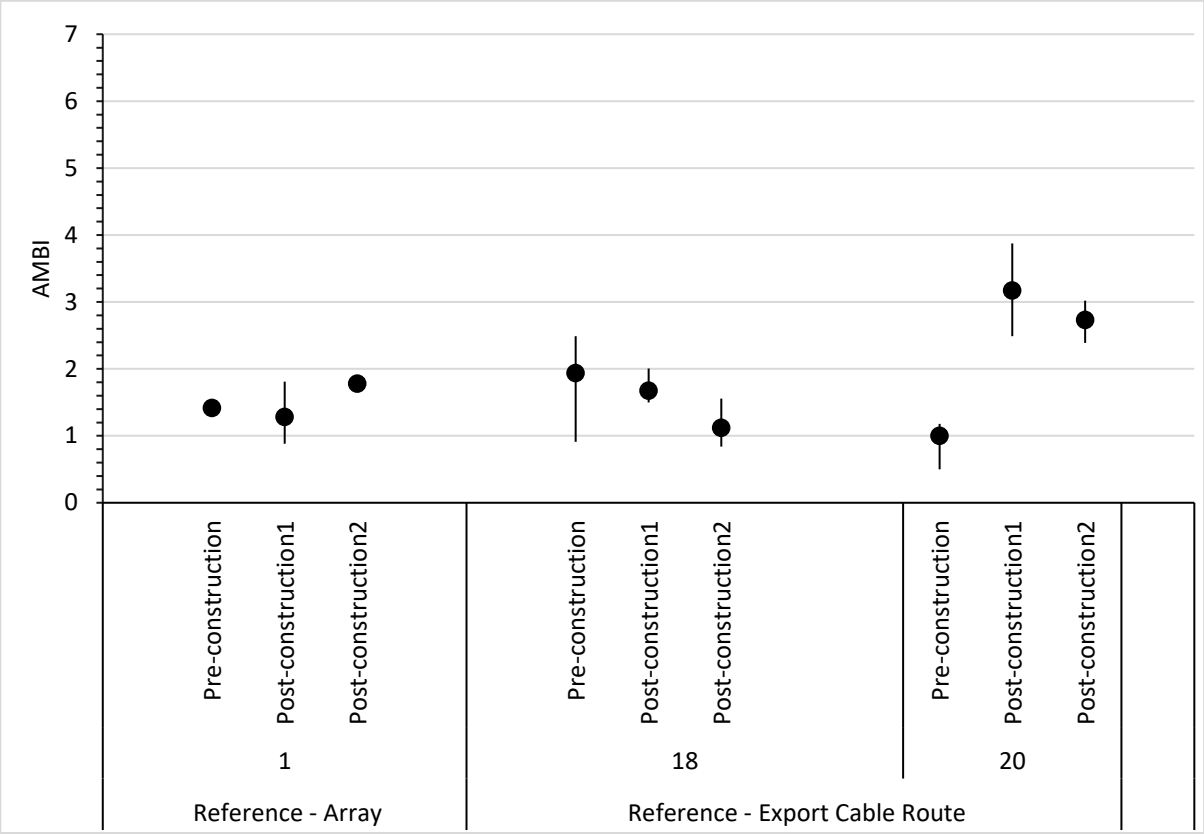


Figure 26. AMBI score range observed during the survey period – Site 4: reference



3.4.2 Statistical Analysis and Comparison

The RELATE function of PRIMER found no significant correlation between AMBI scores and the distance of stations from the nearest WTG within the array area (Table 24). Additionally, no correlation was observed between AMBI scores and distance from the nearest WTG at stations outside the array area in both post-construction surveys.

A correlation was identified between AMBI scores and TOC within the array area for the second post-construction survey, but not the first post-construction survey. This correlation was also seen within the ECR and the reference stations during the second post-construction survey. Within the array area, there was no correlation between distance of a station from nearest WTG and TOC.

Table 24. RELATE analyses output comparing correlations between AMBI, TOC (LOI%) and distance from nearest WTG

Groups	Survey Phase	Sample statistic (Rho):	Significance level of sample statistic:
Within Array Area			
AMBI vs Distance from WTG	Pre-construction	0.09	9.4%
	Post – construction 1	-0.004	42.3%
	Post – construction 2	0.092	12%
AMBI vs TOC (LOI%)	Pre-construction	0.08	16%
	Post – construction 1	0.13	14.5%
	Post – construction 2	0.238	2.5%
Distance from WTG vs TOC (LOI%)	Pre-construction	-0.083	77.3%
	Post – construction 1	-0.077	79.6%
	Post – construction 2	-0.058	67.4%
Outside Array Area			
AMBI vs Distance from WTG	Pre-construction	1	0.1%
	Post – construction 1	0.102	13.9%
	Post – construction 2	-0.057	63.8%
AMBI vs TOC (LOI%)	Pre-construction	0.155	6%
	Post – construction 1	0.471	0.5%
	Post – construction 2	-0.079	73.9%
Distance from WTG vs TOC (LOI%)	Pre-construction	0.155	7.4%
	Post – construction 1	0.088	18.3%
	Post – construction 2	0.168	8.9%
ECR			
AMBI vs Distance from WTG	Pre-construction	0.163	13.4%
	Post – construction 1	0.031	39.5%
	Post – construction 2	0.598	1%
AMBI vs TOC (LOI%)	Pre-construction	0.481	2.9%
	Post – construction 1	0.311	9.5%
	Post – construction 2	0.445	2.1%
Distance from WTG vs TOC (LOI%)	Pre-construction	-0.036	58.5%
	Post – construction 1	0.249	11.2%
	Post – construction 2	0.014	40.4%
Reference			
AMBI vs Distance from WTG	Pre-construction	0.276	9.8%
	Post – construction 1	-0.122	76.1%
	Post – construction 2	0.344	3.1%
AMBI vs TOC (LOI%)	Pre-construction	0.18	24.3%
	Post – construction 1	0.324	10.6%
	Post – construction 2	0.655	0.3%

