PA/05908/23 & EA/00007/18

PROPOSED CONVERSION FROM A TEMPORARY TO A PERMANENT TUNA FARMING AREA AS ESTABLISHED IN PA/02175/18; RETAINING THE APPROVED TOTAL BIOMASS OF FISH AND ALL RELATIVE CONDITIONS

ENVIRONMENTAL IMPACT ASSESSMENT UPDATE REPORT

VOLUME 2: TECHNICAL APPENDICES

Version 1: January 2025

Report Reference:

Adi Associates Environmental Consultants Ltd, 2025. PA/05908/23 & EA/00007/18 - Proposed Conversion from a Temporary to a Permanent Tuna Farming Area as Established in PA/02175/18; retaining the approved total biomass of fish and all relative conditions. Environmental Impact Assessment Report – Technical Appendices. San Gwann, January 2025.

CONTENTS

Technical Appendix 1: Remote Sensing Survey Report 2018

Technical Appendix 2: Marine Ecology Baseline Report 2018

Technical Appendix 3: Environmental Monitoring – Integrated Assessment Reports (2019 – 2023)

PA/05908/23 & EA/00007/18

PROPOSED CONVERSION FROM A TEMPORARY TO A PERMANENT TUNA FARMING AREA AS ESTABLISHED IN PA/02175/18; RETAINING THE APPROVED TOTAL BIOMASS OF FISH AND ALL RELATIVE CONDITIONS

Technical Appendix 1

REMOTE SENSING SURVEY REPORT 2018

Prepared by Seastar Surveys Ltd (UK)

Supporting Documents for

Environmental Impact Assessment Update Report

ADI Associates – Environmental Consultants Ltd

Malta Environmental Baseline: Acoustic and Camera Surveys April / May 2018

Survey Report

19th June 2018

Seastar Survey Ltd. Project Number – J/18/516

For further information please contact Steven Dewey
Seastar Survey Ltd., Ocean Quay, Belvidere Road, Southampton, SO14 5QY
Email: sdewey@seastarsurvey.co.uk

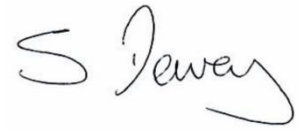
Please cite this report as:

MacMillan, A., O'Dell, J., and Dewey, S. (2018). Malta Environmental Baseline: Acoustic and Camera Surveys. A report to ADI Associates by Seastar Survey Ltd., 15 pages.

Signed Declaration

Attn: Director of Environment and Resources
Environment and Resources Authority
Malta

I, Steven Dewey, who carried out the remote sensing surveys (or part thereof) for the marine environment study for the EIA for the proposed extension to an existing tuna farm operation off the Northeast coast of Malta, hereby declare that such study was solely carried out by me on behalf of Seastar Surveys Ltd and the company takes responsibility for any statement and conclusion contained therein.



19 June 2018

Date

Signature

Signed Declaration

Attn: Director of Environment and Resources
Environment and Resources Authority
Malta

I, Abigail MacMillan, who carried out the remote sensing surveys (or part thereof) for the marine environment study for the EIA for the proposed extension to an existing tuna farm operation off the Northeast coast of Malta, hereby declare that such study was solely carried out by me on behalf of Seastar Surveys Ltd and the company takes responsibility for any statement and conclusion contained therein.

19 June 2018

Date

Signature

Contents

1 INTRODUCTION 1
2 ACOUSTIC SURVEY 3
2.1 Mobilisation 3
2.2 Survey Equipment 3
2.3 Survey Plan 3
2.3.1 Bathymetric Survey 3
2.3.2 Sidescan Sonar Survey 4
2.4 Deployment 4
2.5 Horizontal control 5
2.6 Vertical control 5
2.6.1 Tides 5
2.6.2 Speed of Sound Profiles 6
2.6.3 Vessel Motion Reference 6
2.7 Processing 7
2.7.1 Bathymetric Survey 7
2.7.2 Sidescan Sonar Survey 7
2.8 Survey Success and Weather 8
2.8.1 Bathymetric Survey 8
2.8.2 Sidescan Sonar Survey 10
3 CAMERA SURVEY 11
3.1 Mobilisation 11
3.2 Survey Equipment 11
3.3 Camera Survey Plan 11
3.3.1 Deployment 12
3.3.2 Survey Success and Weather 12

List of Figures

Figure 1.1: Areas surveyed by Seastar as part of the 2018 baseline survey: Area 1 - offshore area (red box) and Area 2 – area inshore of existing fish farm (green box). The area in blue was surveyed previously. Existing fish farm indicated in black box. 2

Figure 2.1: Proposed bathymetry line plans for the two survey areas. Fish farm indicated in green and red. Blue hashed area and white area surveyed previously. 4

Figure 2.2: Navigation check being performed alongside Fekruna Quay 6

Figure 2.3: Bathymetric survey track plots for all successful survey lines in area 1 9

Figure 2.4: Bathymetric survey track plots for all successful survey lines in area 2 9

Figure 3.1: Targets of potential features of interest identified from the sidescan sonar data. The blue hashed area was surveyed during a previous drop-down camera survey. 11

Figure 3.2: Track plots of the camera transects across all the identified target locations of interest and along the length of the existing fish farm 13

List of Tables

Table 2.1: Daily progress during the acoustic surveys 8

Table 3.1: Daily progress and weather during the camera survey 13

1 INTRODUCTION

Seastar Survey Ltd ('Seastar') were contracted by Adi Associates – Environmental Consultants Ltd ('ADI') to undertake hydrographic and environmental survey work in an area of seabed located approximately 5 km off St Pauls Bay, on the northeast coast of Malta.

The objectives of the surveys were to collect bathymetric data to inform a numerical model and to collect sidescan sonar data to identify seabed features and sediment types, which would be ground-truthed during a subsequent environmental survey using a drop-down camera system.

For the bathymetric survey work two areas were to be surveyed; an offshore area (area 1) indicated by the red box in Figure 1.1, and an area close to an existing fish farm (area 2), which is indicated by a green box in Figure 1.1.

Existing sidescan sonar data was available courtesy of Professor T. Gambin from the University of Malta for the majority of area 1, and therefore, during this survey, data was only collected to infill 2 gaps in the existing coverage for area 1, and to collect data from area 2.

The survey area for the drop-down camera work was slightly different, with the offshore area (area 1) being larger and covering both the red and some of the blue box shown in Figure 1.1, as well as all of area 2.

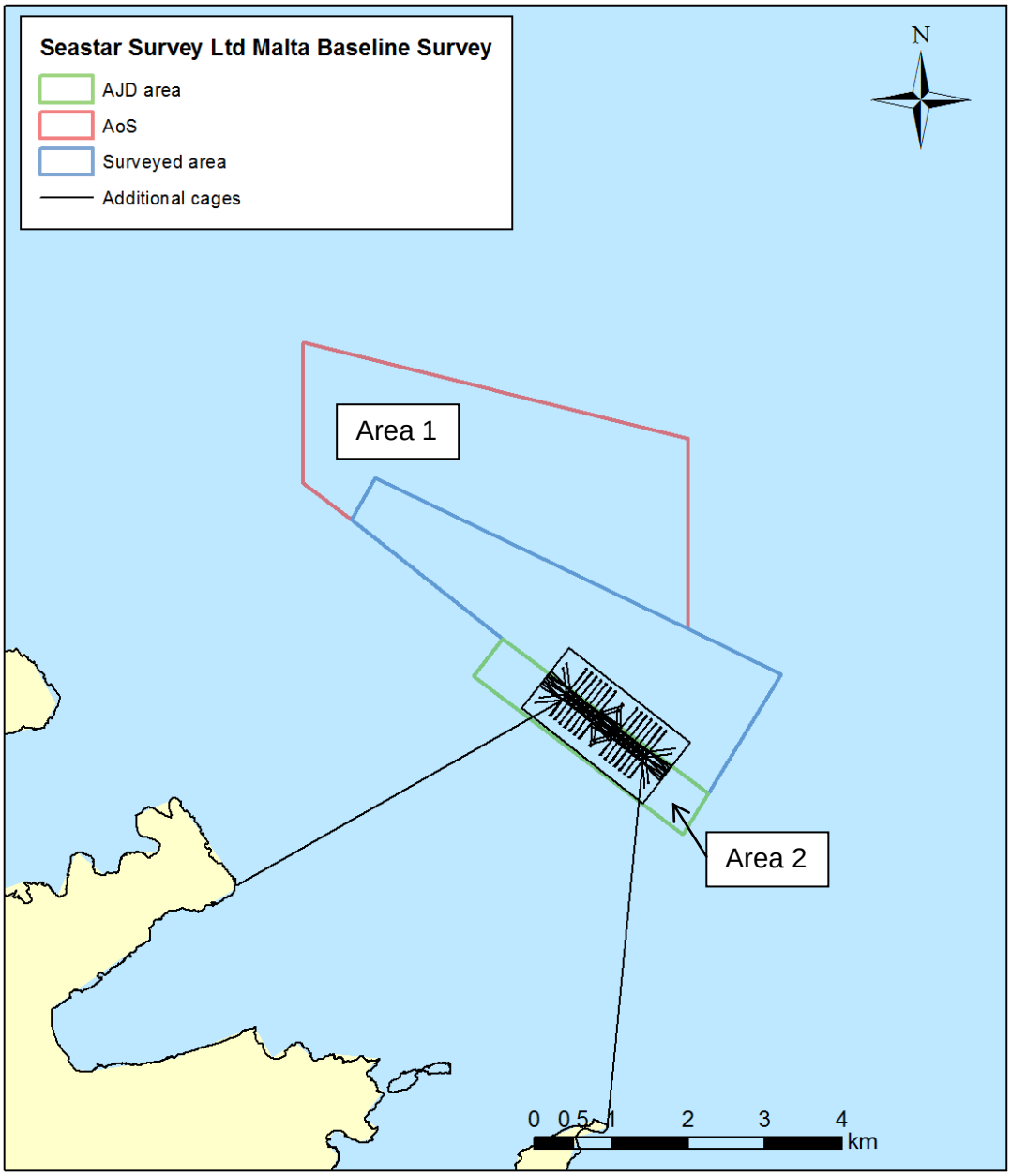


Figure 1.1: Areas surveyed by Seastar as part of the 2018 baseline survey: Area 1 - offshore area (red box) and Area 2 – area inshore of existing fish farm (green box). The area in blue was surveyed previously. Existing fish farm indicated in black box.

2 ACOUSTIC SURVEY

2.1 Mobilisation

Seastar transported all equipment and personnel from Southampton to Malta by road between Thursday 19th and Monday 23rd April 2018. All survey operations were conducted from MV *Awrata*, a 14 m, steel workboat owned and operated by Azzopardi Fisheries. Throughout the project the vessel worked out of Fekruna Quay, Xemxija.

The acoustic survey equipment was mobilised and tested on MV *Awrata* on Monday 23rd April 2018.

2.2 Survey Equipment

The following equipment was used during the acoustic surveys;

- Hemisphere GNSS V320 GPS and vector compass
- Marimatech E-Sea Sound 206 single-beam echosounder (33 & 200 kHz)
- TSS motion reference unit (MRU)
- Valeport 606 CTD
- Edgetech 4125 dual frequency sidescan sonar (400 and 700 kHz)
- Cable counter and block
- DT Marine Products Inc. hydro-electric winch
- Co-axial armoured cable
- Helmsman display
- Hypack survey management software
- Edgetech Discover software

2.3 Survey Plan

Prior to the fieldwork, line plans were created in the two survey areas shown in Figure 1.1 using the survey management software Hypack.

2.3.1 Bathymetric Survey

For the bathymetric survey of area 1, 62 main survey lines were planned at 100 m line spacing, in a NE-SW direction. These were intersected by 13 perpendicular cross-lines; 8 were at a line spacing of 300 m and 5 lines were run at 150 m line spacing within the south-west corner of the survey area. The 150 m cross-line spacing was used in order to obtain higher resolution data of a sub-sea channel identified from sidescan sonar data collected previously by Professor Gambin from the University of Malta.

For area 2, 34 main lines were planned at 100 m line spacing in a NE-SW direction. These were intersected by 10 perpendicular cross-lines at 75 m line spacing. The bathymetry line plans for both survey areas are shown in Figure 2.1.

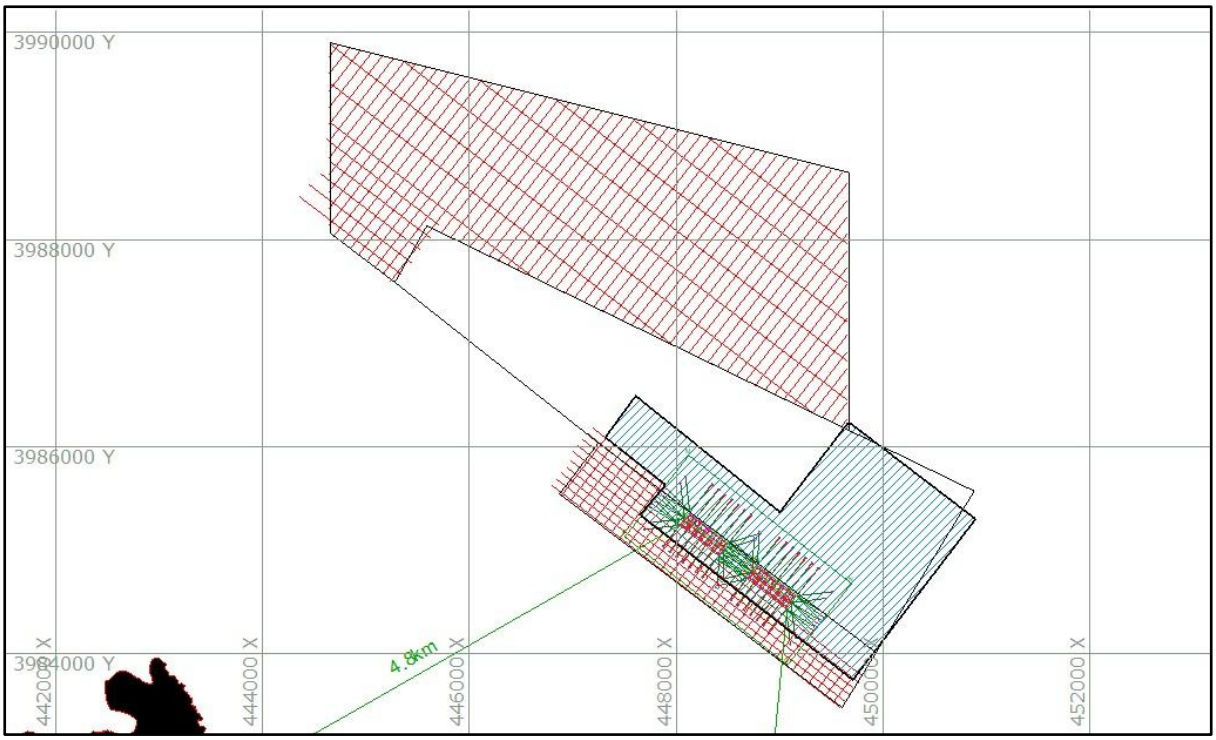


Figure 2.1: Proposed bathymetry line plans for the two survey areas. Fish farm indicated in green and red. Blue hashed area and white area surveyed previously.

2.3.2 Sidescan Sonar Survey

As sidescan sonar data had already been collected for the majority of area 1, and only two lines were required as infill, no line plan was created during the initial planning stage.

For area 2, the sidescan sonar survey was restricted by the anchors and ropes that hold the current fish farm cages in place. As a result, only 2 of the bathymetry survey lines on the south west of the area were run using the sidescan sonar.

2.4 Deployment

The echosounder transducer was pole mounted and secured to the port side of MV *Awrata*. To create a rigid fixing point two horizontal scaffold poles where welded to the boat and the transducer pole was attached to these using scaffold clamps. In addition, fore and aft guy ropes were used to secure the transducer head to the boat to prevent any vibration.

The transducer was positioned 0.5 m below the water line this point then acted as the 0,0-reference point from which all offsets were measured.

The Hemisphere GPS was mounted on the roof of the wheel house, inboard and forward of the echosounder transducer. The GPS offsets were entered into Hypack so that recorded positions were for the location of the echosounder transducer.

The winch and block for the sidescan sonar were aft of the echosounder transducer and the block was suspended from the vessel's crane; once the offsets to the block were measured and entered into Hypack, the crane remained in the same position throughout the duration of the sidescan sonar survey.

A helmsman's display feed from Hypack, showing the survey lines and vessel position, was set up to assist the vessel skipper in driving the survey lines.

During the bathymetry survey the vessel skipper set up on the bearing of the chosen line and vessel speed was reduced to 4.5 knots. The echosounder was used in dual frequency mode and recorded soundings at both 33 and 200 Hz. This ensured best quality data was achieved when moving between shallow and deep water in area 1.

For the sidescan survey the vessel set up on the bearing of the chosen line approximately 500 m before the start of line and speed was reduced to approximately 3 knots. The Edgetech 4125 was deployed from the stern of the vessel and winch wire was paid out until the fish altitude (height above seabed) was approximately 10 m.

2.5 Horizontal control

Survey navigation was achieved through the use of a Hemisphere GNSS V320 GPS and vector compass, which has a positional accuracy of ± 0.3 m.

Raw data from the GPS was input into Hypack and positions were recorded in WGS84 latitude and longitude and converted to UTM grid (UTM North, zone 33 (12 - 18° E)).

For the sidescan sonar the amount of winch wire payed-out was recorded using a cable counter block. The amount of cable out was then entered into Hypack, which used a catenary factor, along with the vessel speed, heading, fish altitude, water depth and the measured offset for the block, to calculate a layback position of the tow-fish relative to the echosounder transducer. The layback was checked by comparing the position of an obvious target within the survey area and adjustment made to the catenary factor.

Navigation checks were performed daily throughout the acoustic surveys against a known location alongside the quay in Xemxija (Figure 2.2).

2.6 Vertical control

2.6.1 Tides

Raw soundings were reduced to local chart datum using tide corrections applied during post-processing. Tidal data from a gauge in the Port of Marsaxlokk were downloaded from https://malta.port-log.net/live/Display.php at the end of the survey period. Tide times were converted from local time to GMT and tidal curves were created, which were then imported into Hypack.

2.6.2 Speed of Sound Profiles

A Valeport 606 CTD was used to measure the speed of sound through the water column at various locations within both area 1 and area 2. The raw bathymetric data was recorded with a default setting of 1500 m/s and corrections for speed of sound were applied to the raw data during post-processing.

2.6.3 Vessel Motion Reference

The heave, pitch, and roll of the vessel were measured using a TSS motion reference unit (MRU) and these data were input directly into the Marimatech echosounder. The raw data was then corrected in real time for vessel motion within the echosounder and the corrected depth, along with the raw data from the MRU, were recorded within Hypack.

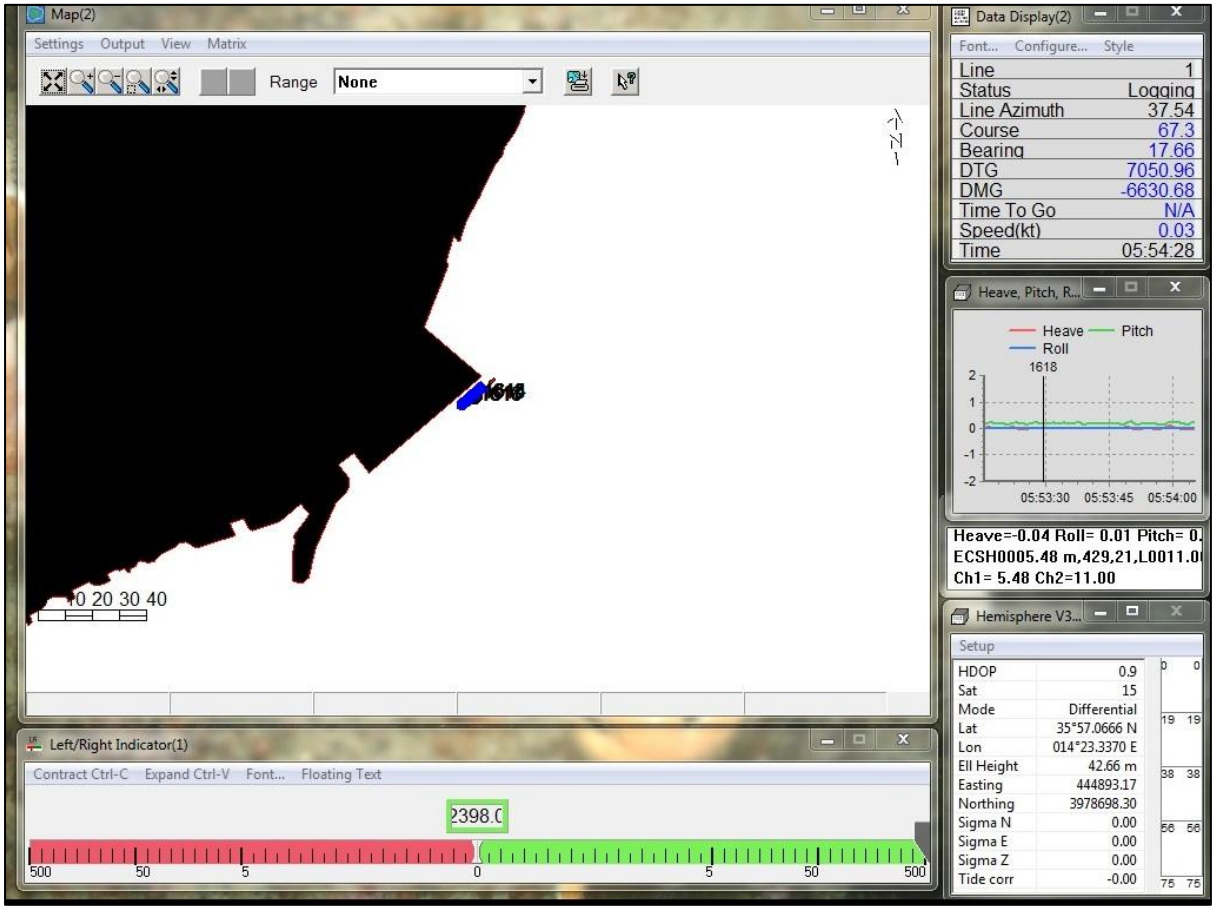


Figure 2.2: Navigation check being performed alongside Fekruna Quay

2.7 Processing

2.7.1 Bathymetric Survey

The raw bathymetry data were processed in Hypack using the Single Beam Editor tool. All spikes, multiple returns, and other erroneous data were removed before applying draught, sound velocity, and tidal corrections. Edit soundings, relative to local chart datum, were then saved before being sorted to a 2 m grid.

Data quality control checks were made against the paper trace, and by comparing edited depths at all of the main survey lines and cross lines “crossover points”. In total there were 339 intersections checked with a mean difference between main lines and cross lines of 0.13 m.

2.7.2 Sidescan Sonar Survey

The raw sidescan data were recorded in the Discover software and saved as .jsf files. These were converted into a Hypack compatible format (.hsx files) and processed in Hypack.

The recorded layback was checked by identifying targets on adjacent lines and cross checking their position.

2.8 Survey Success and Weather

Table 2.1 provides a summary of the survey success and weather for the acoustic surveys.

Table 2.1: Daily progress during the acoustic surveys

Date	Survey Type	Survey Success
24/04/2018	Bathymetry	21 lines
25/04/2018	Bathymetry	28 lines
26/04/2018	Bathymetry	27 lines
27/04/2018		WEATHER DAY
28/04/2018		WEATHER DAY
29/04/2018		WEATHER DAY
30/04/2018	Bathymetry	27 lines
01/05/2018	Sidescan sonar	TECHNICAL DAY
02/05/2018		WEATHER DAY
03/05/2018		WEATHER DAY
04/05/2018	Sidescan sonar	WEATHER DAY
05/05/2018		STAND-DOWN DAY
06/05/2018	Sidescan sonar	3 lines

2.8.1 Bathymetric Survey

The bathymetry survey was carried out on the 24th, 25th, 26th, and 30th April 2018. Strong winds and unfavourable sea conditions at the survey site prevented working between Friday 27th and Sunday 29th of April 2018.

In total, across the two sites, 103 bathymetry lines were run, including lines that were re-run due to poor data quality. In area 1 a total of 74 lines of good quality data were achieved, with one less cross line surveyed than originally planned. Figure 2.3 shows the track plot for all achieved survey lines in area 1.

In area 2 a total of 23 lines of good quality data were achieved. The survey plan for this area had to be altered during the fieldwork due to the prevailing wind and sea conditions. This meant fewer NE-SW main lines were run, but additional cross lines were added. Figure 2.4 shows the track plot for the achieved bathymetric survey lines in area 2.

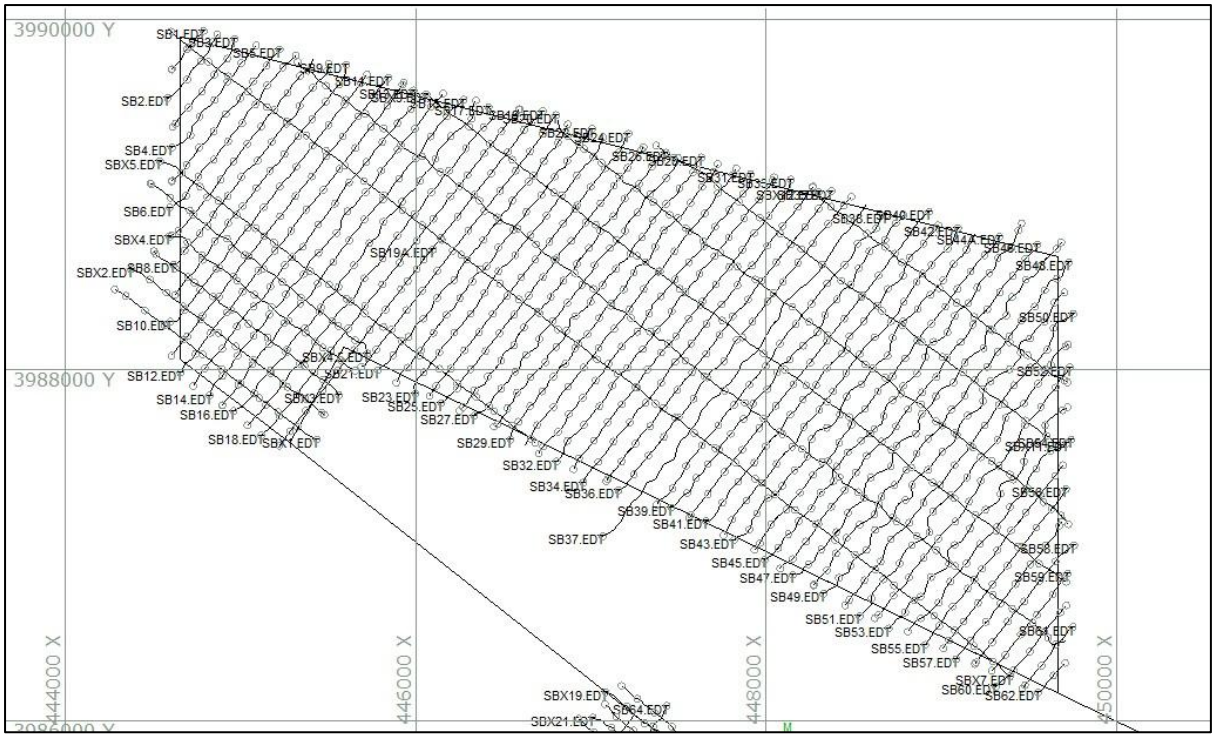


Figure 2.3: Bathymetric survey track plots for all successful survey lines in area 1

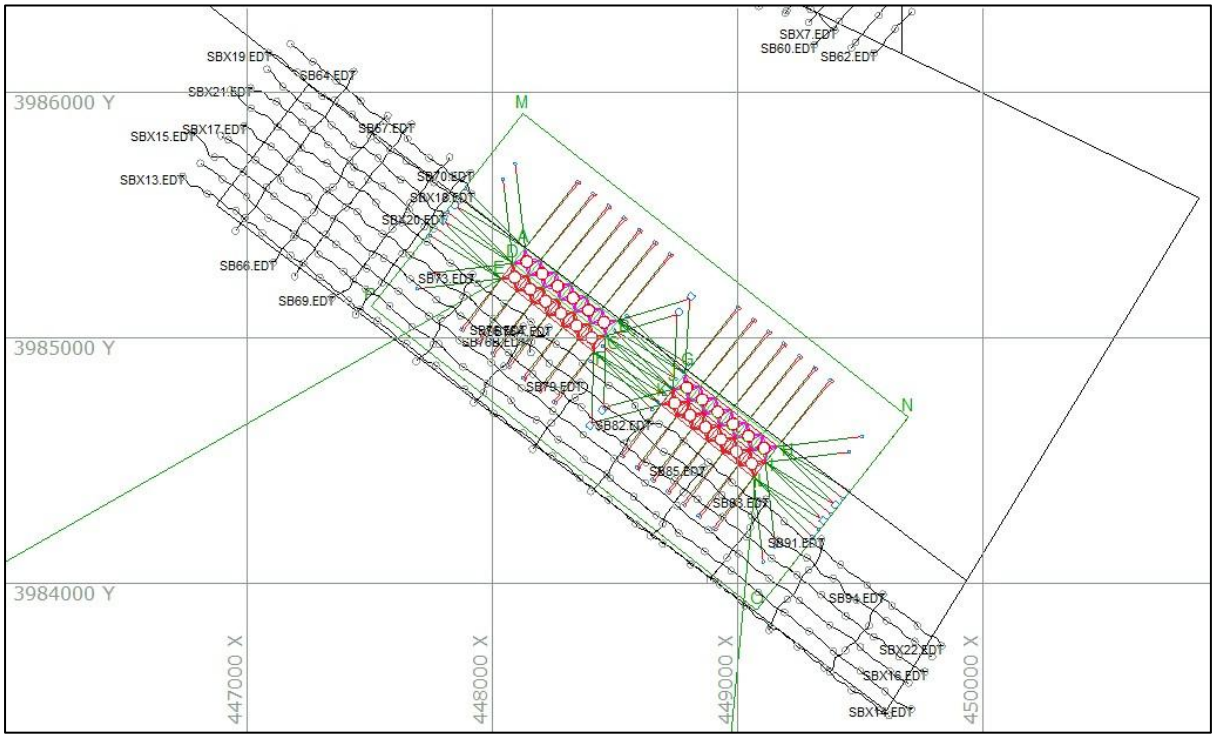


Figure 2.4: Bathymetric survey track plots for all successful survey lines in area 2

2.8.2 Sidescan Sonar Survey

The sidescan sonar survey was attempted on the 1st May 2018 but work was prevented by a power supply issue between the vessel's generator and the winch. Strong winds and rough seas then prevented survey working between Wednesday 2nd and Friday 4th May 2018; survey work was attempted on the 4th May 2018 but once on site the residual swell was too large to collect good data (2 – 3 m swell with intermittent wave heights of > 3 m). Sidescan sonar survey work was carried out on the 6th May 2018 (See Table 2.1).

During the sidescan sonar survey three lines were run in area 1 (two lines of infill, one of which was run in two directions to check layback) and two survey lines were run in area 2.

Due to the location of the anchors and anchor lines for the existing fish farm, only two sidescan sonar lines were run in area 2 (lines SBX13 and SBX14). It was deemed too dangerous to run the sidescan over these anchor lines due to the high risk of snagging the tow-fish.

3 CAMERA SURVEY

3.1 Mobilisation

Following the completion of the acoustic surveys, the sidescan sonar equipment was demobilised on Monday 7th May 2018 and the camera system was mobilised and tested.

3.2 Survey Equipment

- Kongsberg 14-208 camera and flash
- Four video LED lights
- Seastar Survey camera frame
- EdgeDVR Digital video recorder with overlay
- 300 m umbilical

3.3 Camera Survey Plan

The sidescan data collected by Seastar along with the data supplied by Professor Gambin were analysed in order to identify potential features of interest; in total 26 features of interest were identified. Target positions for these were plotted in Hypack (Figure 3.1).

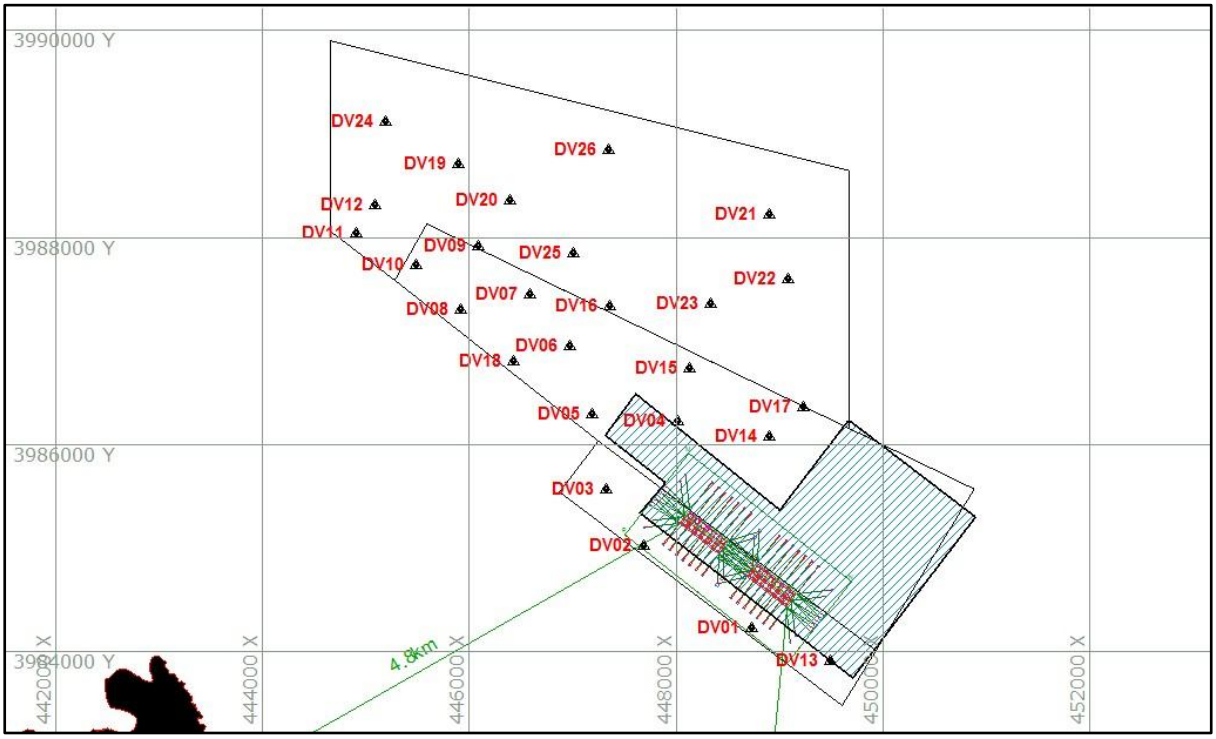


Figure 3.1: Targets of potential features of interest identified from the sidescan sonar data. The blue hashed area was surveyed during a previous drop-down camera survey.

3.3.1 Deployment

The camera and lights were set up on the camera frame so as to optimise field of view and video lighting. The field of view was measured using a calibrated field survey tape measure when the camera frame was on deck and this information assisted with the analysis of the video and stills data acquired.

At each site the vessel set up on the target location and was taken out of gear so as to determine the direction and speed of drift. Once the drift direction was determined the vessel moved ~ 300 m from the target location in the direction of drift, and turned so that the camera transect was driven into the current. Figure 3.2 shows the vessel track for each of the camera deployments.

At the start of line the vessel slowed to between 0.5 and 1.0 knot. The camera frame was deployed using the DT winch and the vessel's crane. The camera frame was attached to the winch wire used during the sidescan sonar survey. The vessel's crane was used to lift the camera frame off the deck and slew it outboard over the stern. Once the cable counter block was in position at the stern of the vessel the camera frame was lowered by paying out on the winch.

The camera umbilical was bulldog taped to the winch wire at regular intervals to prevent it streaming out in the water column, as this could affect how the camera frame flew through the water and result in poor quality data.

As with the sidescan sonar a layback position was calculated and recorded in Hypack, and an output of layback position and GPS time (GMT) was sent to the video overlay and recorded along with the video using the EdgeDVR software. At regular intervals (approximately every minute) the camera frame was landed on the seabed and a high resolution still image was taken of the seabed. These still images were saved on the camera and uploaded at the end of each survey day.

The position of the still images was recorded by noting the time of the photograph with the layback position from the navigation log for the same time.

3.3.2 Survey Success and Weather

The camera survey took place on the 8th, 10th, 15th and 16th of May 2018. The Seastar survey team stood down between the 11th and 14th May 2018 due to the poor weather forecast and restarted when the weather had improved, on the 15th May 2018. Table 3.1 provides a summary of the survey success and weather for the camera survey.

Table 3.1: Daily progress and weather during the camera survey

Date	Survey Success	Weather
07/05/2018	CAMERA MOBILISATION	
08/05/2018	10 Deployments 11 Lines	Light breeze (Force 2) from W, sea state calm
09/05/2018	WEATHER DAY	Sea state too rough to work; 1 - 2 m wave heights, long period swell
10/05/2018	3 Deployments	Survey day cut short as sea state worsened; 1 - 2 m wave heights, increasing white caps
11/05/2018	STANDBY PERIOD	*Poor weather forecast for these days so Seastar's survey team stood down*
12/05/2018		
13/05/2018		
14/05/2018		
15/05/2018	6 Deployments	Cool light breeze (Force 2 - 3) from NE, sea state smooth
16/05/2018	6 Deployments 8 Lines	Gentle breeze (Force 3) and moderate sea state in morning, improved throughout day

A total of 25 deployments were completed; all 26 targets were surveyed (at some locations two targets were surveyed during the same deployment) and an additional transect running along the length of the fish farm within area 2 was also undertaken.

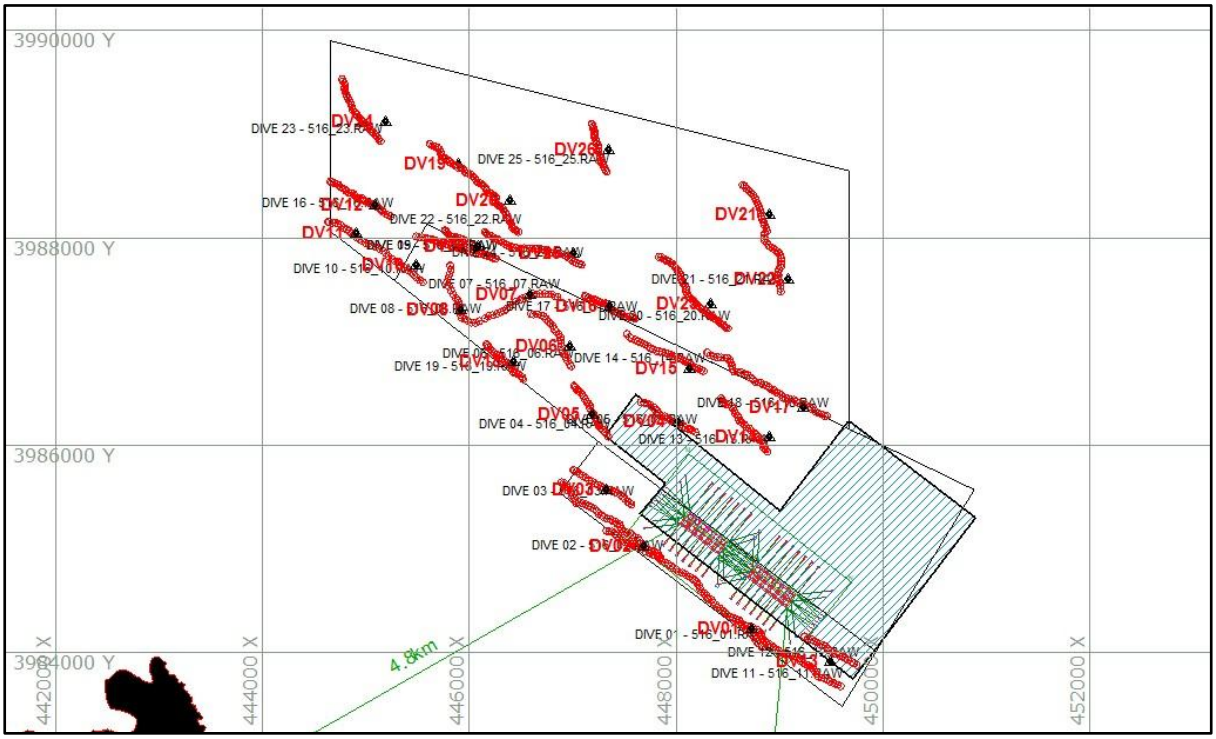


Figure 3.2: Track plots of the camera transects across all the identified target locations of interest and along the length of the existing fish farm

PA/05908/23 & EA/00007/18

PROPOSED CONVERSION FROM A TEMPORARY TO A PERMANENT TUNA FARMING AREA AS ESTABLISHED IN PA/02175/18; RETAINING THE APPROVED TOTAL BIOMASS OF FISH AND ALL RELATIVE CONDITIONS

Technical Appendix 2

MARINE ECOLOGY BASELINE REPORT 2018

Prepared by Ecoserv Ltd (Malta)

Supporting Documents for

Environmental Impact Assessment Update Report

Report on an ecological assessment of an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, undertaken as part of the Environment Impact Assessment in connection with PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta

Prepared by

Joseph A. Borg
BSc MSc PhD (Plymouth) CBiol MIBiol MMBA FIBMS

Logistic & Technical Support:

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137

www.ecoserv.com.mt

ECOSERV'S REPORT REFERENCE NO: 068-18

JUNE 2018

Signed Declaration

Attn: Director of Environment and Resources
Environment and Resources Authority
Malta

I, Joseph A. Borg, who carried out the study (or part thereof) on marine ecology for the EIA for the proposed extension to an existing tuna farm operation off the Northeast coast of Malta, hereby declare that such study was solely carried out by me on behalf of Ecoserv Ltd, and the company takes responsibility for any statement and conclusion contained therein.

13 July 2018

Date

Signature

Signed Declaration

Attn: Director of Environment and Resources
Environment and Resources Authority
Malta

I, Sarah Debono, who carried out the study (or part thereof) on marine ecology for the EIA for the proposed extension to an existing tuna farm operation off the Northeast coast of Malta, hereby declare that such study was solely carried out by me on behalf of Ecoserv Ltd, and the company takes responsibility for any statement and conclusion contained therein.

13 July 2018

Date

Signature

1. INTRODUCTION

1. Adi Associates Environmental Consultants Ltd (hereafter 'ADI'), acting on behalf of their client AJD Tuna Ltd, have commissioned Ecoserv Ltd to undertake an ecological assessment of an area located off Mellieha Bay (northeastern coast of Malta); see Figure 1, which has been identified for potential designation as a tuna penning site. The main aims of the assessment are to collect and analyse data on general physico-chemical attributes of the sediments and water column, and on the ecological characteristics of the site, and to provide ADI with the findings and assist the consultants with predicted potential impacts of the proposed activity on the ecology of the site. Ultimately, the present document will feed into the Environment Impact Assessment for the concerned project; i.e. PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta by placing another 12 tuna cages without any increase in the tonnage of tuna fish caged.

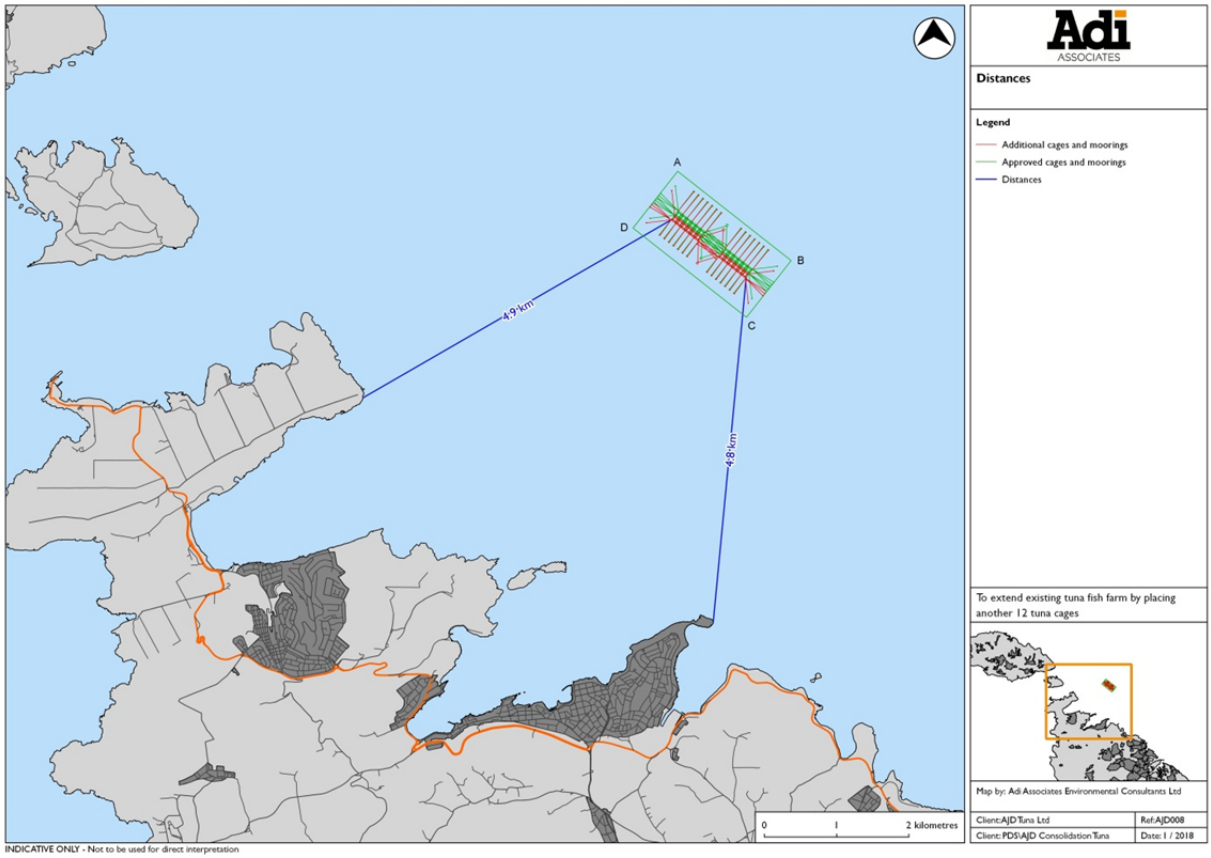


Figure 1. Map showing the site (area marked by points ABCD) off Mellieha Bay, which has been identified for potential designation as a tuna penning site. Cages indicated in green have already been deployed on site, while cages indicated in red are planned to be deployed on issue of the necessary permit. Map source: Adi Associates Environmental Consultants Ltd.

2. A survey of the marine benthic habitats present within an area that overlaps with the one that is the subject of the survey carried out in May 2018 for the present assessment was made in May 2017 (Borg & Evans, 2017); see the area enclosed by the blue boundary in Figure 2. Part of the area currently occupied by AJD Tuna Ltd's 12 tuna cages, and where a further 12 cages are planned to be deployed, falls within the area surveyed by Borg & Evans

in May 2017, however, the area bounded by the green line had not yet been surveyed (see Figure 2). A main aim of the present study was to map the marine benthic assemblages present within the area enclosed by the green boundary and adjacent areas using data from a survey by Seastar Survey Ltd undertaken in May 2018, and from Borg & Evans' survey made in May 2017. Furthermore, the present document also reports on data of physico-chemical attributes of the water column, and of the soft sediment seabed in the vicinity of area ABCD (Figure 1). A further aim was to sample the soft sediment habitat in the vicinity of the area ABCD (Figure 1) to establish the species of benthic flora and fauna present.

3. The findings from the survey made in May 2017 that was undertaken using a remotely operated vehicle (ROV) and which entailed collection of underwater footage of the seabed along transects within the survey area indicated the following (see Borg & Evans, 2017):

- In terms of physical characteristics, the bottom within the area surveyed consisted predominantly of coarse mobile sediments. A drop-off (some 10 m – 25 m high) is present just outside the study area on its northeastern side. What are usually referred to as 'maerl[1] beds' but which are more properly termed 'rhodolith beds' occupied a large part of the study area, which were more dense and continuous in the northeastern (and deeper) (outer) half of the survey area; in many places, the rhodolith beds were interspersed with a bare sand bottom that supported sparse rhodoliths[2]. "Rhodolith beds were densest in the central parts of the study area but the rhodolith density varied, such that they were less dense in the southwestern (shallower) parts of the survey area. A large stretch of predominantly bare sand was present in the southwesterly extreme part of the study area. Depth varied between 46 m and 72 m. The underwater visibility was good (25 – 30 m) throughout the study area, and an appreciable current was noted close to the seabed along some of the transects; as evidenced by debris and other material originating from benthic vegetation that were seen being moved rapidly on the bottom. Some anthropogenic items were observed during the survey; these included glass and plastic beverage bottles, fish traps and other unidentified items.
- In terms of biological characteristics, the following two main biotic assemblage types were recorded from the study area (see Figure 2):

  (i) Association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515)[3]

  (ii) Infralittoral coarse sediment (EUNIS code A5.13)[4]

  The association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents was present as two subtypes: one which was characterised by a rhodolith-rich bottom in which the proportion of rhodoliths covering the bottom was dense, constituting a well developed rhodolith bed, *sensu* Basso *et al*. (2016). This association subtype was present in the deeper parts (> 60 m) of the survey area (Figure 2). The other subtype consisted of a rhodolith bed in which the density of rhodoliths was

[1] 'Maerl' is a term used to describe calcareous sediments dominated by coralline algae. Maerl as used here describes sedimentary habitats in which living or dead unattached calcareous rhodophytes are a dominant component. These algae may take the form of nodules (rhodoliths) or fragmented thalli. However, according to Basso *et al*. (2016), 'rhodolith beds' should be identified and delimited as those areas of the sea floor with >10% cover of live rhodoliths over a minimum surface of 500 m^2, while the term "maerl" refers to a specific type of rhodolith bed that is composed of non-nucleated, unattached growths of branching, twig-like coralline algae. 'Maerl' as used here conforms to the definition of Basso *et al*. (2016).

[2] Rhodoliths consist either of free-living calcareous rhodophytes (red algae), or else of an inner nucleus, such as stone or shell, encrusted by calcareous rhodophytes.

[3] Equivalent to RAC/SPA 'Association with Rhodoliths'; code III.3.2.2.

[4] Equivalent to RAC/SPA 'Biocoenosis of coarse sands and fine gravels under the influence of bottom currents; code III.3.2.

sparser and in which the rhodoliths formed accumulations or were dispersed as single rhodoliths amongst other sediment components; this association subtype was present in areas having an intermediate water depth (50 m – 60 m); see Figure 2. Although no samples of rhodoliths were collected from the survey area, it is well established that a variety of coralline algal species that completely coat coarse sediment granules to form 'cored rhodoliths', contribute to local rhodolith beds; these include *Lithophyllum incrustans*, *Lithothamnion valens*, *Mesophyllum alternans* and *Sporolithon ptychoides*. Where present in the survey area, the rhodolith-rich bottom appeared to comprise a pseudo-hard substratum that supported macroalgae; the predominant alga being *Flabellia petiolata*. The main megafaunal species that was recorded from this association is the cidariid sea urchin *Stylocidaris affinis*. The rhodolith beds occupied the greater part of the area surveyed but the density of the rhodoliths varied greatly, with the general tendency being for the beds to be less dense with a decrease in water depth and on moving from the northeastern parts of the study area to the southwestern parts. Where dense, the rhodolith beds supported the alga *Flabellia petiolata* and, in places, an unidentified filamentous alga. The most abundant megafaunal species recorded from this association were the cidariid sea urchin *Stylocidaris affinis*, the Heart Urchin *Spatangus purpureus*, and the Long-Spined Urchin *Centrostephanus longispinus*. Individuals of the crinoid *Antedon mediterranea*, and single individuals of the seastar *Luidia ciliaris* and of the seaslug *Pleurobranchia meckeli* were also recorded from this assemblage. Burrows of the Common Octopus *Octopus vulgaris* were recorded in some places.

The infralittoral coarse sediment assemblage occurred at the southwestern part of the area surveyed, where the water depth was some 46 m – 50 m. In places, the sediment bottom supporting this assemblage type had current ripples; in places the trough of such ripples had small accumulations of rhodoliths or sparse rhodoliths. Detached algal and plant (seagrass) material was present in places on the seabed where this assemblage occurred but no attached fleshy algae or seagrasses were present. The epifauna associated with this assemblage was impoverished; the only recorded macrofauna comprised the Heart Urchin *Spatangus purpureus* and groups of the Purple Urchin *Sphaerechinus granularis*.

4. The present submission comprises a report of a survey of the main marine benthic habitats, benthic diversity and water quality, undertaken within the concerned study area. Video footage collected during the underwater videographic component of the present survey is appended to the present document and is titled '*Video transects of the seabed in an area off Mellieha Bay proposed for designation as an offshore tuna penning site, made in May 2018*.

2. METHODOLOGY

SEDIMENT AND WATER QUALITY

5. Fieldwork in relation to the water quality survey was undertaken on 4th April 2018. The day during which fieldwork was made was chosen at random but subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Fieldwork was carried out using a 12 m vessel equipped with hoisting jib and winch. The locations of the six sampling stations, A – D and R1 and R2, and shown in Figure 3, and their geographical coordinates and water depth are given in Table 1.