Groups	Survey Phase	Sample statistic (Rho):	Significance level of sample statistic:
Distance from WTG vs TOC (LOI%)	Pre-construction	0.061	33.5%
	Post – construction 1	0.129	16.3%
	Post – construction 2	0.096	20.7%

A PERMANOVA test examining significant differences in AMBI scores between survey phases and sites (within array area, outside array area, export cable route and reference) indicated no effect of site location (Pseudo-F = 2.0497; P (perm) = 0.096) or survey phase (Pseudo-F = 1.1941; P(perm) = 0.33).

The PERMANOVA test examining significant differences in TOC (LOI%) between surveys phases and sites indicated an overall significant effect of site location (Pseudo-F = 16.573; P (perm) = 0.001) but not survey phase (Pseudo-F = 0.41133; P(perm) = 0.658) (Table 25). The results of the PERMANOVA test and assessment of the raw data identified the following trends:

- **Pre-construction:**
  - TOC (LOI%) at stations within the array area and outside the array area were significantly higher than the ECR and reference stations
  - TOC (LOI%) at stations outside the array area were significantly higher than within the array area
- **Post-construction 1:**
  - TOC (LOI%) at stations outside the array area were significantly higher than the ECR and reference stations
- **Post-construction 2:**
  - TOC (LOI%) at stations within the array area were significantly higher than the ECR and reference stations
  - TOC (LOI%) at stations outside the array area were significantly higher than the ECR and reference stations

Table 25. PERMANOVA output comparing Array, ECR and Reference station TOC (LOI%) for pre-construction and post-construction surveys

Groups	t value*	p value
Pre-construction		
Within Array Area vs Outside Array Area	2.4849	0.019
Within Array Area vs Export Cable Route	2.6809	0.019
Within Array Area vs Reference	2.6827	0.015
Outside Array Area vs Export Cable Route	3.0951	0.005
Outside Array Area vs Reference	3.0947	0.03
Export Cable Route vs Reference	0.067345	0.932
Post-construction 1		
Within Array Area vs Outside Array Area	1.8348	0.085
Within Array Area vs Export Cable Route	1.4257	0.18
Within Array Area vs Reference	1.683	0.089
Outside Array Area vs Export Cable Route	2.499	0.02
Outside Array Area vs Reference	2.6862	0.017
Export Cable Route vs Reference	0.79904	0.463
Post-construction 2		
Within Array Area vs Outside Array Area	1.4366	0.162
Within Array Area vs Export Cable Route	3.971	0.001
Within Array Area vs Reference	3.1502	0.005
Outside Array Area vs Export Cable Route	2.5145	0.01
Outside Array Area vs Reference	2.2466	0.03
Export Cable Route vs Reference	1.0123	0.327

4. Conclusions

4.1 OWF Site 1

For OWF site 1, the PERMANOVA analysis found no significant difference in AMBI scores between the array area and reference stations across all survey periods. Similarly, no significant difference in AMBI scores within the array area was observed between the pre- and post-construction surveys. While AMBI scores within the array area showed some fluctuation during the monitoring period, similar patterns of variability were observed at the reference stations. The absence of significant differences between these areas and survey periods suggests that the construction of this OWF did not result in significant changes to the benthic community within the array area relative to reference conditions and the similar pattern in fluctuations of AMBI scores in both the array area and the reference area may suggest that natural variability was the main driver of change.

Similarly, the analysis did not find significant differences between the AMBI scores outside the array area and the reference stations across the survey period.

The RELATE analysis found no correlation between AMBI scores and TOC suggesting that TOC was not influencing the AMBI scores. Within the array area, TOC was significantly higher during the pre-construction survey relative to subsequent post-construction surveys. This suggests that construction of the OWF did not lead to an increase in organic enrichment across the array area as may be expected if colonising epifauna are contributing organic matter to the seabed. However, this analysis may not be sensitive enough to detect very localised changes in TOC in close proximity to WTGs.

Overall, the AMBI analysis seems to support the conclusion of the original benthic analysis conducted during the monitoring programme that concluded changes observed during the survey periods were likely due to natural variability and not the construction of the OWF.