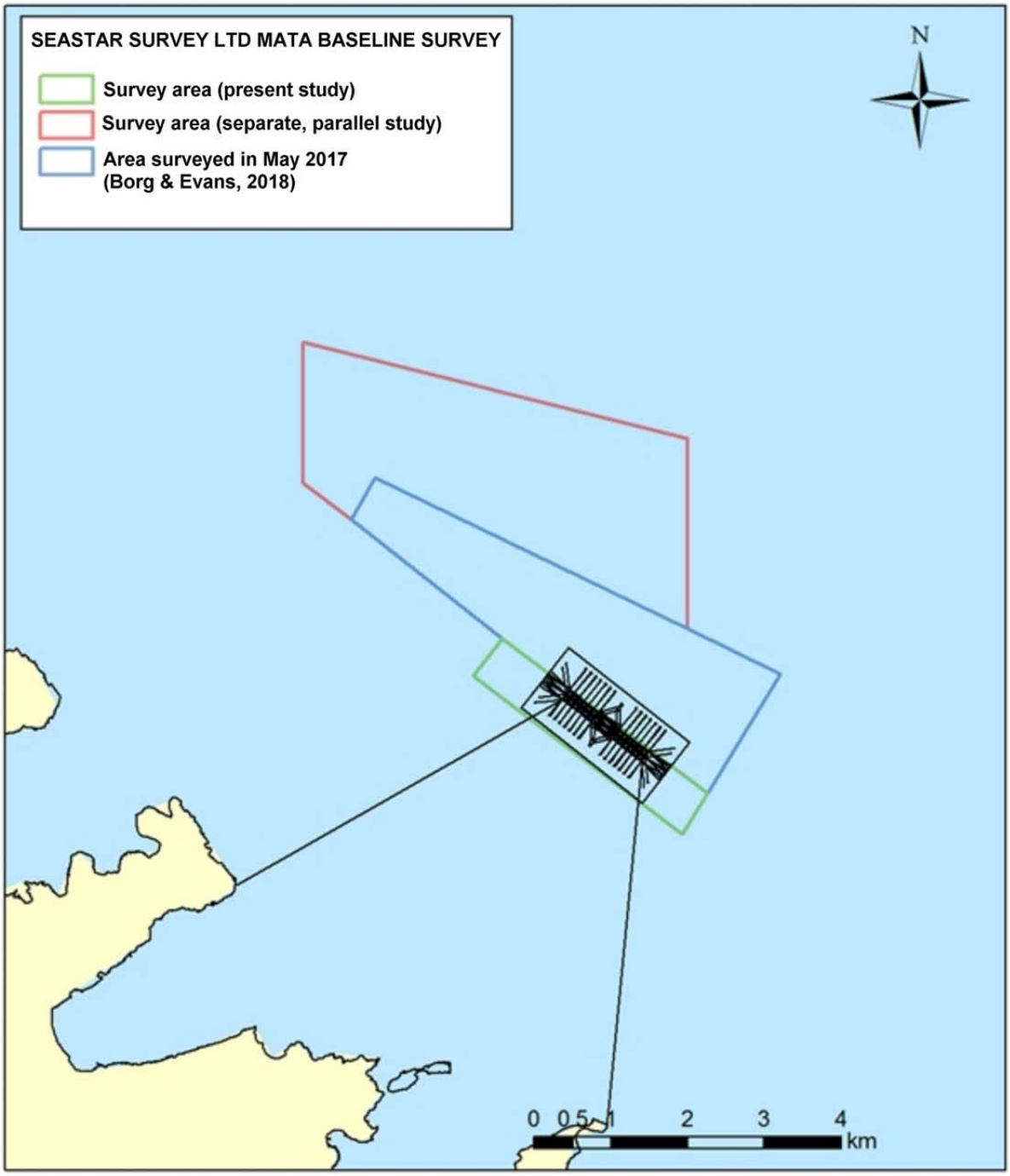


Figure 2. **Map showing: the tuna farm site off Mellieha Bay that is currently used temporarily by AJD Tuna Ltd, and which has been identified for potential designation as a tuna penning site; the area used in the May 2017 benthic habitats survey (blue boundary); the area used in the present benthic habitats survey (green boundary); and the area used in a separate survey undertaken in parallel with the present study. Map source: Seastar Survey Ltd, UK.**

6. The list of physico-chemical attributes that were included in the water quality survey are given in Table 2. Measurements of temperature, salinity, turbidity and dissolved oxygen in water were made *in-situ* at each of the ten stations using a YSI 650 MDS meter connected to a 6920 V2 multi-parameter probe. The meter was calibrated according to the manufacturer's

instructions immediately before use. Measurements using the *in-situ* meter were made at the surface (0.5 m below the surface). Two replicate measurements were taken at each of the six stations A – D, and R1 and R2. Two replicate samples of seawater were then collected from each of the same six stations; samples were collected at a depth of 0.5 m, from each of the six stations using a standard Van Dorn water sampler of 3 L volume. All water samples were transported in a cooler box and maintained at a temperature of 4^{o}C.

7. Estimates of current velocity and direction at the two reference stations (R1 and R2; see Figure 3) were made using drogues according to the La Grange method. The drogues employed for this purpose had four rectangular perspex vanes, each of which has a surface area of 0.2 m^2. The drogues were suspended from an inflatable surface float by means of a length of twine which was 1 m long. The position of the release point (determined using the GPS) and time of the release were recorded. After allowing the drogues to float for a given period of time, the position of the collection point and the time of collection were recorded.

8. For sediment granulometric and chemical studies, samples were collected using a 0.1 m^2 van Veen grab that was deployed from a 12 m vessel equipped with hoisting jib and winch. Two replicate grab samples were collected from each of six stations A – D, and R1 and R2; see Figure 3 and the corresponding geographical coordinates given in Table 1. The list of physico-chemical attributes that were included in the water quality survey are given in Table 3.

BENTHIC DIVERSITY

9. To collect data for benthic diversity studies, a grab sample was taken from each of the four stations A – D using a 0.1 m^2 Van Veen grab that was deployed from a 12 m vessel equipped with hoisting jib and winch. After the grab was brought on board, surplus seawater was drained from the sample by placing it on a 1mm-mesh sieve; the retained sediment and biota were temporarily preserved in 10% formaldehyde in seawater. In the laboratory, each sample was first washed to remove the fine sediment (<0.5 mm fraction) and the preservative, and it was then sorted to separate out all macrofauna (animals larger than 0.5 mm). The motile macrofauna was then identified as far as possible. Where identification to species level was not possible, the different species present were labelled using an alphabetical code (e.g. Mysidacea sp. A, etc.).

BENTHIC HABITATS MAP

10. Fieldwork in relation to the videographic survey to map the distribution of benthic habitats in those parts of the study area which had not been mapped by Borg & Evans (2017) was undertaken by personnel from Seastar Survey Ltd (UK) using the Maltese registered vessel MV Awrata, a 14 m steel workboat owned and operated by Azzopardi Fisheries. During the survey, a towed underwater camera system was used, which had the following specifications:
    - Kongsberg 14-208 camera and flash
    - Four video LED lights
    - Seastar Survey camera frame
    - EdgeDVR Digital video recorder with overlay
    - 300 m umbilical

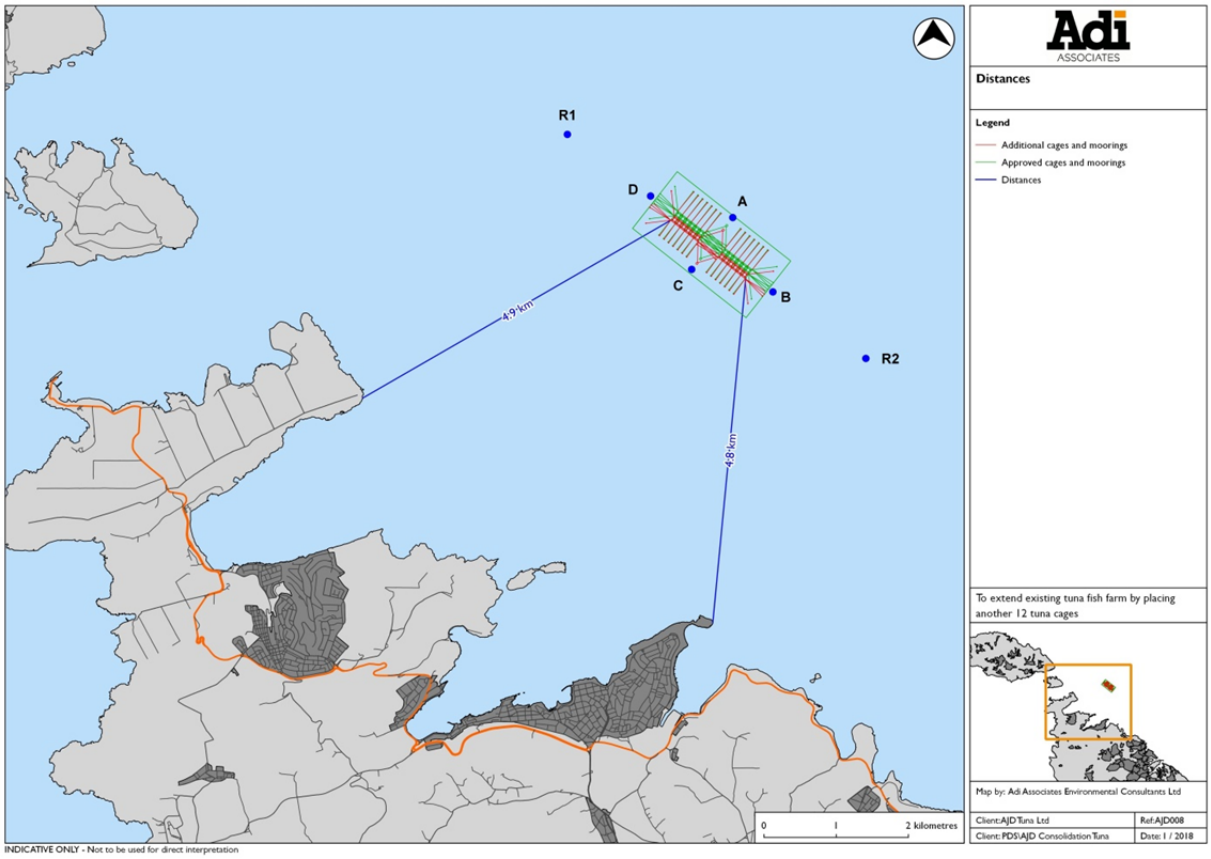


Figure 3. **Map showing the study site off Mellieha Bay, and the six stations used for collecting samples for sediment and water quality, and benthic diversity. Stations A – D are located in the vicinity of the farm cages, while Stations R1 and R2 are reference sites. Map source: Adi Associates Environmental Consultants Ltd.**

Table 1

Latitude/longitude coordinates and depth of the six sampling stations shown in Figure 3. In the field, readings were taken using the boat's Global Positioning System (GPS)[5] set.

Station	Latitude / Longitude	Depth (m)
A	36° 00.584' / 14° 25.780'	50 m
B	36° 00.131' / 14° 26.127'	48 m
C	36° 00.163' / 14° 25.508'	45 m
D	36° 00.567' / 14° 25.367'	48 m
R1	36° 00.848 / 14 24.474'	46 m
R2	35° 59.597 / 14 26.815'	48 m

[5] Chart datum set to European 1950; accuracy degeneration = *ca* 15m.

11. The camera and lights were set up on the camera frame so as to optimise field of view and video lighting. At each site, the vessel was manoeuvred to the transect position and first taken out of gear so as to determine the direction and speed of drift. Once the drift direction was determined, the vessel was manoeuvred to a distance of around 300 m from the transect position in the direction of drift, and then turned so that the camera transect was driven into the current. The positions of the video transects are shown in Figure 4; a total of ten transects were used in the survey. No transects were made within the area occupied by AJD Tuna Ltd's cages since the cages and mooring lines prevented deployment of the video camera along transects, but in any case most of the area had already been surveyed in 2017 (Borg & Evans, 2017). At the start of a transect, the vessel slowed to between 0.5 and 1.0 knot. The camera frame was deployed using the DT winch, wire tow-line and the vessel's crane, and the camera umbilical was bulldog taped to the winch wire at regular intervals to prevent it streaming out in the water column. During deployment, a layback position was calculated and recorded in Hypack, and an output of layback position and GPS time (GMT) was sent to the video overlay and recorded along with the video using EdgeDVR software. At regular intervals (approximately every minute), the camera frame was landed on the seabed and a high resolution still image was taken of the seabed. The still images were saved on the camera and downloaded at the end of each survey day. The position of the still images was recorded by noting the time of the photograph with the layback position from the navigation log for the same time.

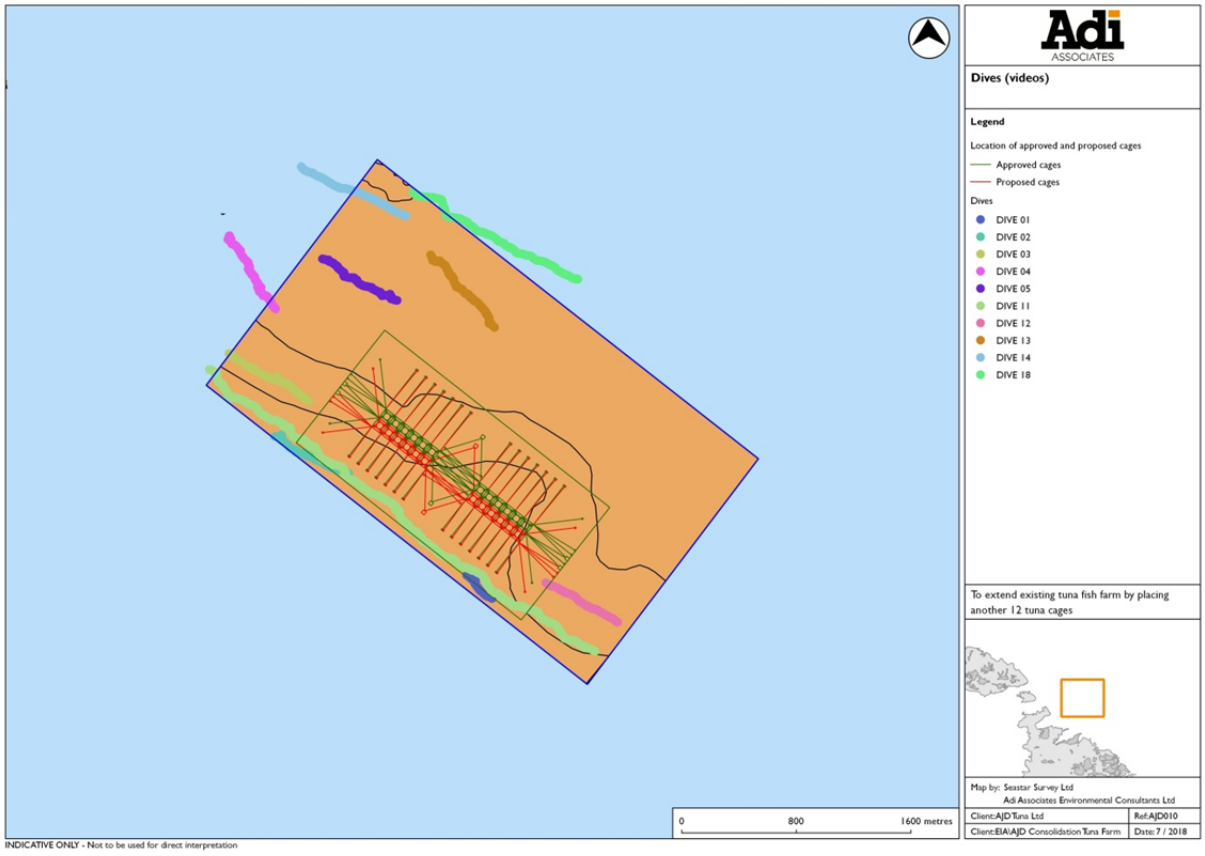


Figure 4. Map showing the survey area (blue boundary) and locations of the ten video transects (referred to as 'Dives' in the figure key) that were used to survey the marine benthic habitats present in the area of interest. Map source: Seastar Survey Ltd (UK) and Adi Associates Environmental Consultants Ltd.

12. Video footage and photographs of the benthic assemblages and species encountered along the transects were recorded on a PC hard drive and later analysed in the laboratory. Photographs taken during the survey were used to illustrate the present report.

13. Characterisation of the benthic assemblages was made using the scheme of Borg *et al*. (2013), which is based on the EUNIS typology that has been adapted for local use.

Table 2. List of physico-chemical attributes, together with the corresponding method of analysis, which were considered in the water quality studies.

Parameter	Method	Units
Temperature	In-situ / Portable Meter	°C
Salinity	In-situ / Portable Meter	psu
Dissolved Oxygen	In-situ / Portable Meter	%, mg/l
Turbidity	In-situ / Portable Meter	NTU
Turbidity (Secchi Depth)	Secchi Disk	m
pH	pH meter	pH units
Chlorophyll a	APAT CNR IRSA 9020 Man 29 2003	µg/l
Total Nitrogen	APAT CNR IRSA 5030 Man 29 2003 + APAT CNR IRSA 4040 A1 Man 29 2003 + APAT CNR IRSA 4050 Man 29 2003	µg/l
Total Phosphorus	APAT CNR IRSA 4110 Man 29 2003	µg/l
Total Carbon	UNI EN 1484:1999	µg/l
Total suspended matter	APAT CNR IRSA 2090 B Man 29 2003	mg/l

Table 3. List of physico-chemical attributes, together with the corresponding method of analysis, which were considered in the sediment quality studies.

Parameter	Method	Units (on D.M.)
Granulometry	Buchanan 1984	g
Total Organic Carbon (TOC)	UNI EN 13137:2002	%
Redox Potential	CNR IRSA 2 Q 64 Vol 3 1985	mV
Sulphide	CNR IRSA 12 Q 64 Vol 3 1986	µg
pH	CNR IRSA 1 Q 64 Vol 3 1985	pH units
Total Nitrogen	CNR IRSA 6 Q 64 Vol 3 1985	mg/g
Total Phosphorus	DM 13/09/1999 SO n°185 GU n°248 21/10/1999 Met XV.I	mg/g

3. RESULTS

14. Ecoserv's laboratory report reference for the present document is **068-18**.

15. The sample reference codes for the water quality and sediment surveys are as follows:

- Water in-situ parameters: W-158-18
- Secchi depth readings: W-159-18
- Water chemical parameters: W-160-18 to W-171-18
- Sediment chemical parameters: S-063-18 to S-074-18
- Sediment granulometry: S-051-18 to S-062-18
- Benthic diversity: S-075-18, S-077-18, S-079-18 and S-081-18
- Video footage: D-025-18 to D-031-18

SEDIMENT AND WATER QUALITY

16. The results of the water quality survey are given in Tables 4 to 6, while those for the sediment quality survey are given in Table 7. The results of granulometric analysis are given in Table 8.

17. The results of *in situ* measurement of physico-chemical parameters of the water column indicate temperature values and levels of salinity, water transparency and dissolved oxygen that are expected of local pristine offshore coastal waters during spring. The Secchi Disc measurements indicated a high water transparency of between 24 m and 29 m.

18. Detectable but low levels of total organic carbon (TOC), total suspended solids (TSS), total nitrogen, and total phosphorous were recorded from the sampling stations, while levels of Chlorophyll *a* were below the limit of detection, thereby indicating a low phytoplankton abundance.

19. A weak southeasterly surface sea current having a speed of between 0.11 m/s and 0.13 m/s was recorded at the two reference stations R1 and R2.

20. The results of chemical analysis of sediments from the sampling stations indicated detectable but low levels of total organic carbon (TOC), total nitrogen, and total phosphorous, while levels of sulphide were below the limit of detection. Values of pH and redox potential were of an order that is expected of background levels for local offshore sediments.

21. The results of granulometric analysis indicate that the sediments characterising the six sampling stations comprise poorly sorted coarse sand having a mean grain size of between 0.55 mm and 0.95 mm.

Table 4. Mean values (± standard deviation) of physico-chemical attributes recorded from the water column at the six sampling stations.

Parameter	Temperature (°C)		Salinity (ppt)		Turbidity (NTU)		Dissolved Oxygen (%)	
Station	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**
SA1	15.82	0.02	37.80	0.28	0.28	0.00	99.94	0.09
SA2	15.79	0.00	37.81	0.00	0.28	0.00	99.80	0.07
SB1	15.89	0.03	37.95	0.01	0.36	0.04	100.32	0.08
SB2	15.86	0.02	37.95	0.01	0.36	0.04	100.30	0.10
SC1	15.91	0.01	37.96	0.00	0.32	0.09	100.38	0.08
SC2	16.05	0.11	37.97	0.02	0.28	0.00	100.60	0.23
SD1	15.96	0.03	37.96	0.01	0.18	0.07	100.40	0.10
SD2	15.92	0.01	37.95	0.00	0.26	0.04	100.30	0.00
R1a	15.83	0.00	37.94	0.00	0.28	0.00	100.16	0.05
R1b	15.83	0.00	37.94	0.00	0.28	0.00	100.10	0.00
R2a	15.86	0.00	37.95	0.02	0.00	0.63	100.06	0.05
R2b	15.85	0.00	37.88	0.01	0.26	0.04	100.00	0.07

Table 5. Mean values (± standard deviation) in metres for water transparency recorded from the six sampling stations using the Secchi Disc method.

Station A		Station B		Station C		Station D		Station R1		Station R2	
Mean	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**
24.00	0.00	29.25	0.35	25.00	0.00	26.00	0.00	26.00	0.00	26.25	0.35

Table 6. Mean values (± standard deviation) of chemical parameters recorded from water samples collected from the six sampling stations.

Parameter	Units	Station A		Station B		Station C		Station D		Station R1		Station R2	
		Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
TOC	mg/L	0.75	0.35	0.50	0.00	0.55	0.35	0.60	0.14	0.90	0.14	0.60	0.14
TSS	mg/L	0.20	0.00	0.20	0.00	0.20	0.00	0.20	0.00	0.20	0.00	0.20	0.00
pH		8.50	0.00	8.50	0.00	8.55	0.07	8.55	0.07	8.55	0.07	8.45	0.07
Chlorophyll a	µg/L	< 0.01	0.00	< 0.01	0.00	< 0.01	0.00	< 0.01	0.00	< 0.01	0.00	< 0.01	0.00
Total Nitrogen	mg/L	3.94	0.43	4.30	0.58	4.03	0.71	3.50	0.10	3.51	0.07	3.96	0.15
Total Phosphorus	µg/L	6.90	0.85	10.10	0.42	10.85	0.35	12.95	2.05	8.25	0.07	7.00	0.42

Table 7. Mean values (± standard deviation) of chemical parameters recorded from sediment samples collected from the six sampling stations.

Parameter	Units	Station A		Station B		Station C		Station D		Station R1		Station R2	
		Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
pH	unit	8.75	0.07	8.75	0.35	9.30	0.00	9.00	0.14	8.90	0.14	8.85	0.21
TOC	%	0.45	0.00	1.90	0.99	0.80	0.71	0.36	0.04	0.58	0.47	0.63	0.40
Sulphide	mg/kg	< 2	0.00	< 2	0.00	< 2	0.00	< 2	0.00	< 2	0.00	< 2	0.00
Total nitrogen	% S.S.	0.04	0.00	0.04	0.00	0.04	0.00	0.04	0.00	0.05	0.00	0.06	0.00
Total Phosphorous	% S.S.	0.02	0.00	0.02	0.01	0.02	0.00	0.02	0.00	0.03	0.00	0.03	0.00
Redox Potential	mV	266.05	6.58	245.65	3.04	233.15	4.60	227.50	3.54	202.30	22.34	167.15	4.03

Table 8. Mean values (± standard deviation) of grain size and sorting, together with classification of sorting and sediment classification for sediment samples collected from the six sampling stations.

Station	Ecoserv sample ref.	Mean sediment grain size (mm)	Wentworth grade classification	Mean Sorting (Ø)	Degree of sorting
A	**S-051-18 / S-052-18**	0.716 ± 0.042	Coarse Sand	2.11 ± 0.09	Very Poorly Sorted
B	**S-053-18 / S-054-18**	0.550 ± 0.055	Coarse Sand	2.29 ± 0.04	Very Poorly Sorted
C	**S-055-18 / S-056-18**	0.751 ± 0.082	Coarse Sand	1.95 ± 0.10	Poorly Sorted
D	**S-057-18 / S-058-18**	0.693 ± 0.072	Coarse Sand	2.14 ± 0.05	Very Poorly Sorted
R1	**S-059-18 / S-060-18**	0.763 ± 0.023	Coarse Sand	1.74 ± 0.10	Poorly Sorted
R2	**S-061-18 / S-062-18**	0.937 ± 0.222	Coarse Sand	2.14 ± 0.33	Very Poorly Sorted

BENTHIC DIVERSITY

22. A classified list of species, and respective abundance, recorded from the four grab samples collected from Stations A – D (Figure 3) is given in Table 9. A total of 1,897 individuals comprising 111 macrofaunal species were recorded. The Polychaeta and Crustacea were the most common taxonomic groups, both in terms of total number of species and in abundance of individuals.

Table 2

Classified list of species recorded from the respective stations, and respective abundance (number of individuals per 0.1 m^2 grab sample).

Classified Species List	Station			
	A	B	C	D
Ecoserv Sample no.	**S-075-18**	**S-077-18**	**S-079-18**	**S-081-18**
SIPUNCULIDA				
Aspidosiphon muelleri		2		1
MOLLUSCA				
Gastropoda				
Ascobulla fragilis		1		
Caecum armorium		1		
Caecum auriculatum				2
Cerithidium submamillatum	1	1		
Euspira nitida	1			
Haminoea hydatis	3			
Opistobranchia sp.	3			
Parthenina interstincta	1	1		
Parvioris ibizenca	1			
Sticteulima jeffreysiana	2		2	
Vitreolina sp.		1		
Volvarina mitrella		2		
Polyplacophora				
Acanthochitana fascicularis	7		1	
Callochiton calcatus	32			
Chiton corallinus	1			
Ischnochiton rissoi	1			
Leptochiton cancellatus	5	6		
Parachiton africanus	4			5
Bivalvia				
Astarte fusca	2		2	4
Coripia corbis		2	3	6

Table 2. Continued…

Classified Species List	Station			
	A	B	C	D
Ecoserv Sample no.	**S-075-18**	**S-077-18**	**S-079-18**	**S-081-18**
Digitaria digitaria	4			
Diplodonta trigona	1			
Gari costulata		1		
Glans trapezia	1			
Gonilia calliglypta		2	2	2
Hiatella arctica		2		
Loripes orbiculatus				1
Modilula phaseolina	2	1		
Musculus costulatus	2			
Papillicardium papillosum		1		
Thracia phaseolina				1
Timoclea ovata	1	1	1	1
NEMERTEA				
Nemertea sp.	1		3	5
POLYCHAETA				
Ampharetidae sp.				1
Aphroditidae sp.			1	
Lepidonotus	2	5		
Capitellidae sp.	30	23	41	14
Cirratulidae sp.	5	3	6	
Dorviliidae sp.	11	21	7	8
Eunice sp.		5	5	4
Marphysa sp.	4			
Glycera sp.	1	5	1	5
Glyceridae sp.	1	2		
Lacydoniidae sp.	13	52	35	9
Lumbrineridae sp. A	2	1		
Lumbrineridae sp. B		1		1
Lumbrineridae sp. C		1		
Maldanidae sp. A				1
Maldanidae sp. B		1		
Nematonereis unicornis	5	4	3	
Nephtydae sp. A	38	38	29	15
Nephtydae sp. B		3	7	10
Nephtydae sp. C				1
Nereidae sp.			1	
Nereis rava	7	1		1
Notomastus sp.	11	9	3	2
Opheliidae sp.	1			16

Table 2. Continued…

Classified Species List	Station			
	A	B	C	D
Ecoserv Sample no.	**S-075-18**	**S-077-18**	**S-079-18**	**S-081-18**
Orbiniidae sp.		3		
Paraonidae sp.	33	26	65	41
Pectinaridae sp.	1	1		
Phyllodocidae	10	5	4	5
Polychaeta sp.	6	9	17	26
Polynoinae sp.			1	
Sabellidae	20	16	3	9
Scalibregmidae sp.	1	3	1	1
Sthenlais sp.				2
Syllidae	56	38	28	68
Terebellidae sp.	2	14		2
CRUSTACEA				
Leptostraca				
Nebalia bipes			1	
Decapoda				
Achaeus sp.		1		
Alpheus dentipes	1			
Anapagurus sp.		1	3	
Cestopagurus timidus	3	3	2	2
Galathea intermedia	2	2	1	
Ilia nucleus	1			
Liocarcinus sp.	1			
Parthenope sp.	5		1	
Processa sp.		1		
Mysidacea				
Mysidacea sp. B	1	1		1
Tanaidacea				
Apseudes sp.	9	1		
Leptochelia savignyi	28	47	20	18
Isopoda				
Anthuridae sp.	4	1	1	6
Cymodoce sp.	39	1	2	2
Eurydice sp.	3	1		
Gnathia sp.		2		1
Janiridae sp.	13	10	10	3
Synisoma sp.	1	2		
Amphipoda				
Amphilochus sp.	4	1	4	2
Aoridae sp.		2	6	4
Apherusa bispinosa		1		1
Caprellidae sp.		17	7	11

Table 2. Continued…

Classified Species List	Station			
	A	B	C	D
Ecoserv Sample no.	**S-075-18**	**S-077-18**	**S-079-18**	**S-081-18**
Cheirocratus sundevallii	4	1	1	
Elasmopus sp.	39	24	33	18
Harpinia sp.	1		1	
Hippomedon oculatus	18	9	8	3
Leptocherius sp.	15	2	8	10
Leucothoe spinicarpa	7	6	7	1
Lysianassa sp.	13	3	3	1
Maera sp.	8	2	9	3
Melita sp.	1	2	5	2
Monoculodes sp. F			1	
Pereionotus testudo	6	3	1	2
Phoxocephalidae sp.	5	10	13	11
Socarnes filicornis	10	1	7	
Stenothoe sp.	1			
Urothoe sp.		1		
Cumacea				
Cumacea sp.	1	2	2	1
ECHINODERMATA				
Echinoidea				
Genocidaris maculata	5	6	1	14
Spatangus purpureus			1	
Stylocidaris affinis	1	1		
CEPHALOCORDATA				
Branchiostoma sp.		3	2	2

VIDEO SURVEY

Physical characteristics of the seabed

23. The bottom within the area surveyed consisted predominantly of coarse mobile sediments. A drop-off (some 10 m – 25 m high) that is characterised by rock exposed to sedimentation is present at the northwestern part of the study area.

24. What are usually referred to as 'maerl[6] beds' but which are more properly termed 'rhodolith beds' occupy a large part of the study area, which were more dense and continuous in the northeastern (and deeper) half of the survey area. In many places, the rhodolith beds were interspersed with a bare sand bottom that supported sparse rhodoliths[7]. In the southwestern half of the survey area, the rhodolith density varied such that they are less dense in the shallower part (45 m – 50 m) of the survey area, where large expanses of bare sand that supported little or no rhodoliths were present. Overall, the seabed had physical features that corresponded with the bathymetry: coarse sand with sparse accumulations of rhodoliths (0 % - 20 % rhodolith cover) was present at a water depth of between 43 m and 50 m; between a water depth of 50 m and 55 m, the seabed comprised coarse sediment having denser rhodolith accumulations (20 % - 50 % rhodolith cover); and in waters deeper than 55 m, the seabed mainly consisted of dense rhodolith beds (50 % - 100 % rhodolith cover). Beyond the rocky drop-off, at water depths exceeding 100 m, the seabed mainly consisted of bare muddy sand.

25. Depth varied between around 43 m and just over 100 m. The underwater visibility was good (25 – 30 m) throughout the study area but flocculate material was noted in the water column along some of the transects.

26. A current was present in places close to the seabed, as evidenced by debris and other material originating from benthic vegetation that were seen being moved on the bottom.

27. Some anthropogenic items were observed during the survey. These included glass and plastic beverage bottles, abandoned fish traps and fishing lines, and other unidentified items. However, no remains of tuna, feed fish used in tuna farming or any other item that may have originated from tuna farming activities, was recorded on the seabed during the survey.

BENTHIC ASSEMBLAGES

28. The main outcome of the benthic survey carried out in May 2018, in combination with data from the survey carried out by Ecoserv in May 2017 (Borg & Evans, 2017) is a map showing the distribution of the main benthic habitats and assemblages (Figures 4 and 5) present in the area surveyed.

[6] 'Maerl' is a term used to describe calcareous sediments dominated by coralline algae. Maerl as used here describes sedimentary habitats in which living or dead unattached calcareous rhodophytes are a dominant component. These algae may take the form of nodules (rhodoliths) or fragmented thalli. However, according to Basso *et al*. (2016), 'rhodolith beds' should be identified and delimited as those areas of the sea floor with >10% cover of live rhodoliths over a minimum surface of 500 m^2, while the term "maerl" refers to a specific type of rhodolith bed that is composed of non-nucleated, unattached growths of branching, twig-like coralline algae. 'Maerl' as used here conforms to the definition of Basso et al. (2016).

[7] Rhodoliths consist either of free-living calcareous rhodophytes (red algae), or else of an inner nucleus, such as stone or shell, encrusted by calcareous rhodophytes.

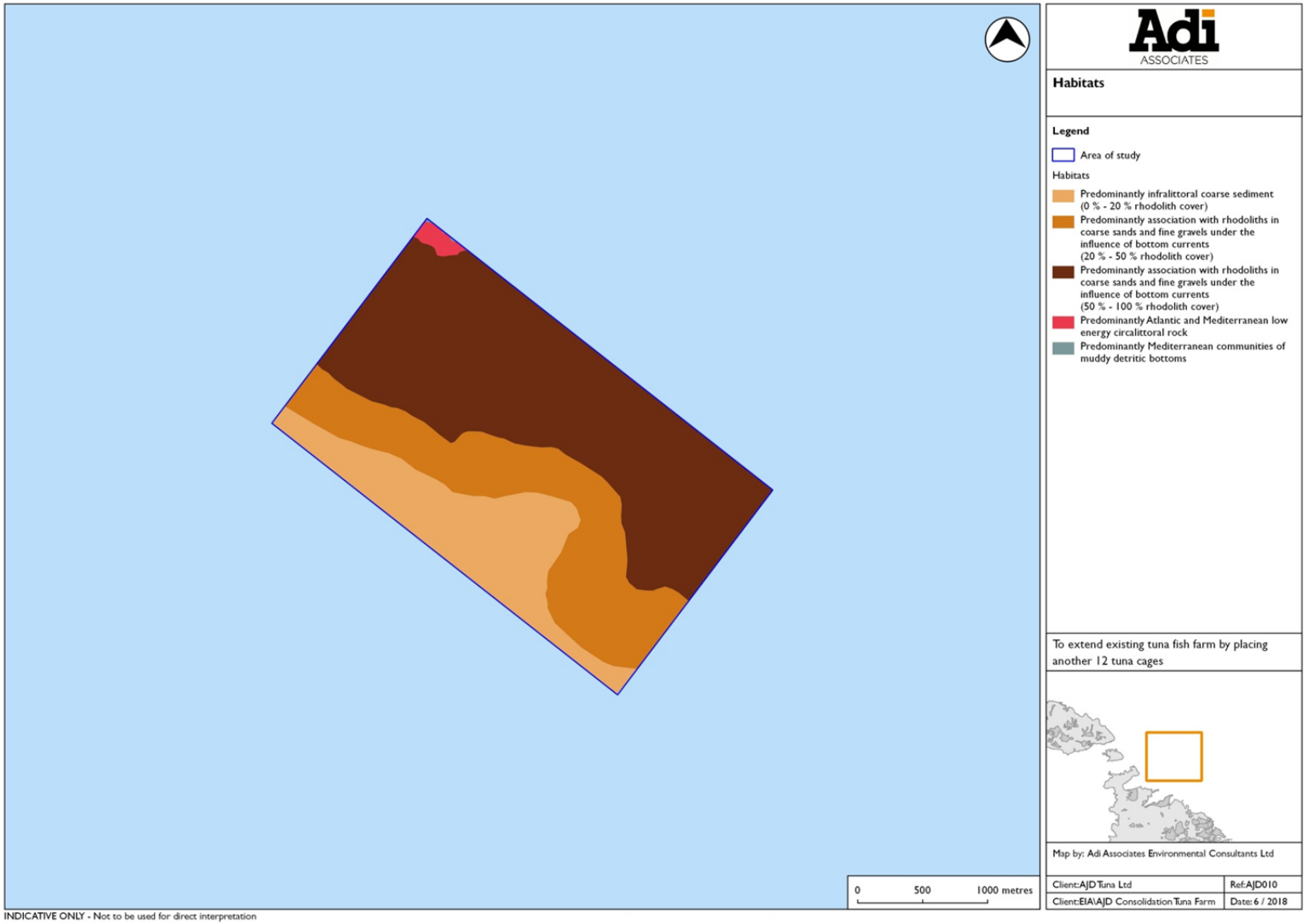


Figure 4. Map showing the main benthic habitats present in the survey area.

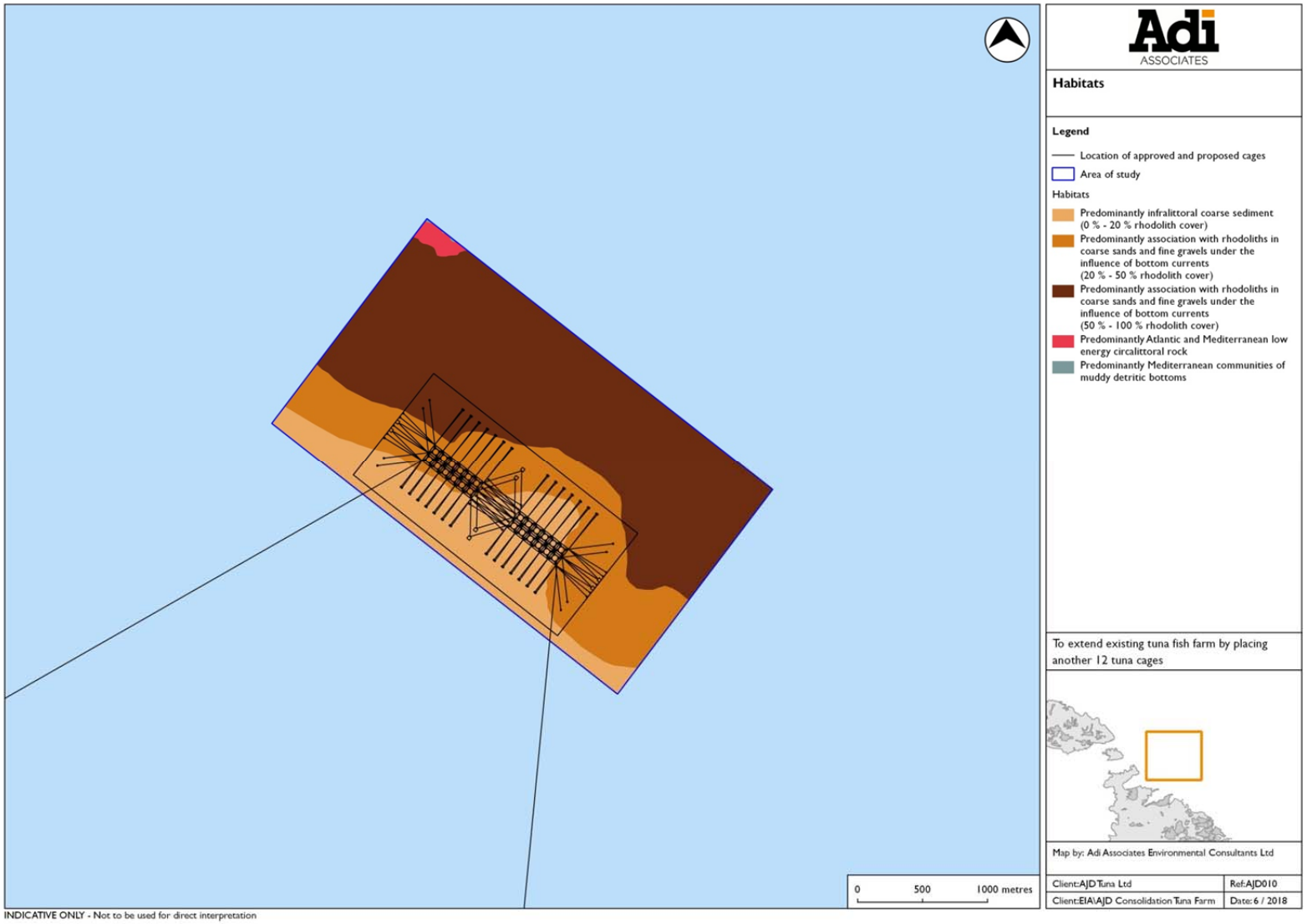


Figure 5. Map showing the main benthic habitats present in the survey area. The area currently occupied by AJD Ltd's 12 Tuna Cages and which has been identified for deployment of 12 additional pens is also shown. Map: Adi Associates Environmental Consultants Ltd.

29. The following two main biotic assemblage types were recorded from the study area:

(i) Association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515)
(ii) Infralittoral coarse sediment (EUNIS code A5.13)
(iii) Mediterranean communities of muddy detritic bottoms (EUNIS code A5.38)
(iv) Atlantic and Mediterranean low energy circalittoral rock (EUNIS code A4.3)

A description of each of the above four assemblage types follows.

Association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents

30. This association was present as two subtypes: one which was predominantly characterised by a rhodolith-rich bottom in which the proportion of rhodoliths covering the bottom was dense (50 % - 100 % cover; see Figure 6) and constituted a well developed rhodolith bed, *sensu* Basso *et al*. (2016). This association subtype was mostly present in the deeper, northeastern half of the survey area (see the brown shaded area in Figures 4 and 5) within the 55 m – 80 m water depth range. The other subtype mainly consisted of a rhodolith bed in which the density of rhodoliths was sparser and predominantly formed accumulations such that the overall rhodolith cover was around 20 % - 50% (see Figure 7); this association subtype was mainly present as a band in the central parts of the survey area (see the orange shaded area in Figures 4 and 5) within the 50 – 55 m water depth range.

31. Preliminary examination of rhodoliths that were retrieved from sediments collected by grab from Stations A, B and D (see Figure 3) indicated that the algal species that contribute to the rhodoliths include species from the following genera: *Lithophyllum, Lithothamnion*, *Mesophyllum* and *Sporolithon* (see Lanfranco *et al*., 1999; Borg and Schembri 2002; Sciberras *et al*., 2009).

32. Where present, the dense rhodolith beds appeared to comprise a pseudo-hard substratum that supported macroalgae; the predominant alga being *Flabellia petiolata* (Figure 6) and *Zonaria tournefortii* but other algae including *Halimeda tuna*, *Peyssonnelia squamaria*, *Dictyota* sp. and unidentified filamentous forms, were also recorded in places.

33. The most abundant megafaunal species that were recorded from this association are the cidariid sea urchin *Stylocidaris affinis* and the Purple Heart Urchin *Spatangus purpureus* (Figure 8); other megafaunal species that were recorded during the survey included several species of sponges and bryozoans (including *Sertella* sp.), the Long-spined Urchin *Centrostephanus longispinus* (Figure 9), the Red Seastar *Echinaster sepositus* (Figure 10), the crinoid *Antedon mediterranea*, the crab *Inachus* sp., and the seastar *Luidia ciliaris*. Furthermore, the presence of openings to numerous burrows in places indicated an associated rich infauna.

Infralittoral coarse sediment

34. This assemblage type occurred as a band at the southwestern part of the study area (see the yellow-brown shaded area in Figures 4 and 5), where the water depth was some 43 m – 50 m. In places, the sediment bottom supporting this assemblage type had small accumulations of rhodoliths or sparse rhodoliths, such that where these were present their cover was some 1 –

20% (see Figures 11 - 14). Detached algal and plant (seagrass) material was present in places on the seabed where this assemblage occurred but no attached fleshy algae or seagrasses were present. The epifauna associated with this assemblage was impoverished; the most abundant macrofaunal species was the Purple Heart Urchin *Spatangus purpureus* (Figure 15) and groups of the Purple Urchin *Sphaerechinus granularis*. However, the presence of openings to burrows present in many places indicated the presence of a rich infauna.

Figure 6. Photograph of the seabed taken at a point along Transect 5, showing a close-up of a dense rhodolith bed. The green alga visible in the photo is *Flabellia petiolata*.

Figure 7. Photograph of the seabed taken at a point along Transect 12, showing a close-up of a sparse rhodolith bed.

Figure 8. **Photograph of the seabed taken at a point along Transect 5, showing a close-up of a rhodolith bed intermixed with bare sediment. The five orange coloured long-spined urchins visible in the photo are individuals of *Stylocidaris affinis*. The large purple coloured urchin on the right hand side of the photo is an individual of the Purple Heart Urchin *Spatangus purpureus*.**

Figure 9. **Photograph of the seabed taken at a point along Transect 3, showing a close-up of a rhodolith bed. An individual of the Long-spined Urchin *Censtrostephanus longispinus* is visible at the top right hand corner of the photo adjacent the alga *Flabellia petiolata* (green).**

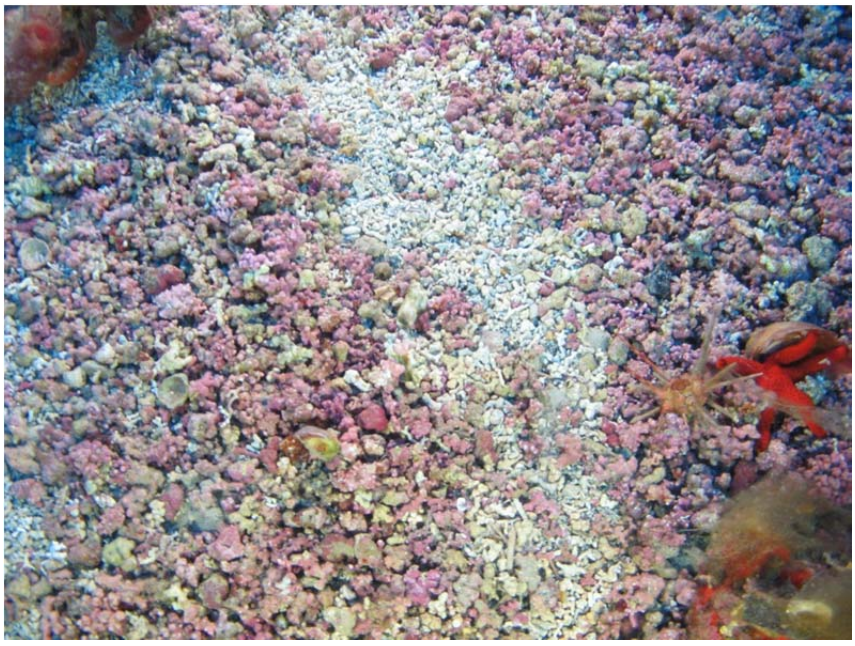


Figure 10. Photograph of the seabed taken at a point along Transect 5, showing a close-up of a rhodolith bed. An individual of the urchin *Stylocidaris affinis* and another of the Red Seastar *Echinaster sepositus* are visible on the right side of the photo.

Figure 11. Photograph of the seabed taken at a point along Transect 2, showing a close-up of an assemblage of infralittoral coarse sediment.

Figure 12. Photograph of the seabed taken at a point along Transect 2, showing a close-up of an assemblage of infralittoral coarse sediment. An individual rhodolith is visible at the centre of the photo.

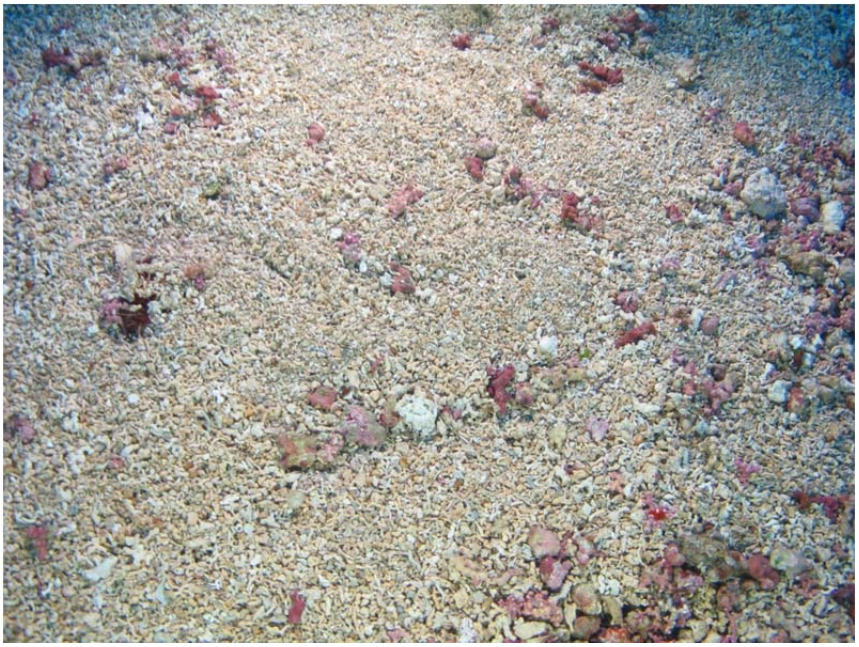


Figure 13. Photograph of the seabed taken at a point along Transect 11, showing a close-up of an assemblage of infralittoral coarse sediment. Individual rhodoliths are visible in places in the photo.

Figure 14. Photograph of the seabed taken at a point along Transect 11, showing a close-up of an assemblage of infralittoral coarse sediment. Three narrow strips with rhodoliths are visible in the photo.

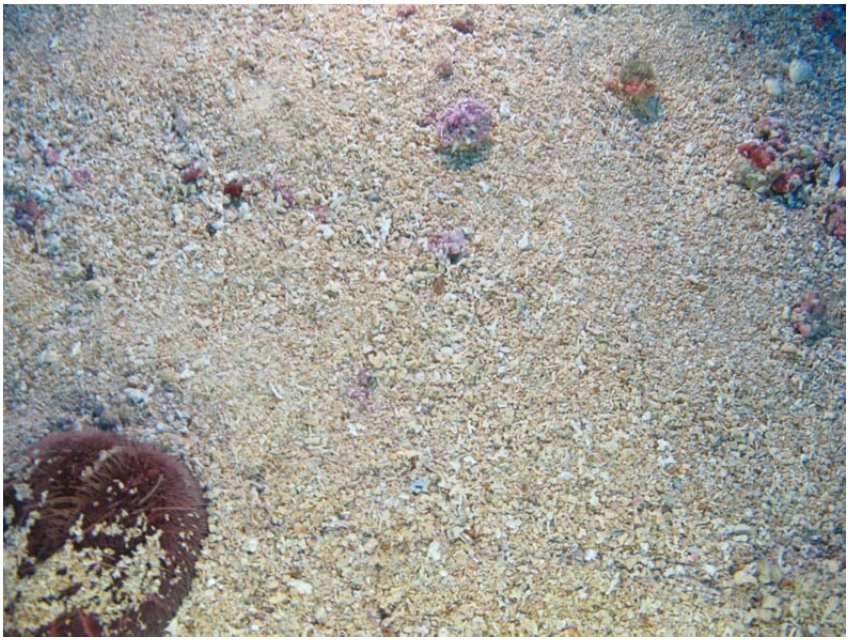


Figure 15. Photograph of the seabed taken at a point along Transect 11, showing a close-up of an assemblage of infralittoral coarse sediment. A few individual rhodoliths (Purple colour) – most of them having a very small size (few mm) – and an individual of the Purple Heart Urchin *Spatangus purpureus*, are visible in the photo.

35. Although in general the area surveyed mainly supported the assemblage types and subtypes as described above and as depicted in Figures 4 and 5, parts within the shaded areas shown in the habitat map (Figures 4 and 5) supported patches with a different assemblage type, such that:
    - The area which supported the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (dense rhodolith bed) had, in places, patches with the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed) ;
    - The area which supported the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed) had, in places, patches with the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (dense rhodolith bed) or patches with the assemblage of coarse infralittoral sediment;
    - The area which supported the assemblage of coarse infralittoral sediment had, in places, the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed).

    Furthermore, comparison between data from video transects made during Borg & Evans' 2017 survey and data from the survey made by Seastar Survey Ltd in May 2018 indicate some differences in the spatial distribution of the assemblage of coarse infralittoral sediment and the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed); these differences are discussed in the discussion section below.

Mediterranean communities of muddy detritic bottoms

36. This assemblage type was recorded from the extreme northwestern corner of the study area (Figures 4 and 5) at a water depth exceeding 100 m and occurred at the base of the 10 m – 25 m high drop-off from where it extended further into deeper waters (Figure 16). No macroflora was recorded from this assemblage type, although detached macroalgae (mainly *Zonaria tournefortii*) were present on the sediment surface in various places. No macrofauna was recorded from this assemblage type but the presence of openings to burrows indicated an associated rich infauna.

Atlantic and Mediterranean low energy circalittoral rock

37. This assemblage type was recorded from the extreme northwestern corner of the study area (Figures 4 and 5) and formed part of the drop-off some 10 m – 25 m high that separated the assemblage of coarse sands and fine gravels under the influence of bottom currents and the assemblage of infralittoral coarse sediments (Figure 17). The associated macroalgae mainly comprised *Zonaria tournefortii* and unidentified coralline algae (Figure 17). The associated macrofauna mainly comprised sponges, bryozoans, and other sessile macrobenthic species. Individuals of the echiuran worm *Bonellia viridis* were recorded in places from this assemblage type.

Figure 16. Photograph of the seabed taken at a point along Transect 21, showing a close-up of a Mediterranean community of muddy detritic bottoms.

Figure 17. Photograph of the seabed taken at a point along Transect 21, showing a close-up of a Mediterranean community of muddy detritic bottoms.

Demersal and pelagic fauna

38. The demersal fish fauna recorded during the survey mainly comprised large shoals of Picarel *Spicara* sp. and individuals of the Comber *Serranus cabrilla*. Several individuals of the Mauve Stinger *Pelagia noctiluca* were recorded in the water column during the survey.

4. APPRAISAL

SEDIMENT AND WATER QUALITY

39. The results of the sediment and water quality surveys indicate physico-chemical characteristics that are typical of marine waters and the seabed off the northeastern coast of Malta. Water depth varies between around 43 m and just over 100 m. The underwater visibility was good (25 – 30 m) throughout the study area but flocculate material (of unknown origin) was present in the water column along some of the transects. A weak southeasterly surface sea current having a speed of between 0.11 m/s and 0.13 m/s was present in the study area.

40. The bottom within the area surveyed consists predominantly of coarse mobile sediments; in the vicinity of the site currently used by AJD Tuna Ltd, the seabed comprises poorly sorted coarse sand having a mean grain size of between 0.55 mm and 0.95 mm. A drop-off, some 10 m – 25 m high, and characterised by rock exposed to sedimentation is present in the northwestern part of the study area. The base of this drop-off is characterised by a bare muddy sand bottom. A large part of the seabed in the study area comprises rhodolith beds, which are more dense and continuous in the northeastern (and deeper) half of the survey area. In many places, the rhodolith beds are interspersed with a bare sand bottom that supports sparse rhodoliths, while in the southwestern half of the survey area, the rhodolith density varies such that they are less dense in the shallower part (45 m – 50 m) of the survey area, where large expanses of bare sand that supported little or no rhodoliths are present. Overall, the seabed has physical features that correspond with the bathymetry: coarse sand with sparse accumulations of rhodoliths (0 % - 20 % rhodolith cover) is present at a water depth of between 43 m and 50 m; between a water depth of 50 m and 55 m, the seabed comprises coarse sediment having denser rhodolith accumulations (20 % - 50 % rhodolith cover); and in waters deeper than 55 m, the seabed mainly consists of dense rhodolith beds (50 % - 100 % rhodolith cover). A current was present in places close to the seabed, as evidenced by debris and other material originating from benthic vegetation that were seen being moved on the bottom.

41. Some anthropogenic items were observed during the survey. These included glass and plastic beverage bottles, abandoned fish traps and fishing lines, and other unidentified items. However, no remains of tuna, feed fish used in tuna farming, or any other item that may have originated from tuna farming activities, was recorded on the seabed during the survey.