4.2 OWF Site 2

Similar to OWF site 1, the PERMANOVA analysis found no significant difference in AMBI scores between the array area and reference stations across all survey periods and no significant difference between the pre-construction survey and first post-construction survey within the array area. Some localised changes were observed, especially at stations 18-20, which shifted from ‘undisturbed’ to ‘slightly disturbed’ and showed a transition from group I (disturbance sensitive) to group III (disturbance tolerant) species. While there were other stations where there was a change in classification, the magnitude of the change in AMBI scores at these sites relative to other sites within the array area and the reference stations may indicate localised influence of the construction of the OWF at these stations. However, the overall absence of significant differences between the array area and the reference stations suggests that widespread effects across the array area were not observed.

The RELATE analysis indicated a significant correlation between AMBI scores and TOC within the array area for the entire survey period. This correlation, where fluctuations in TOC were associated with similar fluctuations in AMBI scores, suggests that AMBI is responding to organic enrichment within the array area. However, the PERMANOVA results showed no significant temporal changes in TOC within the array area between surveys, indicating stable sediment organic content across the survey period. At the reference stations, a significant correlation between AMBI and TOC was only identified during the final post-construction survey.

Overall, while some localised changes were evident in the post-construction surveys, the AMBI analysis seems to support the conclusion of the original benthic analysis conducted during the monitoring

programme that concluded changes observed during the survey periods were likely due to natural variability and not the construction of the OWF.

4.3 OWF Site 3

At OWF site 3, the PERMANOVA analysis found no significant effect of site location or survey phase on AMBI scores, indicating no significant differences in AMBI scores between the array area and reference stations across the survey periods. Similar to OWF site 2, some stations within the array area showed larger magnitude changes in AMBI score during the first post-construction survey (stations 3, 4, and 6) shifting from 'undisturbed' to 'moderately' or 'extremely disturbed'. These changes were temporary, with all stations returning to 'undisturbed' by the second post-construction survey. The reference stations remained largely stable throughout the monitoring period. The absence of statistical significance combined with the temporary nature of the changes, along with recovery of AMBI scores at disturbed stations, suggests that while localised disturbance may have occurred during construction, the benthic communities showed good recoverability and there was no lasting effect on the benthic communities within the array area.

It should be noted that the AMBI software flagged very low abundance or taxa counts at many stations across the array area, suggesting that the AMBI scores and classifications should be treated with a degree of caution.

Analysis of TOC was not possible for this site as TOC concentrations were below the limit of detection at the majority of sites.

4.4 OWF Site 4

PERMANOVA analysis found no significant difference in AMBI scores between all site areas and all survey periods including between the array area and reference stations and between pre- and post-construction surveys in the array area. Similar patterns of variability in AMBI scores were observed at both the array area and reference stations. This suggests that the construction of this OWF did not result in significant changes to the benthic community within the array area.

While TOC (LOI%) within the array area was significantly different from stations outside the array area, ECR and reference site in the pre-construction survey, these significant differences were not observed in the post-construction survey.

The RELATE analysis identified a correlation between AMBI scores and TOC within the array area in the second post-construction survey only, suggesting that TOC may have influenced the AMBI scores. Additionally, PERMANOVA analysis found significant differences in TOC between the array area and reference sites in the second post-construction phase. This suggests that construction of the OWF may have led to an increase in organic enrichment across the array area as may be expected if colonising epifauna are contributing organic matter to the seabed. However, no significance difference in TOC was identified between survey phases in the array area.

Overall, the AMBI analysis seems to support the conclusion of the original benthic analysis conducted during the monitoring programme that concluded changes observed during the survey periods were likely due to natural variability and not the construction of the OWF. The PERMANOVA results for both site location and survey phase effects on AMBI scores suggests that array and reference areas experienced similar levels of variation, which supports natural variability being the primary driver.

5. References

APEM. 2025a. ORJIP BenCH: Benthic Habitat Changes post-construction of offshore wind (RQ1 and 2). Ref: P00015801

APEM. 2025b. ORJIP BenCH: Benthic Habitat Changes post-construction of offshore wind (RQ3, 4 and 5). Ref: P00015801

Borja, A., Barbone, E., Basset, A., Borgersen, G., Brkljacic, M., Elliott, M., Garmendia, J.M., Marques, J.C., Mazik, K., Muxika, I. and Neto, J.M. 2011. Response of single benthic metrics and multi-metric methods to anthropogenic pressure gradients, in five distinct European coastal and transitional ecosystems. Marine pollution bulletin, 62(3), pp.499-513.

GEOxyz (2023) Outer Dowsing Offshore Wind Preliminary Environmental Information Report, Volume 2, Appendix 9.2: Benthic Ecology Technical Report (ECC). Document number: UK4855H-824-RR-02, Revision 1.1. pp.310.

Muxika, I.; Borja, A. and Bonne, W. 2005. The suitability of the marine biotic index (AMBI) to new impact sources along European coasts. Ecological Indicators, 5: 19-31.

Water Framework Directive – United Kingdom Technical Advisory Group (WFD-UKTAG). 2014. UKTAG Transitional and Coastal Water Assessment Method, Benthic Invertebrate Fauna, Infaunal Quality Index, WFD-UKTAG, pp.2-38.

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