BENTHIC DIVERSITY

42. Analysis of the grab samples showed the presence of macrofauna that is typical of the benthic biotic assemblages that characterisize the lower infralittoral to circalittoral transition zone and the upper circalittoral zone that occurs off the northeastern coast of the Maltese islands. (cf. Borg *et al.*, 1998; Schembri 1998; Sciberras *et al.*, 2009). A high diversity of macrobenthic fauna was recorded from the grab samples; the two most represented taxonomic groups, in terms of species richness and abundance, were the polychaetes and the crustaceans. No protected species were recorded from any of the grab samples.

BENTHIC ASSEMBLAGES

43. Overall, the benthic biotic assemblages in the study area are characteristic of ones present in the infralittoral and circalittoral zones off the northeastern coast of the Maltese Islands (e.g. Borg *et al*., 1998; Schembri 1998; Sciberras *et al.,* 2009; Schembri, 2011).

44. Four main biotic assemblage types were recorded from the study area: (i) Association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515); (ii) Infralittoral coarse sediment (EUNIS code A5.13); Mediterranean community of muddy detritic bottoms (EUNIS code A5.38); and Atlantic and Mediterranean low energy circalittoral rock (EUNIS code A4.3). The former association was present as two assemblage subtypes: (i) dense rhodolith beds (having a rhodolith cover of between 50 % and 100 %), some of which may possibly be classified as maerl (sensu Basso *et al*., 2016), which occupy a large part of the northeastern half of the study area; and (ii) sparser rhodolith beds (having a rhodolith cover of between 20 % and 50 %), which occupy the central parts of the area surveyed. The assemblage of infralittoral sediment was present in the shallower, southwestern parts of the study area and in places supported sparse rhodolith accumulations (having a rhodolith cover of between 1 % and 20 %). The Mediterranean community of muddy detritic bottoms and the assemblage of Atlantic and Mediterranean low energy circalittoral rock were present in the northwestern corner of the study area.

45. It is emphasised that although the area surveyed mainly supported the assemblage types and subtypes described above, parts within the different areas that represent different habitats (Figures 4 and 5) support patches with a different assemblage type, such that:

- The area which supported the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (dense rhodolith bed) had, in places, patches with the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed) ;
- The area which supported the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed) had, in places, patches with the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (dense rhodolith bed) or patches with the assemblage of coarse infralittoral sediment;
- The area which supported the assemblage of coarse infralittoral sediment had, in places, the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed).

Furthermore, differences in the spatial distribution of the assemblage of coarse infralittoral sediment and of the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (sparse rhodolith bed) were evident when comparing data from video transects made during Borg & Evans' 2017 survey with data from the survey made by Seastar Survey Ltd in May 2018. These differences, which are mostly applicable to the shallower (43 m – 55 m) parts of the study area indicate that the soft sediment seabed there is dynamic and undergoes changes that involve shifting of accumulations of rhodoliths from one place to another, possibly even over large distances of several hundred metres. Such changes would happen during very strong wave action, typically during strong northeasterly winds, such as ones that characterised autumn 2017 and winter 2018. As a result, the spatial distribution of the aforementioned two habitat types changes.

46. Although video footage collected from the present survey enabled recording of several macroalgal species, including *Flabellia petiolata* and Zonaria tournefortii which appeared to be the most abundant, several other algal species are known to be associated with the association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (see Borg *et al*., 1998; Borg & Schembri, 2008; Schembri, 2011). Likewise, apart from the megafauna, including the urchin *Stylocidaris affinis,* the Heart Urchin *Spatangus purpureus,* the crinoid *Antedon mediterranea* and the Needle-Spined urchin *Centrostephanus longispinus*, and other species recorded from the present survey, numerous other mega- and macrofaunal species occur in association with the rhodolith habitats (see Borg *et al*., 1998; Borg & Schembri, 2008; Schembri, 2011). Apart from these mega- and large macrofaunal species, rhodolith beds support numerous small macrofaunal species including polychaete, mollusc, crustacean, and echinoderm taxa (e.g. Schembri, 2011).

47. No fleshy algae were recorded from the assemblage of infralittoral sediment but very sparse accumulations of rhodoliths or single rhodoliths were present in places, especially in the troughs formed by the current ripples. The megafauna recorded from this assemblage type comprised the Heart Urchin *Spatangus purpureus* and the Purple Urchin *Sphaerechinus granularis.* However, this assemblage undoubtedly supports a rich infauna as evidenced by the macrofaunal species (Table 9) recorded from the grab samples collected from Stations A – D (Figure 3). The recorded species are typical of the assemblage of infralittoral to circalittoral coarse sediment assemblages present of the northeastern coast of Malta within the 45 m to 80 m depth range.

48. The study area is located within the boundaries of the '*MT0000105 Marine Area in the Northeast of Malta*' Special Area of Conservation of International Importance declared by Government Notice 851 of 2010[8] under the provisions of the *Flora, Fauna and Natural Habitats Protection Regulations, 2006*. This area forms part of the European Union's NATURA 2000 network.

49. In Maltese waters, the main rhodolith-forming algae in rhodolith/maerl beds are *Lithothamnion corallioides* and *Phymatolithon calcareum/Lithothamnion minervae*[9] with *Peysonnelia rosa-marina*, *Mesophyllum* sp., and *Neogoniolithon brassica-florida* constituting a minor component (Lanfranco *et al*., 1999). Associations with rhodoliths are a habitat type that qualifies sites for inclusion in national inventories of natural sites of conservation interest as required by the Protocol for Specially Protected Areas and Biodiversity in the Mediterranean (SPA/BD) of the Barcelona Convention[10]. Furthermore, the coralline algae *Lithothamnion corallioides* and *Phymatolithon calcareum* are listed in Annex V (Animal and plant species of Community interest whose taking in the wild and exploitation may be subject

[8] *Malta Government Gazette* No.18,633, 17 August 2010.

[9] It is not possible to distinguish between *Phymatolithon calcareum* and *Lithothamnion minervae* using gross morphology alone.

[10] The *Convention for the Protection of the Mediterranean Sea against Pollution* (the Barcelona Convention) was adopted on 16th February 1976. A number of protocols were adopted under this convention, amongst which is the *Protocol concerning Mediterranean Specially Protected Areas* done at Geneva on 3 April 1982. The parties later amended this protocol and its name changed to *Protocol for Specially Protected Areas and Biodiversity in the Mediterranean* (SPA/BD). Malta ratified this new Protocol on 28th October 1999. A draft reference list of habitat types for the selection of sites to be included in the National Inventories of Natural Sites of Conservation Interest was drawn up at the Fourth Meeting of National Focal Points for Specially Protected Areas (Tunis, 12-14 April 1999) [see UNEP(OCA)/MED WG.154/7]. The most recent '*Classification of benthic habitat types of the Mediterranean*' dated 2006 is available from the UNEP RAC/SPA at http://rac-spa.org/sites/default/files/doc_fsd/lrhm_en.pdf

to management measures) of the European Union's 'Habitats Directive' as amended[11]. Both species probably occur in the rhodolith beds in the present study area; however, only microscopic examination of samples of rhodoliths collected from the area will confirm this.

50. *Lithothamnion corallioides*, *Phymatolithon calcareum*, together with *Lithothamnion minervae* are listed in Schedule III (Animal and plant species of national interest whose conservation requires the designation of Special Areas of Conservation), and the first two named also in Schedule VII (Animal and plant species of Community interest whose taking in the wild and exploitation may be subject to management measures) of the *Flora, Fauna and Natural Habitats Protection Regulations, 2006* as amended[12], which transpose the requirements of the EU's Habitats Directive to local legislation.

32. Rhodolith and maerl beds are included in the UNEP/MAP/RAC-SPA "Reference list of marine habitat types for the selection of sites to be included in the national inventories of natural sites of conservation interest" (UNEP/MAP/RAC-SPA, 2006) while an action plan for their conservation has been formulated (UNEP/MAP/RAC-SPA, 2008), both within the ambit of the Barcelona Convention. Within European legislation, Council Regulation (EC) 1967/2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, bans the use of specific fishing gear (trawl nets, dredges, shore seines or similar nets) on coralligenous or maerl beds[13]. In order to conform to the requirements of EC 1967/2006, the local 'Implementation and Enforcement of Certain Fisheries Management Plans Order' (Legal Notice 354 of 2013) amends Zones C and G referred to in Annex V of EC 1967/2006 that originally overlapped with rhodolith beds as well as closed to trawling all areas where conclusive evidence exists for the presence of such beds (see Figure 44 in LN 354/2013).

32. The Needle-spined sea-urchin, *Centrostephanus longispinus* is listed in the Habitats Directive under Annex IV (Animal and plant species of Community interest in need of strict protection), in Appendix II of the Bern Convention[14], and in Annex II of the SPA/BD Protocol)[15]. This

[11] The European Union's *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora* is known as the 'Habitats Directive'. Annexes I and II of this Directive have been amended by Council Directive 97/62/EC of 27 October 1997. Annex I of the Habitats Directive lists natural habitats whose conservation requires the designation of Special Areas of Conservation. Annex II lists species of plants and animals whose habitats must be protected for their survival. Annex III lists criteria for selecting sites eligible for consideration as "Sites of Community Importance" and designation as Special Areas of Conservation, while Annex IV lists species of Union interest in need of strict protection. Annex V lists species of plants and animals of Union interest whose taking from the wild and exploitation is subject to management, and Annex VI lists prohibited methods and means of capture and killing of mammals and fish, and prohibited modes of transport. In anticipation of the 2004 enlargement of the EU, the Annexes of the Habitats Directive were modified by the Act of Accession signed in Athens on 16th April 2003, to take into account the expanded geographical area of the EU15+10. The annexes were further amended by Council Directive 2006/105/EC of 20 November 2006 in anticipation of Bulgaria and Romania joining the European Union in 2007 and then again by Council Directive 2013/17/EU of 13 May 2013 due to the accession of the Republic of Croatia.

[12] These regulations were last amended by the Flora, Fauna and Natural Habitats (Amendment) Regulations, 2013 (Legal Notice 322 of 2013).

[13] According to this Regulation, "Mäerl is a collective term for a biogenic structure due to several species of coralline red algae (Corallinaceae), which have hard calcium skeletons and grow as unattached free living branched, twig-like or nodule corallines algae on the seabed, forming accumulations within the ripples of mudflats or sandflats seabed. Maerl beds are usually composed of one or a variable combination of red algae, in particular, *Lithothamnion coralloides* and *Phymatolithon calcareum*". In this definition, 'maerl' is used in the wider sense to refer to 'rhodolith beds' as defined by Basso *et al.* (2016); true maerl is a particular type of rhodolith bed.

[14] The Bern Convention is the *Convention on the Conservation of European Wildlife and Natural Habitats*. Malta acceded to this Convention on the 26th November 1993. Appendix II of the Bern Convention lists strictly protected species of fauna

species is also protected locally under the *Flora, Fauna and Natural Habitats Protection Regulations, 2006* as amended, where it is listed in Schedule V (Animal and Plant Species of Community Interest in need of Strict Protection).

5. IMPACTS ON MARINE ECOLOGY

51. The present assessment of impacts will consider the following phases:
(i) Cage deployment phase
(ii) Operational (tuna farming) phase

Where details on the proposed activity are not available or insufficiently detailed, hence resulting in a degree of uncertainty, the 'precautionary principle' is applied and the worse case scenario is considered. The present assessment of impacts considers the study area within which the ecological assessment described above was made.

52. In making the present assessment of impacts, the procedure will be as follows:
- The main source of impact will be identified and described, and specifically established as adverse or beneficial.
- The likely severity and extent, as well as the receptors and sensitivity of the latter will be described.
- Any possible mitigation measures will be indicated.
- The following criteria will be used to determine the level of overall impact:
  - **Insignificant**: no impact or change is predicted in space and time;
  - **Low**: low level of impact that is localised in space, i.e. within the area of interest (AoI), and occurring over a short time period of a few days to a few weeks, and which may be mitigated.
  - **Moderate:** moderate level of impact that may extend beyond the area of influence and occurring over a longer time period of several months, and which may not necessarily be mitigated.
  - **High**: high level of impact that may extend well beyond the area of influence, which will probably leave some permanent/residual effects, and which may not necessarily be mitigated.
- The duration of the impact and residual effects will be considered.

The above procedure will be adopted using knowledge of marine ecology of the study area as baseline.

and the Convention prohibits the deliberate capture, the destruction of breeding or resting sites, the deliberate destruction, and the deliberate killing of, and trade in, these species.

[15] A number of species are listed in annexes to the SPA/BD Protocol: Annex II lists endangered or threatened species and Annex III lists species whose exploitation is regulated.

POTENTIAL IMPACTS DURING THE CAGE DEPLOYMENT PHASE

Source of impact

- **Disturbance to marine fauna resulting from increased vessel activity during deployment of cage moorings, ropes and tuna pens**
- **Accidental and/or deliberate spillage of toxic substances and contaminants from vessels used to deploy cage moorings**
- **Deployment of cage moorings**

Disturbance to marine fauna resulting from increased vessel activity during deployment of cage moorings, ropes and tuna pens

53. An increase in vessel activity is envisaged in the vicinity of the tuna penning site to enable deployment of the cage moorings, mooring ropes and tuna pens. This is expected to result in disturbance to pelagic fauna present in the general area where the new tuna pens will be deployed. Although detailed data on the pelagic fauna that occur within the study area are lacking, it is expected that several species of pelagic fish, turtles and cetaceans migrate in its vicinity. Such fauna will be exposed to disturbance from the increased vessel activity and from deployment of the cage moorings, ropes and tuna pens. However, the fauna that are expected to be affected are mobile and will swim away from the affected area such that there will be a small deviation of the migratory route without significant adverse effects to the animals.

54. Good practice and measures to reduce disturbance to a minimum are the only mitigation measures to reduce potential adverse impacts.

55. Taking the above into consideration, the overall level of impact is predicted to be **insignificant to low**.

56. With respect to the duration of impact and residual effects; the impacts will be temporary and effective during deployment of the cage moorings, ropes and tuna pens.

Accidental and/or deliberate spillage of toxic substances and contaminants from vessels used to deploy cage moorings

57. Given that vessels, including ones used to deploy the cage moorings, ropes and tuna pens, will be used during installation of the pens, there is a potential for introduction of hazardous substances and chemicals, whether deliberate, accidental or indirect into the marine environment. However, excepting an accident, whether such introduction of hazardous substances and chemicals into the marine environment will actually occur will largely depend on good management and work practices, and effectiveness of environmental protection measures.

58. The introduction of hazardous substances and chemicals (for example, fuel and lubricants, amonsgt others) may have toxic effects on the marine flora and fauna, which could include reduction in reproductive potential and capacity, fertilisation success, development and physiological function. However, the site concerned is located in deep offshore waters that are characterised by a high hydrodynamic regime, hence any small spillage of hazardous

substances and chemicals will be rapidly dispersed and are not expected to have a significant impact on the marine biota present in the vicinity.

59. Any introduction of toxic substances and contaminants will depend heavily on application of precautionary measures, and on the toxicity and levels of substances and contaminants potentially introduced to the marine environment. Therefore, good practice and measures to reduce spillage into the marine environment, hence ones that prevent the introduction of toxic substances and contaminants to the marine enviroment will be important to mitigate potential adverse impacts.

60. Taking the above into consideration, the overall level of impact is predicted to be **insignificant** unless there is large accidental or deliberate spillage, in which case the level of impact is predicted to be **low to medium.**

61. With respect to the duration of impact and residual effects; the impact of potential introduction of toxic substances and contaminants will be temporary and of very short duration (few days), as long as there is no large accidental or deliberate spillage.

Deployment of cage moorings

62. Deployment of the cage mooring is expected to impact the benthic habitat when the concrete block ends up resting on the seabed as there will be direct physical contact with the latter, although the area of the seabed that will be significantly impacted is that which will be occupied by the mooring block. All benthic flora and fauna, the latter mostly comprising sessile and slow moving invertebrates, that will end up underneath the mooring block will be decimated. The more motile fauna, such as fast moving invertebrates and fishes are expected to move away rapidly from a mooring block that is being deployed and will not be affected adversely.

63. On making contact with the soft sediment seabed, disturbance of the latter will lead to suspension of sediment in the water column. Settling of the suspended sediment on the bottom will lead to smothering of flora and sessile fauna, resulting in potential adverse effects on such organisms, although the concerned species are usually adapted to disturbance from suspended sediment and will recover quickly, while the high energy environment of the area will help rapid removal of any sediment particles that may have been deposited on the biota.

64. Good practice and measures to reduce the adverse impact of deployment of the mooring on the seabed, for example, by avoiding dragging the mooring block on the seabed during deployment, are the only mitigation measures to reduce potential adverse impacts.

65. Taking the above into consideration, the overall level of impact is predicted to be **high** within the area that will be occupied by the mooring block, but **insignificant to low** on the sessile benthic species present in the vicinity (a few metres away) of the deployed mooring block.

66. With respect to the duration of impact and residual effects; the impact on the flora and fauna that will end up beneath the mooring clock will be permanent, while impacts on the flora and sessile fauna present in the immediate vicinity of the block will be temporary and of very short duration (few days).

POTENTIAL IMPACTS DURING THE OPERATIONAL (TUNA FARMING) PHASE

Source of impact

- **Disturbance to marine fauna resulting from increased vessel activity during tuna farming**
- **Accidental and/or deliberate spillage of toxic substances and contaminants from vessels used in connection with the tuna penning operations**
- **Decreased light reaching the seabed as a result of shading by the tuna cages**
- **Increased nutrient input, originating from the farmed tuna's waste and feed fish, to the water column**
- **Deposition of organic matter, originating from the farmed tuna's waste and feed fish, on the seabed**
- **Generation of a surface slick comprising fish oils released from the feed fish**
- **Littering of the seabed underneath the tuna cages and in their vicinity**
- **Attraction of wild fauna to the tuna farm**

Disturbance to marine fauna resulting from increased vessel activity during tuna farming

67. An increase in vessel activity is envisaged in the vicinity of the tuna penning site in connection with the tuna farming activity. A number of vessels are expected to operate in the vicinity of the tuna penning site in connection with the farming activity. These include work boats that will be used to transport the feed fish and to feed the caged tuna, boats used for general maintenance of the tuna pens, and vessels used during the period when the tuna are harvested. The latter vessels will be the largest ones used in connection with the tuna farming activity but will only be present during the 2 – 3 month period during which harvesting of the tuna will be carried out and normally anchor some distance offshore from the tuna farm. The presence of vessels is expected to result in disturbance, mainly through generation of underwater noise, to pelagic fauna present in the general area where the new tuna pens will be deployed. Although detailed data on the pelagic fauna that occur within the study area are lacking, it is expected that several species of pelagic fish, turtles and cetaceans migrate in its vicinity. Such fauna will be exposed to disturbance, mainly through generation of underwater noise, from the increased vessel activity in the vicinity of the tuna farm. However, the fauna that are expected to be affected are mobile and will swim away from the tuna penning site such that there will be a small deviation of the migratory route without significant adverse effects to the animals.

68. Good practice and measures to reduce disturbance to a minimum are the only mitigation measures to reduce potential adverse impacts.

69. Taking the above into consideration, the overall level of impact is predicted to be **insignificant to low**.

70. With respect to the duration of impact and residual effects; the impacts will be effective throughout the period when tuna farming is carried out.

Accidental and/or deliberate spillage of toxic substances and contaminants from vessels used in connection with the tuna penning operations

71. A number of vessels are expected to operate in the vicinity of the tuna penning site in connection with the farming acvitiy. These include work boats that will be used to transport the feed fish and to feed the caged tuna, boats used for general maintenance of the tuna pens, and vessels used during the period when the tuna are harvested. The latter vessels will be the largest of the ones used in connection with the tuna farming activity but will only be present during the 2 – 3 month period during which harvesting of the tuna will be carried out. Because of the regular presence of such vessels in the vicinity of the tuna penning site, there is a potential for accidental or deliberate introduction of hazardous substances and chemicals (for example, fuel and lubricants, amonsgt others), whether deliberate, accidental or indirect, into the marine environment. However, excepting an accident, whether such introduction of hazardous substances and chemicals into the marine environment will actually occur will largely depend on good management and work practices, and effectiveness of environmental protection measures.

72. The introduction of hazardous substances and chemicals may have toxic effects on the marine flora and fauna, which could include reduction in reproductive potential and capacity, fertilisation success, development and physiological function. However, the site concerned is located in deep offshore waters that are characterised by a high hydrodynamic regime; hence, any small spillage of hazardous substances and chemicals will be rapidly dispersed and are not expected to have a significant impact on the marine biota present in the vicinity.

73. Any introduction of toxic substances and contaminants will depend heavily on application of precautionary measures, and on the toxicity and levels of substances and contaminants potentially introduced to the marine environment. Therefore, good practice and measures to reduce spillage into the marine environment, hence ones that prevent the introduction of toxic substances and contaminants to the marine enviroment, will be important to mitigate potential adverse impacts.

74. Taking the above into consideration, the overall level of impact is predicted to be **insignificant** unless there is a large accidental or deliberate spillage, in which case the level of impact is predicted to be **low to medium.**

75. With respect to the duration of impact and residual effects; the impact of potential introduction of toxic substances and contaminants will be temporary and of very short duration (few days), as long as there is no large accidental or deliberate spillage.

Decreased light reaching the seabed as a result of shading by the tuna cages

76. Tuna cages typically have a diameter of around 50 m and support a cage net that is some 35 m high. The cage net and the tuna they hold are expected to produce a shading effect and reduce the amount of light reaching the seabed. The reduced light availability will have an adverse effect on any rhodoliths present on the seabed, even if these are present in small accumulations or are sparsely distributed on the bottom, given that the photosynthetic capacity of the algae making up the rhodoliths will be decreased such that they will stop growing or die. With regard to any associated megafauna and macrofauna; the sparse rhodolith accumulations recorded from the site identified for tuna penning are not known to support a high diversity of associated fauna, at least compared to dense rhodolith beds,

while the fauna that occurs in association with such habitat is more typical of lower infralittoral and upper circalittoral coarse sediments. Therefore, the main adverse impact is expected to be mostly on the rhodoliths.

77. The shading effect cannot be mitigated unless the cages are removed and is a consequence of the presence of a floating structure – the tuna pen - which cannot be modified or replaced by another structure that does not cause shading.

78. Taking the above into consideration, the overall level of impact is predicted to be **high** on any rhodoliths present within the area that will be occupied by a tuna cage, but **insignificant** in other areas at the tuna penning site.

79. With respect to the duration of impact and residual effects; the impact will be effective throughout the period when the tuna pens are in place (c. 6 months); however, once the latter are removed, recovery (which will require at least a few months) is expected since coralline algae will rapidly recolonise any rhodoliths whose algal component would have demised.

Increased nutrient input, originating from the farmed tuna's waste and feed fish, to the water column

80. The tuna farming operations are expected to result in some nutrient and organic loading of the water column; the nutrients and organic matter will mainly originate from faecal matter excreted by the farmed tuna and from decomposition of any uneaten feed fish that will end up on the seabed. Water quality surveys have been carried out at local tuna penning sites since the early 2000's. During these surveys, standard water quality attributes, namely dissolved oxygen, temperature, salinity, turbidity, nitrates, phosphates, Chlorophyll *a*, ammonia, and counts of intestinal bacteria, as well as sea currents, were measured at a number of sampling stations located in the immediate vicinity of the tuna farms and at up-current and down-current reference stations. The results of such surveys indicate that, very rarely, lowered levels of oxygen, reduced water transparency and elevated nutrient (nitrates and/or phosphates and/or ammonia) levels were recorded from the tuna penning sites during the farming season (July – December). However, the observed changes in the monitored attributes were often sporadic and not statistically significant, and have not resulted in appreciable alteration of water quality. Elevated counts of intestinal bacteria have also been occasionally recorded but since such organisms do not originate from the tuna but from sewage, their presence were not attributed to the tuna penning activities *per se*, although there is the possibility that large ships (e.g. the processing ships present during harvesting of the tuna) may be the source of such contamination through discharge of sewage from their holding tanks. Such favourable results with respect to water quality are attributed to the high energy environment, particularly strong sea currents present, that characterise the offshore area where the proposed tuna penning site is located, and which lead to rapid and effective dispersal of nutrients that may originate from the tuna farming activity.

81. Nevertheless, good practice and measures to reduce loading of the water column with nutrients and organic matter are recommended; in particular excessive loading by organic matter can be reduced by ensuring that overfeeding is avoided, such that the amount of uneaten feedfish that are introduced to the marine environment will be minimal.

82. Taking the above into consideration, the overall level of impact of nutrient and organic matter loading of the water column on water quality and associated biota (e.g. plankton) is predicted to be **insignificant to low**.

83. With respect to the duration of impact and residual effects; the impact will be effective throughout the period when tuna farming is carried out (4 - 6 months), with progressively reduced effects as the tuna is harvested and the reared biomass reduced.

Deposition of organic matter, originating from the farmed tuna's waste and feed fish, on the seabed

84. The tuna farming operations are expected to result in organic loading of the seabed; the organic matter will mainly originate from decomposition of uneaten feed fish that may end up on the seabed. Such organic loading is expected to have a large impact on benthic habitat, which would result in changes to sediment quality and to the species composition of biotic assemblages associated with lower infralittoral/upper circalittoral coarse sediment habitat. In cases where the impact is large and adverse, loss of habitat and biodiversity may occur.

85. Video surveys of the seabed underneath tuna cages have been undertaken regularly at local tuna since the early 2000's. The main aim of such surveys was to gather qualitative and semi-quantitative data, using direct observation, on the physical and biological characteristics of the seabed underneath the tuna pens. The results of these surveys have indicated that towards the end of each penning season (in autumn) considerable amounts of uneaten feed fish littered the seabed in the area lying directly below the tuna pens, but not in areas beyond the perimeter of the tuna pens. This resulted in alterations in the physical and biological characteristics of the seabed under the pens, namely: (i) changes in biological characteristics, which typically consist of high population densities of detritus-feeding and scavenging benthic (i.e. associated with seabed) fauna, and whose occurrence is unusual considering the benthic habitat type present at the tuna penning sites surveyed; (ii) alterations in physical characteristics, which typically consist of the presence of large quantities of fish bones and baitfish that are gradually consumed by scavengers or eventually decompose. The results of the video surveys also indicated that the amount of uneaten feed fish present varied considerably between the different pens, and between different farms, with some only having a few feed-fish beneath them and others having multiple layers of decomposing feed-fish. Once the tuna farming season is over (late winter), a negligible amount of uneaten feed-fish remain on the seabed below the pens. However, thick layers of fish bones and of decomposing organic material persist under some of the pens. These observations indicate a consistent pattern, with the volume of uneaten feed-fish on the seabed decreasing only when the tuna have been harvested (and therefore there is no further addition of feed-fish). Any uneaten fish remaining on the seabed at this time will continue to decompose slowly and, if present in large numbers, form a continuous layer of decomposing organic material. Sometimes, following storms and possibly due to strong bottom currents, this layer is admixed with the underlying mobile sediment. In places where the decomposition process is complete, the only remains are fish bones that eventually disperse in the sediment leaving little or no trace of the original uneaten fish on the surface. Once the source of the impact (periodic addition of new uneaten food) is removed, slow recovery to the original state is characterised by the re-appearance of certain megafaunal

species (e.g. the irregular sea urchin *Spatangus purpureus* and the crinoid *Antedon mediterranea*) that form part of the original fauna that characterise the bare muddy sand bottom of the areas where the tuna farms are located.

86. Monitoring of sediment quality at local tuna penning sites has also been carried out regularly since the early 2000's. The main aim of such monitoring is to assess the levels of organic carbon content and organic nitrogen content of the sediments, as well as sediment granulometric characteristics. Moreover, at least one survey involving assessment of levels of pollutants, including heavy metals and organic pollutants, was carried out at some of the extant tuna penning sites. The monitoring design of the surveys to assess organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, was based on a Beyond **BACI**[16] layout, in which the results of quantitative analyses of sediment samples collected from the tuna farming site and from a number of control sites before the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. Overall, the findings from surveys that were aimed at assessing organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, indicated 'pulse' (i.e. short duration) changes in the physico-chemical properties of the sediment following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens but no significant permanent alterations of the sediment characteristics at the operational sites have been recorded to date. Where significant changes were detected, these appeared to have resulted from accumulation of large amounts of uneaten feed-fish in the vicinity of the tuna pens, which decompose slowly causing alterations in the physico-chemical properties of the sediments. The results of the surveys aimed at assessing levels of heavy metals and pollutant organics indicated that no elevated levels were present in the sediments in the vicinity of the tuna farms.

87. Monitoring of benthic diversity at local tuna penning sites has also been carried out regularly since the early 2000's. The main aim of such monitoring is to assess for potential changes in benthic species populations and habitat that may result from the tuna penning activities. The monitoring design was based on assessing total species richness and total abundance of selected benthic faunal species, as these are deemed good indicators of the overall state of species and habitats associated with the seabed. As in the case of the physico-chemical attributes monitoring component, the design for monitoring of benthic diversity was based on a Beyond **BACI** layout, in which the results of quantitative analyses of samples collected from the tuna farming site and from a number of control sites **before** the start of the farming operations are compared with those obtained **after** a farming season using advanced statistical analyses. Overall, the findings from monitoring of benthic diversity indicate a significant 'press' (i.e. long-lasting) adverse impact (manifested as a significant decrease in total macroinvertebrate species richness and/or decrease in the abundance of one or more of the indicator species) following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens. Furthermore, enhanced productivity in the general area of the tuna farms and beyond, as a result of the

[16] **B**efore **A**fter **C**ontrol **I**mpacted; see Underwood (1992): Underwood, A. J. (1992) Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161: 145 –178.

tuna-penning activities, was evident from significant increases in the abundance of some of the indicator species recorded in some of the monitoring sessions. These observations are a strong indication that, where present, adverse impacts on the benthic macroinvertebrate assemblages and habitat at the tuna penning sites have resulted from processes that are mainly attributed to accumulation of large amounts of uneaten feed-fish and slow decomposition of same, in the vicinity of the tuna pens. The uneaten feed-fish attract scavengers and other opportunistic fauna that cause changes to the original species composition of the benthic assemblages, while slow decomposition of the accumulated material causes alterations in the physico-chemical properties of the sediments, and presumably of the sediment-water interface, leading to adverse conditions for the biota originally present. A number of scientific publications, which present detailed results – mainly as described above - of the influence of local tuna penning activities on marine benthic habitat, are available; see Manion *et al* (2014; 2017; 2018).

88. Good practice and measures to reduce excessive loading of the seabed by organic matter are the main mitigation measures that can be adopted to avoid or at least reduce adverse impacts on the benthic biota and habitat present in the vicinity of the tuna penning site. Essentially, good feed management procedures will be very important to mitigate adverse impacts resulting from organic loading of the seabed. The following measures are deemed particularly important: (i) Feeding of the tuna should be carefully monitored and stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten feed ending up on the bottom. The tuna operators may want to implement a procedure to ensure proper feed management by having random checks of the seabed below the tuna pens made by an independent environmental monitor; (ii) In the case of accident, should an inordinate amount of dead uneaten feed-fish end up on the bottom, every attempt should be made to recover as much of the material as possible using techniques that do not have an adverse effect on the seabed habitat.

89. Taking the above into consideration, the overall level of impact of organic matter loading of the seabed, and hence on benthic biota and habitats present at the tuna penning site, is predicted to be **medium to high** within the seabed area directly underneath the cages; and **insignificant to low** in the seabed area beyond.

90. With respect to the duration of impact and residual effects; the impact will be effective throughout the period when tuna farming is carried out.

Generation of a surface slick comprising fish oils released from the feed fish

91. The tuna farming activity is expected to generate oils and fats that are released from the thawing feed-fish when these are fed to the tuna. Release of such substances occurs when the semi-frozen feed fish are introduced in the tuna pens, and when uneaten feed-fish end up outside the fish cages. The resulting floating slick of fatty substances that accumulate on the surface may be transported offshore or inshore, depending on sea current strength and direction. Such substances, commonly known as ‘fish farm slime’, have caused much public concern and outcry. Although they are not deemed to have any toxic effects on pelagic marine species and habitats, they are aesthetically unpleasing and a nuisance to bathers, divers and coastal recreational activities, because of their sheer presence in the water and since they deposit on the shore and on artificial surfaces (e.g. boat hulls etc.). The deposition of such substances on the shore is not envisaged to have any large adverse effects on marine

species and habitats, given that they will rapidly biodegrade; however, this has not yet been assessed given the complete lack of studies that deal specifically with this aspect.

92. Good practice and measures to reduce the release of oils and fats from the feed fish, restrict their presence to the immediate vicinity of the tuna farm (e.g. by using booms), and carrying out immediate collection of the substances (e.g. using skimmers) when appreciable amounts of them are released to the marine environment, are the main mitigation measures that can be adopted to avoid or at least reduce their presence on the surface in coastal areas close to the fish farms and inshore.

93. Taking the above into consideration, the overall level of impact when floating oily and fatty substances originating from the feed fish end up on the surface in offshore waters and are potentially transported inshore, is predicted to be **medium to high** from the aesthetics and water quality for recreational activities points of view, but **insignificant to low** with respect to adverse impacts on marine ecology, including shore habitat where they may be deposited.

Littering of the seabed underneath the tuna cages and in their vicinity

94. The results of video surveys made below tuna cages at local tuna penning sites have indicated that, in places, a considerable amount of anthropogenic items is present below the pens that appear to originate from the farm operations; these include concrete weights with ropes attached, sheets and sacks of fabric and other material, car tyres, lengths of rope and other unidentified items. While plastic items are known to be hazardous to marine life, items deposited on the seabed lead to physical alteration of the bottom leading to potential changes to the benthic habitat present in the vicinity of the fish farm.

95. Good practice and measures to reduce littering of the seabed by anthropogenic items originating from the tuna penning activities are the main mitigation measures that can be adopted to avoid littering of the seabed. Should any items originating from the fish farm accidentally end up in the sea, whether floating or deposited on the seabed, these should be recovered immediately.

96. Taking the above into consideration, the overall level of impact when anthropogenic items originating from the fish farm end up in the sea, whether floating or deposited on the seabed, is predicted to be **low** to **medium**.

Attraction of wild fauna to the tuna farm

97. Fish farms, including tuna ranches, are known to attract a variety of wild marine pelagic fauna. These include: shoals of small pelagic fish (such as Clupeid species) which eat the fragments of feed fish that are released in the water, and the biota growing on the tuna pen nets; medium-sized predators such as *Coryphaena hippuris* and *Seriola dumerilii* which feed on the small pelagic fish that aggregate in the vicinity of the tuna cages; large pelagic predators including cetaceans (namely dolphins), which feed on the medium-sized predators and uneaten feed fish present outside the tuna pens; and wild tunas that are attracted to the caged tuna and also feed on uneaten feed fish that end up outside the tuna pens. Such aggregations of wild pelagic fauna are not envisaged to be adversely affected by the tuna penning activities *per se*, since they will be acquiring food that will potentially lead to enhanced local production. However, the aggregations tend to attract fishermen who carry

out fishing activities in the vicinity of tuna farm such that they will harvest the wild fish present there; indeed because of such 'facilitated' harvesting of wild fish, fish farms have been described by marine ecologists as serving as 'ecological traps'. The problem at local tuna farms gets more complicated since fishermen who target the wild tunas and carry out their activities in the vicinity of the farms may actually be the cause of whole dead tunas ending up on the seabed in the vicinity of the tuna farms. This problem is highlighted in Arechavala-Lopez *et al*. (2015); fishermen deploy fishing lines in the vicinity of the tuna farms with an aim to catch wild tuna that aggregate there. Any tunas that are caught may: (i) either break free but will have the hook and a length of fishing line attached to their mouth, which may eventually become entangled against the cage mooring ropes, such that the fish will be restricted in its ability to swim or get exhausted trying to break free but in both cases will end up dying; or (ii) become entangled against the cage mooring ropes and, being unable to retrieve them, the fishermen[17] cut them free, however, the hook and length of fishing line attached to their mouth may, again, eventually become entangled against the cage mooring ropes, leading to (i) as stated previously. Fishermen have also been observed to clean tunas they would have caught and discard the head and offal overboard.

98. Prohibition/strict control of fishing activities in the vicinity of the tuna farms is the main mitigation measure that can be adopted to avoid detrimental (and sometimes) illegal harvesting of wild fish, including tunas) in the vicinity of the fish farms.

99. Taking the above into consideration, the overall level of impact of uncontrolled fishing activities that are aimed at harvesting pelagic wild fauna, including tunas, which aggregate in the vicinity of the tuna farms, leading to the adverse effects described in para 100 above, is predicted to be **low**.

6. REFERENCES

Arechavala-Lopez P., Borg J. A., Sˇegvic´-Bubic´ T., Paolo Tomassetti P., Özgül A.. & Sanchez-Jerez P., 2015. Aggregations of wild Atlantic Bluefin Tuna (*Thunnus thynnus* L.) at Mediterranean offshore fish farm sites: Environmental and management considerations. Fisheries Research 164: 178-1

Basso D., Babbini L., Kaleb S., Bracchi V.A., Falace A. (2016). Monitoring deep Mediterranean rhodolith beds. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26(3), 549-561; DOI: 10.1002/aqc.2586

Borg J.A., Howege H.M., Lanfranco E., Micallef S.A., Mifsud C. & Schembri P.J., 1998. The macrobenthic species of the infralittoral to circalittoral transition zone off the northeastern coast of Malta (Central Mediterranean). *Xjenza* 3(1): 16-24. [Malta].

Borg J.A., Knittweis L. & Schembri P.J. (2013) *Compilation of an interpretation manual for marine habitats within the 25 NM Fisheries Management Zone around the Republic of Malta.* [MEPA tender reference: T2/2013]. MEPA, Malta; 218pp.

[17] According to the site managers, the wild tuna caught by the amateur fishermen are sometimes cut free on being approached by fisheries officers who make regular site visits to the fish farms using a vessel owned by the local fisheries department.

Borg J. A. & Schembri P. J., 2008. *Report on a marine benthic survey using remote underwater videography in an area off eastern Comino*. Malta: Ecoserv Ltd; 26pp.

Borg J. A., Howege H.M., Lanfranco E., Micallef S. A., Mifsud C. & Schembri P.J., 1998. The macrobenthic species of the infralittoral to circalittoral transition zone off the northeastern coast of Malta (Central Mediterranean). *Xjenza* 3(1): 16-24. [Malta].

Lanfranco, E.; Rizzo, M.; Hall-Spencer, J.; Borg, J.A. & Schembri, P.J. (1999) Maerl-forming coralline algae and associated phytobenthos from the Maltese Islands. *The Central Mediterranean Naturalist* 3(1): 1-6.

Mangion M., Borg J. A., Thompson R. & Schembri P. J., 2014. Influence of tuna penning activities on soft bottom macrobenthic assemblages. Marine Pollution Bulletin 79; 164-174.

Mangion M., Borg J. A., Sanchez Jerez P & Schembri P. J., 2017. Assessment of benthic biological indicators for evaluating the environmental impact of tuna farming. Aquaculture Research 48: 5797 – 5811.

Mangion M., Borg J. A., Sanchez-Jerez P., 2018. Differences in magnitude and spatial extent of impact of tuna farming on benthic macroinvertebrate assemblages. Regional Studies in Marine Science 18: 197 – 207.

Schembri P. J., 1998. Maerl ecosystems of the Maltese islands. In: Dandria, D. [ed.] *Biology abstracts MSc, PhD 1998 and contributions to marine biology:* pp.35-37. Msida, Malta: Department of Biology, University of Malta; iv+38pp. [Malta].

Schembri P. J., 2011. North offshore aquaculture zone - report on an ecological survey within an area off eastern Comino, proposed for designation as an offshore aquaculture zone, made in January - February 2011. Malta: Ecoserv Ltd; 24pp.

Sciberras M., Rizzo M., Mifsud J. R., Camilleri K., Borg J. A., Lanfranco E. & Schembri P. J., 2009. Habitat structure and biological characteristics of a maerl bed off the northeastern coast of the Maltese Islands (central Mediterranean). *Marine Biodiversity* 39: 251 - 264.

UNEP-MAP-RAC/SPA (2006). *Reference list of marine habitat types for the selection of sites to be included in the national inventories of natural sites of conservation interest*. UNEP-MAP-RAC/SPA; 5pp.

UNEP-MAP-RAC/SPA (2008) Action Plan for the conservation of the coralligenous and other calcareous bio-Concretions in the Mediterranean Sea. UNEP-MAP-RAC/SPA, 21pp.

PA/05908/23 & EA/00007/18

PROPOSED CONVERSION FROM A TEMPORARY TO A PERMANENT TUNA FARMING AREA AS ESTABLISHED IN PA/02175/18; RETAINING THE APPROVED TOTAL BIOMASS OF FISH AND ALL RELATIVE CONDITIONS

Technical Appendix 3

ENVIRONMENTAL MONITORING – INTEGRATED ASSESSMENT REPORTS (2019 – 2023)

Prepared by Ecoserv Ltd (Malta)

Supporting Documents for

Environmental Impact Assessment Update Report

Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site

Integrated assessment of monitoring of water quality and video surveys undertaken in 2019 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay

Prepared by

JOSEPH A. BORG
BSc MSc PhD (Plymouth) FIBMS FMBA FRSB CBiol

FOR

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

ECOSERV'S REPORT REFERENCE: 195-19

NOVEMBER 2019

1. INTRODUCTION

1. An environmental monitoring program is required as part of the environmental permit (EP) for tuna penning operations carried out by AJD Tuna Ltd and Malta Mariculture Ltd at their tuna farm sites off Mellieha Bay. Ecoserv submitted a proposal for such environmental monitoring, which was subsequently approved by the Environmental Resources Authority (ERA).

2. The proposal by Ecoserv refers to collection of water samples from the four (4) monitoring stations from a depth of approximately 0.5 - 1 m. Additionally, the water quality survey includes *in situ* measurement of dissolved oxygen (DO), salinity, temperature and turbidity, at the same stations using a multi parameter meter. Measurement of current speed and direction also form part of the monitoring proposal. Two water quality sessions will be undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

3. Ecoserv's proposal also refers to a video survey using a remotely operated vehicle (ROV) that will be undertaken below a select number of fish cages to assess for the following:

   - Level of uneaten feed accumulating on the seabed;
   - Species diversity and abundance of megafauna;
   - Marine litter; and
   - Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

   The video survey will be undertaken using a remotely operateed vehicle (ROV) that will be navigated below, as much as possible, a select number of tuna cages at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay; the video footage will later be analysed in the laboratory. Ecoserv proposed that the video footage of the seabed will be collected in the vicinity of eight cages; four cages at each of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites. The cages selected for monitoring using video footage will be chosen at random in the field by the scientists on the day of monitoring but the selected cages will be as distant from each other as possible to allow for representative assessment. Video footage of the seabed will also be collected from each of four stations located at a distance from AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites, where the bottom may support a habitat of high ecological importance; namely soft bottom / maerl habitat located west, north and east of the site, as well as at 'Is-Sikka l-Bajda' located south of the site. The advantages of a video survey of the seabed in the vicinity of the tuna pens and at reference sites are that: (i) the results of the monitoring will be available within a few weeks and will clearly indicate the state of the seabed in the vicinity of the cages; (ii) the main output – the video footage – is in itself illustrative and will readily, clearly, and visually, show any change/adverse impact of the tuna farming activities on the seabed, including to the operator himself; and (iii) the video footage may also be used readily by the ERA to effectively illustrate and inform planners, policy makers, politicians and the general public of the situation of the seabed below the cages. Ecoserv's proposal also indicates that, based on the outcome from the video surveys, in the eventuality that the findings indicate large changes in physical and biological characteristics of the seabed following the tuna penning activities, then the ERA would reserve the right to request a quantitative study to assess, in greater detail, any alterations to the benthic habitat. This would be done through quantitative assessment of sediment quality and benthic assemblages, as per the related component of the ERA's ToR. Such strategy will also

serve as incentive for the operators to ensure proper management of the tuna farm activities and avoid potential adverse impacts on the seabed, as well as avoiding additional monitoring and associated high cost. Two video survey sessions will be undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

4. Finally, the obligations set out in the permit also refer to an integrated assessment of the environmental monitoring undertaken during any one year, which is the subject of the present submission. The present document comprises Ecoserv's report of integrated assessment of the findings from the water quality monitoring and video survey sessions undertaken in spring and autumn 2019 in the vicinity of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay (northeastern coast of Malta).

2. METHODOLOGY AND RESULTS

Water quality

5. Fieldwork in relation to the spring and autumn 2019 water quality sessions was undertaken in March 2019 and September 2019 respectively. The day on which the survey was held was chosen at random but selection was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. In situ measurements and collection of seawater samples were made at a total of four stations.

6. To view the methodological details and results of the *in situ* measurements and laboratory analyses, the reader is referred to Borg and Agius (2019a; 2019b).

7. The results of sea current measurement made in March 2019 indicated a current direction of SE / E, and a current speed of between 0.080 ms^{-1} and 0.101 ms^{-1}; such that the western station served as the 'up-current station' and eastern station served as the 'down-current station'. The results of sea current measurement made in September 2019 indicated a SSW to SE current direction, and a current speed of between 0.090 ms^{-1} and 0.106 ms^{-1}; such that such that the western station served as the 'up-current station' and eastern station served as the 'down-current station'.

8. Values of temperature, salinity, dissolved oxygen, turbidity and Secchi Disc depth recorded from the four water quality monitoring stations were similar, overall, during both spring and summer 2019 sessions.

9. No floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the sea surface during the March 2019 survey; this observation was corroborated by aerial photographs of the survey area that were taken on the same day when the water quality survey was carried out, and which indicated absence of floating material, including floating oily substances (commonly referred to as 'sea slime'). The aerial photos taken in Spring 2019 also indicated that: (i) of the 8 cages used by AJD Tuna Ltd, two cages had a net and appeared to hold tuna; (ii) of the 8 cages used by Malta Mariculture Ltd, two cages had a net and appeared to hold tuna. During the Summer 2019 monitoring session, some oil slicks and foam were observed on the surface during fieldwork. Such patches were dispersed and recorded

close to the boundary line of the tuna farms, in the vicinity of the western station. Otherwise no floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the surface in the rest of the study area during this survey. This observation was corroborated by aerial photographs of the survey area taken on the same day when the water quality survey was carried out, and which indicated absence of appreciable amounts of floating material, including floating oily substances (commonly referred to as 'sea slime'). However, the aerial images taken in summer 2019 indicated patches with a dispersed oily substance on the sea surface in the vicinity of the western station. The aerial photos also indicated that all of the 12 cages used by AJD Tuna Ltd and Malta Mariculture Ltd appeared to hold tuna.

10. Mean values of pH, Total Nitrogen, Total Phosphorous, Chlorophyll *a,* total organic carbon (TOC) and total suspended solids (TSS) in seawater recorded from the four stations were similar, overall, during both spring and summer 2019 sessions.

Video survey

11. Fieldwork in relation to the spring and autumn 2019 video survey was undertaken in May / June and September 2019 respectively. The day on which the survey was held was chosen at random but selection was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Video footage of the seabed was collected using an ROV. In May / June 2019, video footage was recorded from below a total of seven tuna pens - three cages belonging to AJD Tuna Ltd (AJD Cage 3, AJD Cage 13, and AJD Cage 18) and four belonging to Malta Mariculture Ltd (MML Cage 7, MML Cage 8, MML Cage 9 and MML Cage 12), and at three reference sites (NE reference, SE reference and Sikka l-Bajda reference). Although the plan was to collect video footage of the seabed from below a fourth tuna cage (belonging to AJD Tuna Ltd) and fourth reference site (northwest reference), adverse sea conditions and time constraints precluded this. In September 2019, video footage of the seabed was recorded from below a total of eight tuna pens - three cages belonging to AJD Tuna Ltd (AJD Cage 1, AJD Cage 5, AJD Cage 14 and AJD Cage 16) and four belonging to Malta Mariculture Ltd (MML Cage 7, MML Cage 11, MML Cage 20 and MML Cage 22), and at four reference sites (NW reference, NE reference, SE reference and SW reference).

12. The 'uneaten food index' designed by Borg & Schembri to enable comparison of the relative amounts of dead fish present under the pens (see Holmer et al, 2008) was used in the present assessment to quantify the amount of uneaten feed fish present on the seabed below a tuna pen, if applicable. The index, which ranges between 0 and 4, is described in Table 1.

13. To view the methodological details and results of the video surveys, the reader is referred to Borg and Agius (2019c; 2019d).

14. The results of the two surveys (one held in May / June 2019, and the other in September 2019) have been presented as a video recording showing the state of the seabed at the tuna pens and reference sites surveyed, that is appended to the respective report. During the May / June 2019 survey, MML Cage 7 and MML Cage 9 held tuna. During the September 2019 survey, all of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna pens held tuna.

Table 1.

The 'uneaten food index' devised by Borg & Schembri (see Holmer et al., 2008) for the purpose of quantifying and comparing the amount of dead uneaten feed-fish under the different tuna-pens.

Index value	Description
0	No uneaten fish present
1	< 1 uneaten fish present per m^2 of seabed
2	> 1 uneaten fish present per m^2 of seabed, but the fish do not form a continuous layer covering the seabed
3	> 1 uneaten fish present per m^2 of seabed. Fish form a single, uninterrupted layer within at least a $1m^2$ area on the seabed.
4	> 1 uneaten fish present per m^2 of seabed. Fish form two or more uninterrupted layers on top of each other within at least a $1m^2$ area on the seabed.

15. The results of the May / June 2019 survey indicated the following:
    - The bottom below the seven tuna pens and at two of the reference sites (NE reference and SE reference) consisted predominantly of coarse mobile sediments, namely coarse sand. The surface of the mobile sediment had conspicuous crests and troughs that were some 20 cm high, and most probably resulted from strong current action, although no significant sea currents were observed close to the bottom during the survey. The troughs of soft sediment had sparse accumulations of rhodoliths[1], such that the latter had an overall percent coverage of some 0 % - 20 %. Very small patches of bedrock appeared to be present below MML Cage 9. At the Sikka l-Bajda reference site, the bottom comprised a mosaic with patches of seagrass *Posidonia oceanica* growing on soft sediment and photophilic algae growing on bedrock that characterises this reef area. The underwater visibility was good and ranged around 20 m – 25 m. Water depth was between 50 m (Malta Mariculture Ltd's site) and 53 m (AJD Tuna Ltd's site) below the tuna pens, 60 m at the NE reference site, 54 m at the SE reference site and 17 m at the Sikka l-Bajda reference site. A few anthropogenic items were recorded on the seabed; these mainly consisted of an unidentified item, a building brick, short lengths of rope, small concrete weights with ropes attached, unidentified strips of ? PVC ? metal and an abandoned fish trap. It is assumed that the short lengths of rope and small concrete weights with ropes attached originate from the tuna farming activities. No fish bones or remains of tuna were recorded from below the seven tuna pens and at the three reference sites. However, a single bone (vertebra) which may have originated from a tuna individual was recorded from below MML Cage 9. A few uneaten feed-fish (around four individuals were counted in all) were present on the seabed below MML Cage 8, but none were present on the seabed below the other cages or at the reference sites.

    - The seabed below the seven tuna pens and two of the reference sites (NE reference and SE reference) supported Infralittoral coarse sediment (EUNIS code A5.13). In places, the sediment bottom supporting this assemblage type had accumulations of rhodoliths, such that

[1] Rhodoliths consist either of free-living calcareous rhodophytes (red algae), or else of an inner nucleus, such as stone or shell, encrusted by calcareous rhodophytes.

where present their cover was some 1 – 20%. The megafauna recorded from this assemblage type mainly comprised a high density of the irregular sea urchin *Spatangus purpureus*. Individuals of the seastar *Lurida ciliaris* and of the urchin *Stylocidaris affinis* were present in places. The seabed at the Sikka l-Bajda reference site supported a mosaic with patches of the biocenosis of *Posidonia oceanica* meadows (EUNIS code A5.535) and the biocoenosis of infralittoral algae (EUNIS code A3.131); see Figures 8 and 9. The seagrass *Posidonia oceanica* appeared to be in a good state. Demersal fishes, namely Comber *Serranus cabrilla*, Weever Fish *Trachinus* sp., and Stingray *Dasyatis pastinaca* were recorded below some of the tuna pens. The pelagic fish fauna recorded in the vicinity of the tuna pens included very large shoals of Bogue *Boops boops* and Shad *Alosa* sp.

16. The results of the September 2019 survey indicated the following:

- The bottom below the eight tuna pens and three of the reference sites consisted predominantly of coarse mobile sediments, namely coarse sand, while at the Sikka l-Bajda reference site the bottom comprised a mosaic with patches of seagrass *Posidonia oceanica* growing on soft sediment and photophilic algae growing on bedrock that characterises this reef area. The underwater visibility was good and ranged around 20 m – 25 m. Water depth was between 50 m (Malta Mariculture Ltd's site) and 54 m (AJD Tuna Ltd's site) below the tuna pens, 60 m at the NE reference site, 57 m at the NW reference site, 52 m at the SE reference site and 19 m at the SW Sikka l-Bajda reference site. A few anthropogenic items were recorded on the seabed below the tuna pens, some of which, namely the large sheet of fabric (or possibly a sack used to hold feed fish), short lengths of rope and small concrete weights with ropes attached, appear to have originated from the tuna farming activities. A tuna carcass was recorded on the seabed below Malta Mariculture Ltd's Cage 7; Ecoserv's consultants immediately contacted the site manager who took due action such that the carcass was retrieved by SCUBA divers. Otherwise, no fish bones or remains of tuna were recorded from below the remaining tuna pens and at the three reference sites. Some of the tuna pens had small amounts (uneaten food index value = 1) of uneaten feed fish on the seabed below them, while an appreciable amount of uneaten feed fish (uneaten food index value = 1 - 2) was present on the seabed below AJD Tuna Ltd's Cage 14. Communication with the site manager re the latter observation indicated that the appreciable amount of uneaten feed fish resulted from accidental rupture of the feed net present on the surface in the tuna cage, and release of an inordinate amount of feed fish. The site manager was advised to make arrangements so that as much as possible of the feed fish are retrieved.

- The biological characteristics recorded from below the eight tuna pens and three reference sites indicated the presence of benthic assemblages and habitat types that are typical of the area; the seabed below the seven tuna pens and three of the reference sites supported a biocoenosis of infralittoral coarse sediment (EUNIS code A5.13), which in many places had small accumulations of rhodoliths or sparse rhodoliths, such that where present their cover was some 1 – 20%. The megafauna recorded from this assemblage type was rather impoverished compared to that recorded during the previous survey made in March 2019 (see Borg & Agius, 2019c) and mainly comprised occasional individuals of the irregular sea urchin *Spatangus purpureus*. However, this observation held true for the seabed under the tuna pens, as well as for that at the NE, NW and SW reference sites which had the same benthic habitat type. This would seem to indicate that the observation of impoverished megafauna is not related to the effects of the tuna penning activities. The seabed at the Sikka l-Bajda reference site supported a mosaic with patches of the biocenosis of *Posidonia oceanica* meadows and the biocoenosis of infralittoral algae; the seagrass *Posidonia oceanica*

appeared to be in a good state and unimpacted by the tuna penning activities. The demersal fish fauna and pelagic fish fauna swimming close to the tuna cages were typical of that which occurs in local offshore coastal waters, but were present in a much higher abundance in the vicinity of the tuna cages; this is to be expected given that offshore cages used for aquaculture and fish ranching attract large shoals of wild fishes.

4. APPRAISAL

Water quality

17. Differences in values of temperature, salinity, dissolved oxygen and turbidity levels amongst the four water quality monitoring stations, recorded in spring and summer 2019, were very small and typical for offshore waters during the respective season.

18. No floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the sea surface during the spring 2019 survey. However, some oil slicks and foam were recorded on the sea surface during the summer 2019 survey; such patches were dispersed and recorded close to the boundary line of the tuna farms, in the vicinity of the western station. Otherwise no floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the surface in the rest of the study area during this survey.

19. The results for pH, Total Nitrogen, Total Phosphorous, Chlorophyll *a,* total organic carbon (TOC) and total suspended solids (TSS) in seawater recorded from the four stations were similar during both spring and summer 2019 sessions, and typical for offshore waters during the respective season.

20. In conclusion, the results of the two water quality sessions made in spring and summer 2019 at the site off Mellieha Bay used by AJD Tuna Ltd and Malta Mariculture Ltd for tuna penning activities show, overall, that values of the monitored attributes were generally within a range that would be expected of local offshore waters, and no appreciable differences in values were noted amongst the four sampling stations, including the 'up-current' and 'down-current' stations. However, some oil slicks and foam were recorded on the sea surface during the summer 2019 survey, which coincides with the peak of the tuna penning season; such patches were dispersed and recorded close to the boundary line of the tuna farms, in the vicinity of the western station. It appears that during the peak of the tuna farming, as has been reported in the past, there is the possibility of release of oil slicks that originate from the feed fish (mackerel, sardines etc.), although in the present case, when detected during the summer 2019 monitoring session, these were not appreciable large. Therefore, although that the findings of the present water quality monitoring session indicate that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna farming activities have not resulted in appreciable alteration of water quality in terms of the monitored attributes, every effort should be made by the tuna farm operators to reduce the introduction of feed fish oils to the marine environment. If feed fish oils are released, these should be retained within the confines of the cages and collected using skimmers and / or other appropriate equipment. Any feed fish oils released to the marine environment, should not be allowed to be transported by water movement beyond the confines of the tuna farm.

Video survey

21. The results of the video survey undertaken in both May / June 2019 and September 2019 sessions indicated similar physical and biological characteristics of the seabed below the seven tuna pens surveyed, when compared to those at the reference sites. Furthermore, the physical and biological characteristics of the seabed below the seven tuna pens and at the two reference sites are similar to those indicated by Borg (2017; 2018) in his reports of video surveys of the seabed made in the same area in 2017 and in 2018 prior to initiation of the tuna penning activities in the area. Some anthropogenic items, including ones originating from the tuna farming activities, were present under the tuna pens, which arguably may be viewed as contributing to some alteration of the physical characteristics of the seabed at the tuna penning sites.

22. During the survey held in May / June 2019, no fish bones or remains of tuna were recorded from below the tuna pens and reference sites, however, a single bone (vertebra) which may have originated from a tuna individual was recorded from below one of Malta Mariculture Ltd's tuna cages. A few uneaten feed-fish (around four individuals were counted in all) were present on the seabed below one of Malta Mariculture Ltd's tuna cages, but none were present on the seabed below the other cages or at the reference sites. During the survey held in September 2019, a dead tuna carcass was recorded on the seabed from under one of Malta Mariculture Ltd's tuna cages, and an appreciable amount of uneaten feed fish were recorded on the seabed under one of AJD Tuna Ltd's tuna cages. However, the tuna carcass was retrieved by the operator, as were most of the uneaten feed fish that were accidentally released below one of the tuna cages.

23. Overall, the findings from the May / June and September 2019 surveys indicate that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning activities have not resulted in appreciable alteration of the biological characteristics of the seabed at the sites used by the two companies. To mitigate potential adverse impact of the tuna penning activities on the seabed at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites, the same recommendations stated in Borg & Agius (2019c; 2019d) are emphasized; namely: (i) feeding of the tuna should be carefully monitored and stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten food ending up on the bottom; (ii) in the case of accident, should an inordinate amount of dead uneaten feed-fish end up on the bottom, these should be picked up by divers and disposed; (iii) any anthropogenic items that end up on the seabed in the vicinity of the tuna pens should be removed by divers.

4. REFERENCES

Borg J. A. (2017). Report on a video survey of benthic habitats in an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, made in May 2017. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. (2018). Report on an ecological assessment of an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, undertaken as part of the Environment

Impact Assessment in connection with PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. & Agius A. (2019a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off the northeastern coast of Malta. Report of a water quality survey at the tuna penning site used by AJD Tuna Ltd and Malta Mariculture Ltd off the north east coast of Malta, made in March 2019. Malta; Ecoserv Ltd., unpublished report, 29pp.

Borg J. A. & Agius A. (2019b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off the northeastern coast of Malta. Report of a water quality survey at the tuna penning site used by AJD Tuna Ltd and Malta Mariculture Ltd off the north east coast of Malta, made in September 2019. Malta; Ecoserv Ltd., unpublished report, 36pp.

Borg J. A. & Agius A. (2019c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in April and May 2019 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 13pp.

Borg J. A. & Agius A. (2019c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in September 2019 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 16pp.

Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site

Integrated assessment of monitoring of water quality and video surveys undertaken in 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay

Prepared by

JOSEPH A. BORG
BSc MSc PhD (Plymouth) FIBMS FMBA FRSB CBiol

FOR

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

ECOSERV'S REPORT REFERENCE: 023-21

FEBRUARY 2020

1. INTRODUCTION

1. An environmental monitoring program is required as part of the environmental permit (EP) for tuna penning operations carried out by AJD Tuna Ltd and Malta Mariculture Ltd at their tuna farm sites off Mellieha Bay. Ecoserv submitted a proposal for such environmental monitoring, which was subsequently approved by the Environmental Resources Authority (ERA).

2. The proposal by Ecoserv, bearing reference P-tuna-farming-monitoring_revised_082018, refers to collection of water samples from the four (4) monitoring stations from a depth of approximately 0.5 - 1 m. Additionally, the water quality survey includes *in situ* measurement of dissolved oxygen (DO), salinity, temperature and turbidity, at the same stations using a multi parameter meter. Measurement of current speed and direction also form part of the monitoring proposal. Two water quality sessions will be undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

3. Ecoserv's proposal also refers to a video survey using a remotely operated vehicle (ROV) that will be undertaken below a select number of fish cages to assess the following:

   - Level of uneaten feed accumulating on the seabed;
   - Species diversity and abundance of megafauna;
   - Marine litter; and
   - Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

   The video survey will be undertaken using a remotely operateed vehicle (ROV) that will be navigated below, as much as possible, a select number of tuna cages at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay; the video footage will later be analysed in the laboratory. Ecoserv proposed that the video footage of the seabed will be collected in the vicinity of eight cages; four cages at each of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites. The cages selected for monitoring during the video survey will be chosen at random in the field by the scientists carrying out the work on the day of monitoring but the selected cages will be as distant from each other as possible to allow for representative assessment. Video footage of the seabed will also be collected from each of four stations located at a distance from AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites, where the bottom may support a habitat of high ecological importance; namely soft bottom / maerl habitat located west, north and east of the site, as well as at 'Is-Sikka l-Bajda' located south of the site. The advantages of a video survey of the seabed in the vicinity of the tuna pens and at reference sites are that: (i) the results of the monitoring will be available within a few weeks and will clearly indicate the state of the seabed in the vicinity of the cages; (ii) the main output – the video footage – is in itself illustrative and will readily, clearly, and visually, show any change/adverse impact of the tuna farming activities on the seabed, including to the operators; and (iii) the video footage may also be readily used by the ERA to effectively illustrate and inform planners, policy makers, politicians and the general public of the situation of the seabed below the cages. Ecoserv's proposal also indicates that, based on the outcome from the video surveys, in the eventuality that the findings indicate large changes in physical and biological characteristics of the seabed following the tuna penning activities, then the ERA would reserve the right to request a quantitative study to assess, in greater detail, any alterations to the benthic habitat. This would be done through quantitative assessment of sediment quality and benthic assemblages, as per the related component indicated in the ERA's ToR. Such

strategy will also serve as incentive for the operators to ensure proper management of the tuna farm activities and avoid potential adverse impacts on the seabed, as well as avoiding additional monitoring and associated high cost. Two video survey sessions will be undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

4. Finally, the obligations set out in the permit also refer to an integrated assessment of the environmental monitoring undertaken during any one year, which is the subject of the present submission. The present document comprises Ecoserv's report of integrated assessment of the findings from the water quality monitoring and video survey sessions undertaken in spring and autumn 2020 in the vicinity of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay (northeastern coast of Malta).

2. METHODOLOGY AND RESULTS

Water quality

5. Fieldwork in relation to the spring and autumn 2020 water quality sessions was undertaken in May 2020 and October 2020 respectively. The day of holding of the survey was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. In situ measurements and collection of seawater samples were made at a total of four stations.

6. To view the methodological details and results of the *in situ* measurements and laboratory analyses, the reader is referred to Borg and Agius (2020a; 2020b).

7. The results of measurement of sea current speed and direction made in May 2020 indicated that the sea current direction on the day of sampling was SE, and the current speed ranged between 0.089 ms^{-1} and 0.100 ms^{-1}; hence Station A served as the 'up-current station' and Station D served as the 'down-current station'. The results of measurement of sea current speed and direction made in October 2020 indicated that the sea current direction on the day of sampling was SSE, and the current speed ranged between 0.106 ms^{-1} and 0.100 ms^{-1}; hence Station A served as the 'up-current station' and Station D served as the 'down-current station'.

8. No floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the surface in the study area during both the May and October 2020 sessions. Due to the COVID-19 pandemic, it was not possible to take aerial photos of the study area during the May 2020 session. The observations from the October 2020 session were corroborated by aerial photographs of the survey area which indicated the absence of floating material including floating oily substances (commonly referred to as 'sea slime'). The aerial photos also indicated that all of AJD Tuna Ltd's and Malta Mariculture Ltd's cages held tuna at the time of holding of the October 2020 session.

9. During both the May 2020 and October 2020 sessions, differences in temperature, salinity, dissolved oxygen, turbidity levels and Secchi Depth amongst the four stations were small and, overall, levels of these attributes are considered typical for offshore waters during spring.

10. During the May 2020 session, results for TOC and TSS indicated low levels of these attributes at all four stations. Mean values of TSS varied between 2.90 mg/L at station A and 4.00 mg/L at Station B. Mean values for TOC ranged from 0.92 mg/l at Station C and 1.00 mg/L at Station B. In comparison to the previous session held in September 2019, TSS levels recorded from the May 2020 survey were slightly higher, overall, whereas levels of TOC were slightly lower. During the October 2020 session, mean values for TSS varied between 2.50 mg/L at stations B and C and 3.80 mg/L at Station A, while mean values for TOC ranged from 0.83 mg/l at Station C and 0.85 mg/L at Stations A and D. These values for the October 2020 session indicated that differences in levels of these two attributes amongst the monitoring stations were not appreciable, while the recorded levels were similar or lower compared to those recorded from the previous May 2020 survey.

11. During the May 2020 session, values of pH recorded from the four stations were between 8.27 at Stations C and D, and 8.29 at Stations A and B; such values are within the typical range for offshore waters. Chlorophyll *a* was not recorded above the detection limit of 0.3 µg/L at any of the four stations. The recorded levels of total nitrogen were lower compared to the previous session held in September 2019. During the previous session, values for total nitrogen ranged between 16.80 µg/l at Station D and 12.50 µg/l at Station A. During the May 2020 session, the recorded levels of total nitrogen were between 0.60 µg/L at Station C, and 1.20 µg/L at Station A. Levels of total phosphorous recorded during the previous September 2019 session ranged between 3.05 µg/l at station A and 2.58 µg/l at Station C. Levels of total phosphorous recorded during the May 2020 session were higher, ranging between 36.85 µg/l at Station D and 44.60 µg/l at Station A. However, a trend of decreasing total phosphorous levels on going form Station A to Station D was noted, which ran counter to the recorded current direction on the day and indicated that the observed high levels were probably not due to the tuna farming activities. During the October 2020 session, values of pH recorded from the four stations were between 8.18 at Station A and 8.22 at Stations B and C; such values were deemed to be within the typical range for offshore waters. Chlorophyll *a* was recorded at low levels of between 0.2 µg/L at Stations A and B, and 0.39 µg/L at Station C. The recorded levels for total nitrogen were 0.90 µg/L at all four stations, which is similar to the levels reported from the previous May 2020 session, where the recorded levels were between 0.60 µg/L and 1.20 µg/L. Levels of total phosphorous recorded during the October 2020 session ranged between 1.25 µg/L at Station D, and 4.05 µg/L at Station B. These levels were lower than those recorded from the previous May 2020 session, when values ranged between 36.85 µg/L and 44.60 µg/L.

12. The conclusions reached for the May 2020 session were that the results of the water quality monitoring survey showed that values of the monitored attributes were generally within a range that would be expected of local pristine offshore waters, except for levels of total phosphorous, which appear to be elevated but for which no explanation can be readily made. No large differences in levels of the monitored physico-chemical parameters were noted amongst the four stations, including the 'up-current' station (Station A) and 'down-current' station (Station D). The conclusions reached for the October 2020 session were that the results of the water quality monitoring survey showed that values of the monitored attributes were generally within a range that would be expected of local pristine offshore waters. No appreciable differences in levels of the monitored physico-chemical parameters were noted amongst the four stations, including the 'up-current' station (Station A) and 'down-current' station (Station D).

Video survey

13. Fieldwork in relation to the spring and autumn 2020 video surveys was undertaken in April and September 2020 respectively. The day on which the survey was held was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Video footage of the seabed was collected using an ROV deployed from an 11 m vessel. During fieldwork, the ROV was deployed adjacent a tuna pen at a given compass cardinal point and lowered to the seabed there. The ROV was then manoeuvred to the other side of the tuna pen, i.e. towards the opposite compass cardinal point, while collecting video footage of the seabed. Video imagery from the ROV was recorded by the unit's HDI camera and saved on a laptop's hard disc on board the vessel during deployment. In April 2020, video footage was recorded from below a total of eight tuna pens – four cages belonging to AJD Tuna Ltd (AJD Cage 3, AJD Cage 5, AJD Cage 15 and AJD Cage 18) and four belonging to Malta Mariculture Ltd (MML Cage 7, MML Cage 10, MML Cage 20 and MML Cage 23), as well as at four reference sites (NW reference, NE reference, SE reference and SW reference). In September 2020, video footage of the seabed was again recorded from below a total of eight tuna pens - four cages belonging to AJD Tuna Ltd (AJD Cage 2, AJD Cage 6, AJD Cage 13 and AJD Cage 17) and four belonging to Malta Mariculture Ltd (MML Cage 7, MML Cage 10, MML Cage 20 and MML Cage 22), as well as at four reference sites (N reference, E reference, S reference and W reference).

14. The 'uneaten food index' designed by Borg & Schembri to enable comparison of the relative amounts of dead fish present under the pens (see Holmer et al, 2008) was used in the present assessment to quantify the amount of uneaten feed fish present on the seabed below a tuna pen, if applicable. The index, which ranges between 0 and 4, is described in Table 1.

Table 1.

The 'uneaten food index' devised by Borg & Schembri (see Holmer et al., 2008) for the purpose of quantifying and comparing the amount of dead uneaten feed-fish under the different tuna-pens.

Index value	Description
0	No uneaten fish present
1	< 1 uneaten fish present per m^2 of seabed
2	> 1 uneaten fish present per m^2 of seabed, but the fish do not form a continuous layer covering the seabed
3	> 1 uneaten fish present per m^2 of seabed. Fish form a single, uninterrupted layer within at least a $1m^2$ area on the seabed.
4	> 1 uneaten fish present per m^2 of seabed. Fish form two or more uninterrupted layers on top of each other within at least a $1m^2$ area on the seabed.

15. To view the full methodological details and results of the video surveys, the reader is referred to Borg and Agius (2020c; 2020d).

16. The results of the April 2020 and September 2020 surveys have been presented as video footage showing the state of the seabed at the tuna pens and reference sites surveyed, appended to the respective report. During the April 2020 survey, only AJD Tuna Ltd's Cages 3 and 5 held tuna, while none of Malta Mariculture Ltd's cages held tuna. During the September 2020 survey, most of AJD Tuna Ltd's and Mariculture Ltd's cages held tuna.

17. The results of the April 2020 survey indicated the following:
    - In terms of physical characteristics, the bottom below the eight tuna pens and three of the reference sites (NE reference, NW reference and SE reference) consisted predominantly of coarse mobile sediments, namely coarse sand and rhodoliths[1], while at the Sikka l'Bajda reference site, the bottom comprised a mosaic with patches of seagrass *Posidonia oceanica* growing on soft sediment and photophilic algae growing on bedrock that characterises this reef area. The underwater visibility was good and ranged around 20 m – 25 m. Water depth was between 50 m (Malta Mariculture Ltd's site) and 53 m (AJD Tuna Ltd's site) below the tuna pens, 57 m at the NE reference site, 62 m at the NW reference site, 54 m at the SE reference site and 18 m at the SW Sikka il-Bajda reference site. A number of anthropogenic items were recorded on the seabed below the tuna pens, some of which, namely short lengths of rope and small concrete weights with ropes attached appear to have originated from the tuna farming activities. No remains of tuna or feed fish were recorded from below the tuna pens or at the four reference sites.

    - The biological characteristics recorded from below the eight tuna pens and three reference sites indicated the presence of benthic assemblages and habitat types that are typical of the area; the seabed below the eight tuna pens and three of the reference sites (NE reference, NW reference and SE reference) mainly supported Sublittoral Sediment (EUNIS code A5), of which the predominant assemblage type was an association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515). In places, the sediment bottom supporting this assemblage type had accumulations of rhodoliths, such that, where present, their cover was some 1 – 20%. Where the coarse sediment was appreciably consolidated, it supported sparse stands of the alga *Flabellia petiolata* and other unidentified algae. The megafauna recorded from this assemblage type comprised the Heart Urchin *Spatangus purpureus*, the Long Spined Urchin *Centrostephanus longispinus* and the Red Lance Urchin *Stylocidaris affinis*, all of which were present in a high density in places. The recorded high density of these megafaunal species was attributed to organic enrichment of the seabed underneath the tuna pens as a result of input of waste from the tuna penning activities. The organic matter serves as food for macro- and megafaunal species, supporting a high density of the organisms. The seabed at the Sikka l'Bajda reference site supported a mosaic with patches of the biocenosis of *Posidonia oceanica* meadows (EUNIS code A5.535) and the biocoenosis of infralittoral algae (EUNIS code A3.131). The seagrass *Posidonia oceanica* appeared to be in a good state and unimpacted by the tuna penning activities. The demersal fish fauna and pelagic fish fauna swimming close to the tuna cages were typical of that which occurs in local offshore coastal waters and mainly comprised individuals of Comber *Serranus cabrilla* and Rainbow Wrasse *Coris julis*. Large shoals of Bogue *Boops boops* were recorded below some of the tuna pens.

- It was concluded that the results of the April 2020 video survey indicated similar physical and biological characteristics of the seabed below the eight tuna pens when compared to those at the reference sites, and were also similar to those recorded from the previous video surveys held in 2019. Furthermore, the physical and biological characteristics of the seabed below the eight tuna pens and at the three reference sites (NE reference site, NW reference site and SE reference site) were similar to those indicated in reports of video surveys of the seabed made in the same area in 2017 and in 2018 prior to initiation of the tuna penning activities in the area. In terms of biological characteristics, the recorded megafaunal species were the same ones that occur in association with the same habitat type (association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents) in pristine offshore waters at a similar depth range. Therefore, the findings from the April 2020 survey indicated that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning activities have not resulted in appreciable alteration of the biological characteristics of the seabed at the sites used by the two companies.

18. The results of the September 2020 survey indicated the following:

- In terms of physical characteristics, the findings were similar to those from the April 2020 survey; namely, the bottom below the eight tuna pens and at three of the reference sites (N reference, E reference and S reference) consisted predominantly of coarse mobile sediments, namely coarse sand and rhodoliths[1], while at the Sikka l'Bajda reference site (W reference) the bottom comprised a mosaic with patches of seagrass *Posidonia oceanica* growing on soft sediment and photophilic algae growing on bedrock that characterises this reef area. The underwater visibility was good and ranged around 25 m – 30 m. Water depth was between 50 m (Malta Mariculture Ltd's site) and 55 m (AJD Tuna Ltd's site) below the tuna pens, 56 m at the N reference site, 61 m at the E reference site, 54 m at the S reference site and 17 m at the SW Sikka il-Bajda (W) reference site. These observations were also similar to those made during the previous three video surveys, however, the presence of feed fish, albeit not in large quantities, under some of the tuna pens, particularly below those at Malta Mariculture Ltd's tuna penning site, as well as the presence of white patches that in most places were associated with what appeared to be the remains of fish in a very advanced stage of decomposition, indicated some alteration of the physical characteristics of the seabed below some of the tuna pens. Several anthropogenic items were recorded on the seabed; these included ones (such as short lengths of rope and small concrete weights with ropes attached) that seem to have originated from the tuna farming activities. Two tuna carcasses (one of which appeared to be in a very advanced state of decomposition) were recorded on the seabed below AJD Tuna Ltd's Tuna Pen 2, and another carcass was present below Tuna Pen 13 at the same (AJD Tuna Ltd's) site. However, this finding was reported to the site manager who took immediate action by having SCUBA divers retrieve one of the carcasses from below Tuna Pen 2 and that present below Tuna Pen 13. Feed fish, in different states of decomposition, were recorded in places below some of the tuna pens, however, no feed fish were recorded at any of the four reference sites.

- In terms of biological characteristics, again, the findings were similar to those from the April 2020 survey; namely, the seabed below the eight tuna pens and at three of the reference sites (N reference, E reference and S reference) mainly supported Sublittoral Sediment (EUNIS code A5), of which the predominant assemblage type was an association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515). In places, the sediment bottom supporting this assemblage type had

accumulations of rhodoliths such that, where present, their cover was some 1 – 20%. Where the coarse sediment was appreciably consolidated it supported sparse stands of the alga *Flabellia petiolata* and other unidentified algae. The megafauna recorded from this assemblage type comprised the Heart Urchin *Spatangus purpureus*, the Long Spined Urchin *Centrostephanus longispinus*, the Red Lance Urchin *Stylocidaris affinis* and the crinoid *Antedon mediterranea*. Of these, the Long Spined Urchin *Centrostephanus longispinus* was present in a high density in places. Other megafauna recorded during the survey included the seastar *Echinaster sepositus* and the sea slug *Aplysia fasciata*.

- The demersal fish and pelagic fish fauna swimming close to the seabed and in the vicinity of the tuna cages, respectively, were typical of those that occur in local offshore coastal waters and mainly comprised numerous individuals of an unidentified Goby Gobiidae sp., individuals of the Comber *Serranus cabrilla*, of Bream *Diplodus* spp. and of the Rainbow Wrasse *Coris julis*, as well as large shoals of Bogue *Boops boops* and of Blotched Picarel *Spicara maena*, and shoals of Amberjack *Seriola dumerilii*. Individuals of the Common Stingray *Dasyatis pastinaca* were recorded swimming close to the seabed under some of the tuna cages; some of the individuals were noted consuming feed fish. This species was therefore evidently scavenging on the seabed for uneaten feed fish, while the numerous individuals of the unidentified Goby would also be scavenging pieces originating from the feed fish. Several individuals of Atlantic Blue Fin Tuna *Thunnus thynnus* were recorded swimming in the vicinity of AJD Tuna Ltd's Tuna Pen 6. It would seem that the ABFT are attracted to tuna pens by the presence of individuals of the same species held in the pens and by the uneaten feed fish that pass through the tuna cage mesh and are carried away from the pens by sea currents.

4. APPRAISAL

Water quality

19. Differences in values of temperature, salinity, dissolved oxygen, turbidity levels and Secchi Depth amongst the four water quality monitoring stations, recorded in spring and autumn 2020, were small and typical for offshore waters during the respective season.

20. No floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the sea surface during both spring and autumn 2020 sessions.

21. The results for pH, total nitrogen, Chlorophyll *a,* total organic carbon (TOC) and total suspended solids (TSS) in seawater recorded from the four stations were similar during the spring 2020 session and considered to be not elevated, overall, but TSS levels were slightly higher when compared to values recorded from the previous September 2019 session. However, during the spring session, levels of total phosphorous were higher overall than the previous sessions held in 2019, while a trend of decreasing total phosphorous levels on going form Station A to Station D was noted, which ran counter to the recorded current direction on the day. This would seem to indicate that the observed high levels were probably not due to the tuna farming activities but to some other unexplained source. This notion is strengthened by the observation that the recorded phosphorous levels were much higher in Spring 2020 compared to levels that are

usually recorded during the autumn session when tuna penning activities are at a peak. Furthermore, levels of total nitrogen recorded during the Spring 2020 session were not elevated. One would expect that if the source of pollution is tuna penning, then levels of both phosphorous and nitrogen would be elevated. One possible source of the elevated total phosphorous levels is some vessel that was cruising by (not necessarily very close to the NAS) at the time when the water samples were being collected. In such a case, discharge of grey water containing phosphates could very well be the source. However, this notion is speculative.

22. The results for levels for TSS and TOC recorded during the October 2020 session indicated that differences in values of these two attributes amongst the monitoring stations were not appreciable, while the recorded levels were similar or lower compared to those recorded from the previous May 2020 survey. The results for pH, Total Nitrogen, Total Phosphorous, Chlorophyll *a,* total organic carbon (TOC) and total suspended solids (TSS) in seawater recorded from the four stations were similar during the October 2020 session, while the recorded levels were similar or lower compared to those recorded from the previous May 2020 survey.

23. In conclusion, the results of the two water quality sessions made in spring and autumn 2020 at the site off Mellieha Bay used by AJD Tuna Ltd and Malta Mariculture Ltd for tuna penning activities show that, except for levels of total phosphorous, values of the monitored attributes were generally within a range that would be expected of local offshore waters and not deemed elevated, while no appreciable differences in values were noted amongst the four sampling stations, including the 'up-current' and 'down-current' stations. The anomalous elevated levels of total phosphorous that were recorded during the May session, may not necessarily be attributed to the tuna penning activities, but this observation merits further attention. In this regard, following consultation with the ERA, addition of two sampling stations for water quality monitoring to the current sampling design is proposed. Each of the two additional stations should be located some 500 m from the NAS, one at each extreme end of the latter, depending on the current direction. The results of water quality monitoring at such stations should help interpretation of potential elevated levels of one or more of the monitored parameters (as has been recorded for phosphorous during the spring 2020 session). The proposed revised layout of the water quality monitoring stations is presented in the appendix that accompanies the present report.

24. In terms of cumulative impacts; the results of water quality monitoring undertaken during 2020 indicate the absence of appreciable cumulative effects. Notwithstanding this and the overall conclusions reached in the present assessment, every effort should be made by the tuna farm operators to reduce the introduction of potential pollutants, including feed fish oils, to the marine environment. If feed fish oils are released, these should be retained within the confines of the cages and collected using skimmers and / or other appropriate equipment. Any feed fish oils released to the marine environment, should not be allowed to be transported by water movement beyond the confines of the tuna farm.

Video survey

25. During the survey held in April 2020, no remains of tuna or feed fish were recorded from below the tuna pens or at the four reference sites. However, a number of anthropogenic items were recorded on the seabed below the tuna pens, some of which, namely short lengths of rope and

small concrete weights with ropes attached, appear to have originated from the tuna farming activities. During the survey held in September 2020, small numbers of feed fish were present under some of the tuna pens, particularly below cages at Malta Mariculture Ltd's tuna penning site. In places, white patches that seemed to be associated with what appeared to be the remains of fish in a very advanced stage of decomposition, were also noted. Two tuna carcasses (one of which appeared to be in a very advanced state of decomposition) were recorded on the seabed below AJD Tuna Ltd's Tuna Pen 2, and another carcass was present below Tuna Pen 13 at the same (AJD Tuna Ltd's) site. Immediate reporting of these findings to the site manager led to prompt action whereby SCUBA divers retrieved the concerned carcasses, where this was possible. Feed fish, in different states of decomposition, were recorded in places below some of the tuna pens, however, no feed fish were recorded at any of the four reference sites. Several anthropogenic items were recorded on the seabed, which included ones that seem to have originated from the tuna farming activities.

26. In terms of biological characteristics, the findings from the April 2020 video survey indicated similar features of the seabed below the tuna pens when compared to the reference sites that had the same bottom type. However, some of the recorded megafaunal species were present in an unusually high density; this can be attributed to organic enrichment of the seabed underneath the tuna cages as a result of input of waste from the tuna penning activities. The organic matter serves as food for macro- and megafaunal species, supporting a high density of the organisms. The findings from the September 2020 video survey also indicated similar features of the seabed below the tuna pens when compared to the reference sites that had the same bottom type, while some of the recorded megafaunal species were again present in a high density. Again, this may be attributed to organic enrichment of the seabed underneath the tuna cages resulting from input of waste, including uneaten feed fish originating from the tuna penning activities. Uneaten feed fish were serving to attract benthic and demersal scavengers, such as Stingrays, which could be seen feeding on the baitfish. Furthermore, the uneaten feed fish that passed through the cage net seemed to attract individuals of Atlantic Blue Fin Tuna (ABT) *Thunnus* thynnus, which were seen swimming in the vicinity of some of the tuna pens.

27. In conclusion, the findings from the April 2020 and September 2020 surveys indicate that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning activities may be seen as resulting in small alterations to the biological characteristics of the seabed at the sites used by the two companies; these mainly consisted of unusually high densities of scavenger invertebrates and fishes, as well as wild ABT, that are attracted to the sites by the presence of waste, including uneaten feed fish, originating from the tuna farming activities. The anthropogenic items that originated from the tuna farming activities, and which were detected on the seabed under the surveyed tuna pens, may also be viewed as contributing to some alteration of the physical characteristics of the seabed at the tuna penning sites. However, given that the alterations are not large, while they are also reversible, the reported changes to benthic environment at the tuna penning sites are not deemed concerning. Furthermore, in terms of cumulative impacts on the physical and biological characteristics of the seabed, the results of the video surveys undertaken during 2020 indicate no appreciable cumulative effects. This is especially so since observations from video survey held in spring in 2020 and 2019 showed that the fallow period practiced by the tuna operators during January to March / April of each year (when there are no tuna penning activities or these are at a minimum) serves to allow natural recovery of the benthic environment to a state which is similar to that at pristine sites having the same environmental characteristics.

28. Notwithstanding the above conclusion, to mitigate potential alterations to the physical and biological characteristics of the seabed at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites, and avoid potential cumulative effects on the physical and biological characteristics of the seabed resulting from the tuna penning activities, the same recommendations stated in Borg & Agius (2020c; 2020d) are again emphasized here; namely: (i) feeding of the tuna should be carefully monitored and stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten food ending up on the bottom; (ii) in the case of accident, should an inordinate amount of dead uneaten feed-fish end up on the bottom, these should be picked up by divers and disposed; (iii) any anthropogenic items that end up on the seabed in the vicinity of the tuna pens should be removed by divers.

4. REFERENCES

Borg J. A. (2017). Report on a video survey of benthic habitats in an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, made in May 2017. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. (2018). Report on an ecological assessment of an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, undertaken as part of the Environment Impact Assessment in connection with PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. & Agius A. (2020a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 34pp.

Borg J. A. & Agius A. (2020b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in October 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 36pp.

Borg J. A. & Agius A. (2020c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in April 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 22pp.

Borg J. A. & Agius A. (2020d). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in September 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 23pp.

Holmer M., Hansen P. K., Karakassis I., Borg J. A. & Schembri P. J., 2008. Monitoring of Environmental Impacts of Marine Aquaculture. In: Holmer M., Black K., Duarte C., Marba N., & Karakassis I. (editors) Aquaculture in the Ecosystem; pp. 47-85. Heidelberg, Germany: Springer; 326pp.

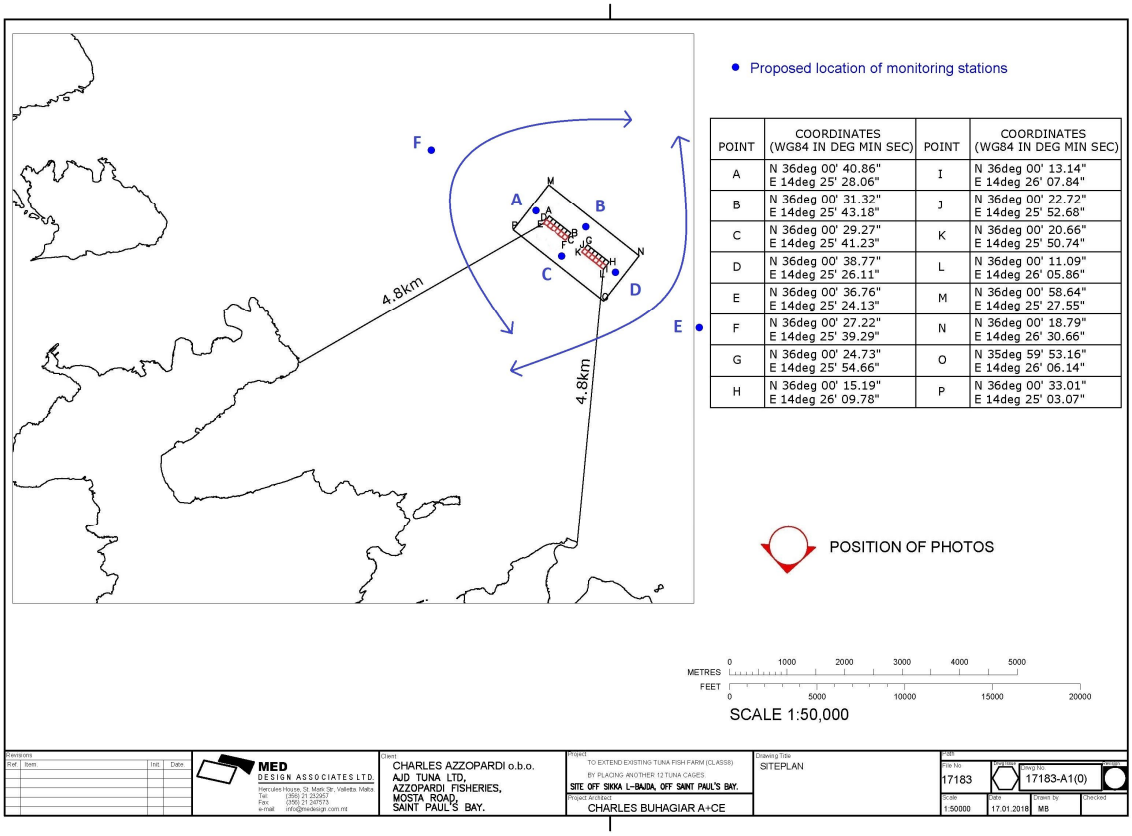
APPENDIX

Environmental monitoring of tuna farming activities

Revision of water quality sampling design in relation to P-tuna-farming-monitoring_revised_082018 (Proposal for regular environmental monitoring of tuna farming activities at offshore sites)

The present revision of the sampling design in relation to monitoring of water quality at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay, is being made following agreement with the Environment and Resources Authority (ERA). The recommendation, which was agreed on by the ERA and the present consultant, is to add a further two sampling stations to the four stations that have been used in water quality monitoring sessions held in 2019 and 2020.

It is proposed that the locations of the two water quality monitoring stations (E and F in Figure 1) will tentatively be as indicated in Figure 1. However, the actual locations will be determined on the day of holding on the water quality survey, depending on the sea current direction, such that one of the stations will be 'up-current' and the other 'down-current'; i.e. the locations of the two stations can be anywhere along a semi-circle drawn north to south for each station.



POINT	COORDINATES (WG84 IN DEG MIN SEC)	POINT	COORDINATES (WG84 IN DEG MIN SEC)
A	N 36deg 00' 40.86" E 14deg 25' 28.06"	I	N 36deg 00' 13.14" E 14deg 26' 07.84"
B	N 36deg 00' 31.32" E 14deg 25' 43.18"	J	N 36deg 00' 22.72" E 14deg 25' 52.68"
C	N 36deg 00' 29.27" E 14deg 25' 41.23"	K	N 36deg 00' 20.66" E 14deg 25' 50.74"
D	N 36deg 00' 38.77" E 14deg 25' 26.11"	L	N 36deg 00' 11.09" E 14deg 26' 05.86"
E	N 36deg 00' 36.76" E 14deg 25' 24.13"	M	N 36deg 00' 58.64" E 14deg 25' 27.55"
F	N 36deg 00' 27.22" E 14deg 25' 39.29"	N	N 36deg 00' 18.79" E 14deg 26' 30.66"
G	N 36deg 00' 24.73" E 14deg 25' 54.66"	O	N 35deg 59' 53.16" E 14deg 26' 06.14"
H	N 36deg 00' 15.19" E 14deg 26' 09.78"	P	N 36deg 00' 33.01" E 14deg 25' 03.07"

Figure 1. Map showing the location of AJD Tuna and MML's tuna penning sites off Mellieha Bay. The locations of the four stations A - D that have been used to monitor water quality during 2019 and 2020 are indicated. The new additional two sampling stations (E and F) are also indicated, however, it should be noted that their locations are not fixed but will be determined on the day of sampling, depending on the sea current direction (see main text in the present document). Base map source: ADI Associates Environmental Consultants.

In situ measurements and collection of seawater samples for later laboratory analyses, will be carried out at the same frequency and considering the same parameters as for the other four stations (A – D), and as detailed in the approved proposal for environmental monitoring.

Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site

Integrated assessment of monitoring of water quality and video surveys undertaken in 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay

Prepared by

JOSEPH A. BORG
BSc MSc PhD (Plymouth) FIBMS FMBA FRSB CBiol

FOR

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

ECOSERV'S REPORT REFERENCE: 047-22

MAY 2022

1. INTRODUCTION

1. An environmental monitoring program is required as part of the environmental permit (EP) for tuna penning operations carried out by AJD Tuna Ltd and Malta Mariculture Ltd at their tuna farm site off Mellieha Bay (hereafter North Aquaculture Site; NAS). Ecoserv submitted a proposal for such environmental monitoring, which was subsequently approved by the Environmental Resources Authority (ERA).

2. The proposal by Ecoserv, bearing reference P-tuna-farming-monitoring_revised_082018 (See Annex 1), refers to collection of water samples from the four (4) monitoring stations from a depth of approximately 0.5 - 1 m. Additionally, the water quality survey includes *in situ* measurement of dissolved oxygen (DO), salinity, temperature and turbidity, at the same stations using a multi parameter meter. Measurement of current speed and direction also form part of the monitoring proposal. As of 2021, the ERA and the present consultant agreed to add a further two sampling stations to the four stations that have been used in water quality monitoring sessions held in 2019 and 2020; such revision of the sampling plan is given in Annex 2. Two water quality sessions will be undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

3. With respect to monitoring of the seabed using underwater videography, Ecoserv's proposal refers to a video survey using a remotely operated vehicle (ROV) that will be undertaken below a select number of fish cages to assess the following:

   - Level of uneaten feed accumulating on the seabed;
   - Species diversity and abundance of megafauna;
   - Marine litter; and
   - Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

   The ROV will be navigated below a select number of tuna cages at the NAS; this will enable collection of the necessary video footage, which will be later analysed in the laboratory. It was proposed that video footage of the seabed will be collected in the vicinity of eight cages (4 cages at each of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites) at the SAZ. The tuna cages selected for monitoring using video footage collected by an ROV will be chosen at random by the scientists on the day of monitoring, but the selected cages will be as distant from each other as possible to allow for representative assessment. Video footage of the seabed will also be collected at stations located at a distance from the NAS but where the bottom may support a habitat of high ecological importance; e.g. seagrass *Posidonia oceanica* habitat present at Sikka l-Bajda located south of the NAS. Ecoserv's proposal (see Annex 1) gives further details of the advantages and uses of the outcomes from such video survey.

4. Finally, the obligations set out in the permit also refer to an integrated assessment of the environmental monitoring undertaken during any one year. The present document comprises Ecoserv's report of integrated assessment of the findings from the water quality monitoring and video survey sessions undertaken in spring and autumn 2021 in the vicinity of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay (northeastern coast of Malta).

2. METHODOLOGY AND RESULTS

Water quality

5. Fieldwork in relation to the spring and autumn 2021 water quality sessions was undertaken in May and September, respectively. The day of holding of the survey was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. In situ measurements and collection of seawater samples were made at a total of six stations.

6. To view the methodological details and results of the *in situ* measurements and laboratory analyses, the reader is referred to Borg and Agius (2021a; 2022a). During the May 2021 session, the two farms between them had four cages with tuna, while during the September 2021 session, all cages belonging to the two farms held tuna (see Borg & Agius 2021a; 2022a).

7. The results of the May 2021 session indicated that the sea current direction on the day of sampling was southeast and the current speed ranged between 0.110 ms^{-1} and 0.102 ms^{-1}; hence Station E served as the 'up-current station' and Station F served as the 'down-current station'. The results of the September 2021 session indicated that on the day of sampling the sea current direction was west and the current speed ranged between 0.161 ms^{-1} and 0.150 ms^{-1}; hence once again Station E served as the 'up-current station' and Station F served as the 'down-current station'.

8. No floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the surface in the study area during both the May and September 2021 sessions. In both sessions, these observations were corroborated by aerial photos of the study area that were taken in June 2021 and September 2021, respectively, which indicated the absence of appreciable amounts of floating material, including floating oily substances (commonly referred to as 'sea slime'). During both the May and September 2021 sessions, values of pH, temperature, salinity, dissolved oxygen, turbidity levels and Secchi Depth amongst the four sampling stations were similar, and levels of these attributes were considered typical for offshore waters during the respective seasons.

9. During the May 2021 session, mean values for TSS varied between 0.45 mg/L at Station A, and 0.60 mg/L at Station F. Mean values for TOC ranged from 1.00 mg/l at Stations B and D and 1.25 mg/L at Station F. Chlorophyll *a* was not recorded above the method detection limit of 0.05 µg/L at stations A to D located in the immediate vicinity of the cages. At Stations E and F, located > 2 Km away northwest and southeast of the cages respectively, chlorophyll *a* was detected at low levels of 0.24 µg/L (Station E) and 0.35 µg/L (Station F). The recorded levels for total nitrogen and total phosphorous did not exceed the respective method detection limits of 1.40 µg/L and 0.30 µg/L at any of the six stations. The recorded differences in values of the considered parameters amongst the six stations were deemed not appreciable and typical of coastal offshore waters during spring.

10. During the September 2021 session, mean values for TSS varied between 0.40 mg/L at Stations A and B, and 0.60 mg/L at Stations E and E. Mean values for TOC ranged from 0.72 mg/l at Station F and 0.99 mg/L at Station D. Chlorophyll *a* was recorded at levels between 0.89 µg/L at Station F and 0.52 µg/L at Station A. The recorded levels for total nitrogen and total phosphorous did not exceed the respective method detection limits of 1.40 µg/L and 0.30 µg/L at any of the six stations.

The recorded differences in values of the aforementioned parameters amongst the six stations were deemed not appreciable and typical of coastal offshore waters during spring. With regard to the slightly elevated levels of Chlorophyll *a*; both reference stations E and F , which are located at a considerable distance from the farm sites, had the highest levels. Therefore, it was concluded that the recorded levels should not be attributed to the tuna penning activities but possibly to higher phytoplankton abundance in local coastal waters during summer.

11. The conclusions reached for both the May and September 2021 water quality monitoring sessions were that values of the monitored attributes were generally within a range that would be expected of local offshore waters, and that no appreciable differences in water quality were noted amongst the six monitored stations, including the 'down-current' and 'up-current' stations. Accordingly, it was concluded that that the tuna farming activities at the NAS had not resulted in appreciable alteration of water quality in terms of the monitored attributes.

Video survey

12. Fieldwork in relation to the spring and autumn 2021 video surveys was undertaken in May and October 2021 respectively. The day on which the survey was held was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Video footage of the seabed was collected using an ROV deployed from an 11 m vessel. During fieldwork, the ROV was deployed adjacent a tuna pen at a given compass cardinal point and lowered to the seabed there. The ROV was then manoeuvred to the other side of the tuna pen, i.e. towards the opposite compass cardinal point, while collecting video footage of the seabed. Video imagery from the ROV was recorded by the unit's HDI camera and saved on a laptop's hard disc on board the vessel during deployment. In both the May and October 2021 surveys, video footage was collected from below a total of eight tuna pens – four cages at each of the two tuna penning sites (AJD Tuna Ltd and Malta Mariculture Ltd) located within the NAS, and at four reference sites Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference. Following each session, the video record was analysed in the laboratory. Characterisation of the benthic assemblages was made using the scheme of Borg *et al*. (2013), which is based on the EUNIS typology that has been adapted for local use.

13. The 'uneaten food index' designed by Borg & Schembri to enable comparison of the relative amounts of dead fish present under the pens (see Holmer et al, 2008) was used in the assessments to quantify the amount of uneaten feed fish present on the seabed below a tuna pen, if applicable. The index, which ranges between 0 and 4, is described in Table 1.

14. The results of the two surveys held in 2021 have been presented as reports and annexed video footage showing the state of the seabed at the tuna pens and reference sites surveyed. To view further details of the methodology used during the ROV surveys and full details of the findings thereof, the reader is referred to Borg and Agius (2021b; 2022b).

15. During the May 2021 session, video footage was collected from the four reference sites (Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference) and from below the following cages:
    - AJD Tuna Ltd Cage 1, Cage 3, Cage 4 and Cage 16;
    - Malta Mariculture Ltd Cage 8, Cage 9, Cage 10 and Cage 22.

During the October 2021 session, video footage was collected from the four reference sites (Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference) and from below the following cages:
- AJD Tuna Ltd Cage 3, Cage 6, Cage 14 and Cage 17;
- Malta Mariculture Ltd Cage 7, Cage 8, Cage 9 and Cage 19.

Table 1.

The 'uneaten food index' devised by Borg & Schembri (see Holmer et al., 2008) for the purpose of quantifying and comparing the amount of dead uneaten feed-fish under the different tuna-pens.

Index value	Description
0	No uneaten fish present
1	< 1 uneaten fish present per m^2 of seabed
2	> 1 uneaten fish present per m^2 of seabed, but the fish do not form a continuous layer covering the seabed
3	> 1 uneaten fish present per m^2 of seabed. Fish form a single, uninterrupted layer within at least a $1m^2$ area on the seabed.
4	> 1 uneaten fish present per m^2 of seabed. Fish form two or more uninterrupted layers on top of each other within at least a $1m^2$ area on the seabed.

16. During the May 2021 survey, four cages between the two farms held tuna. During the October 2021 survey, all of AJD Tuna Ltd's and Mariculture Ltd's cages held tuna.

17. The results of the May 2021 survey indicated the following:

- During both the May and October 2021 sessions, the physical characteristics, including ones related to bottom type and water depth, recorded below the surveyed cages and at the four reference sites were similar to those recorded during the previous video surveys. The bottom below the eight tuna pens and at three of the reference sites (Northwest Reference, Northeast reference and Southeast reference) predominantly consisted of coarse mobile sediments, namely coarse sand. In places, the surface of the mobile sediment had conspicuous crests and troughs that were some 20 cm high, which most probably resulted from strong current action, although no significant sea currents were observed close to the bottom during the surveys. In places, the troughs of soft sediment had accumulations of rhodoliths[1], such that the latter had an overall percent cover of some 0 % - 20 %. At the SW Sikka l-Bajda reference site, the bottom comprised a mosaic with patches of seagrass *Posidonia oceanica* growing on soft sediment and photophilic algae growing on the bedrock that characterise this reef area.
- In May 2021, the underwater visibility was around 20 m – 25 m and in October 2021 it was around 20 m.

[1] Rhodoliths consist either of free-living calcareous rhodophytes (red algae), or else of an inner nucleus, such as stone or shell, encrusted by calcareous rhodophytes.

- During both the May and October 2021 sessions, several anthropogenic items were recorded on the seabed (see Borg & Agius, 2021b; 2022b), some of which (such as short lengths of rope with attached concrete weights, lengths of rope and of heavy chain), appeared to have originated from the tuna farming activities.
- During the May 2021 survey, two tuna carcasses were recorded on the seabed below Cage 8 at Malta Mariculture Ltd's site, and one tuna carcass was recorded below AJD Tuna Ltd's Cage 16. What appeared to be the skeleton of a tuna was recorded from below Malta Mariculture Ltd's Cage 8, and large bones that probably originated from dead tuna were recorded under some of the cages. During the October 2021 survey, three tuna carcasses in various stages of decomposition were recorded below AJD Tuna Ltd's Cage 17, two tuna carcasses (one of which was in an advanced stage of decomposition) and a tuna skeleton were recorded below Malta Mariculture Ltd's Cage 9; and two tuna carcasses were recorded below Malta Mariculture Ltd's Cage 19. In places, bones (e.g. vertebrae) that probably originated from dead tuna were present on the seabed underneath some of the cages. In both sessions, these findings were reported to the site manager so that action will be taken retrieve to retrieve the tuna carcasses that were not yet in an advanced state of decomposition.

- During the May 2021 survey, feed fish (uneaten feed index = 1) were only recorded underneath AJD Tuna Ltd's Cage 16. No feed fish or remains of dead tuna were recorded at any of the four reference sites. During the October 2021 session, feed fish were present below cages as follows:
  - A patch with variable density of feed fish (uneaten feed index = 1 – 2) recorded below AJD Tuna Ltd's Cage 3;
  - Patches with variable density of feed fish (uneaten feed index = 1 – 2) recorded below AJD Tuna Ltd's Cage 6;
  - A patch with feed fish (uneaten feed index = 1) recorded below AJD Tuna Ltd's Cage 14;
  - Sparse, partly decomposed feed fish (uneaten feed index = 0 - 1) recorded below AJD Tuna Ltd's Cage 17;
  - Patches with variable density of feed fish (uneaten feed index = 1 – 2) recorded below Malta Mariculture Ltd's Cage 7;
  - Sparse feed fish (uneaten feed index = 0 - 1) recorded below Malta Mariculture Ltd's Cage 8;
  - Sparse, partly decomposed feed fish (uneaten feed index = 3) recorded below Malta Mariculture Ltd's Cage 19.

  No feed fish were present at any of the four reference sites but a recently-deposited tuna carcass was recorded at the northeast reference site. Patches with what appeared to be *Beggiatoa* were present under some of the cages; presumably their presence is attributed to organic enrichment of the sediment surface following decomposition of feed fish deposited on the seabed.

18. In terms of biological characteristics, the findings from both the May and October 2021 sessions indicated that the seabed surveyed below cages belonging to the two tuna farms, and at the Northwest reference, Northeast reference and Southwest reference, mainly supported Sublittoral Sediment (EUNIS code A5), of which the predominant assemblage type was an association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515). In places, the sediment bottom supporting this assemblage type had accumulations of rhodoliths, such that where present their cover was some 1 – 20%. Apart from the red algae comprising the rhodoliths, typical macroalgae (mostly *Dictyota* sp. and *Flabellia petiolata*) were

recorded from this assemblage type; these mostly grew where the soft sediment was consolidated through the presence of very coarse material such as rhodoliths and stones. In places, the alien alga *Caulerpa cylindracea* were present on the soft sediment surface. The most abundant megafauna recorded in association with this habitat type were the crinoid *Antedon mediterranea*, the Long-spined Urchin *Centrostephanus longispinus*), and the Red Lance Urchin *Stylocidaris affinis*. The seabed at the Sikka l'Bajda reference site supported a mosaic with patches of the biocenosis of *Posidonia oceanica* meadows (EUNIS code A5.535) and the biocoenosis of infralittoral algae (EUNIS code A3.131). The seagrass *Posidonia oceanica* appeared to be in a good state and unimpacted by the tuna penning activities. The demersal fish fauna and pelagic fish fauna swimming close to the tuna cages were typical of that occurring in local offshore coastal waters and included Comber *Serranus cabrilla,* Rainbow Wrasse *Coris julis*, Two-Banded Bream *Diplodus vulgaris*, and unidentified Gobidae and Blennidae. Large shoals of Bogue *Boops boops*, were recorded below some of the tuna pens. During the October 2021 survey, several individuals of the Common Stingray *Dasyatis pastinaca* and of the Bull Ray *Aetomylaeus bovinus* were recorded swimming close to the seabed under most of the tuna cages; individuals of these were noted feeding on the feed fish that had been deposited on the seabed. At the southeast reference site, shoals of Damselfish *Chromis chromis* and of Rainbow Wrasse *Coris julis,* were recorded swimming in the vicinity of the *P. oceanica* meadows present at the site. For both the May and October 2021 sessions, these findings are similar to those reported from previous video surveys at the NAS, and are typical of the seabed present in northeastern coastal areas of the Maltese Islands at a depth of around 50 m.

4. APPRAISAL

Water quality

19. The results of water quality monitoring undertaken at the NAS during both the spring (May 2021) and autumn (October 2021) sessions indicated similar values for the various monitoring physical and chemical parameters, and that the recorded values were typical for offshore waters during the respective season. No floating material, surface oil slicks, tarry residue, surface foam/bubbles or odours were detected on the sea surface during both sessions; the observations were corroborated by aerial photographs of the survey area which indicated absence of appreciable amounts of floating material including floating oily substances (commonly referred to as 'sea slime'). It is notable that even during the autumn session when tuna farming activities are at their peak, no appreciable alteration of water quality was noted at the NAS. Therefore, based on the results from the May and October 2021 monitoring sessions, the tuna farming activities carried out by AJD Tuna Ltd and Mariculture Ltd at the NAS during 2021, have not resulted in appreciable alteration of water quality.

20. In terms of cumulative impacts; the results of water quality monitoring undertaken during 2021 at the NAS indicate the absence of cumulative effects in the area.

21. Notwithstanding the above conclusions, every effort should be made by the tuna farm operators to reduce the introduction of polluting substances to the marine environment, such as feed fish oils. If feed fish oils are released to the marine environment, these should be retained within the confines of the cages and collected using skimmers and / or other appropriate equipment. Any

feed fish oils released to the marine environment, should not be allowed to be transported by water movement beyond the confines of the NAS.

Video survey

22. The results of both video surveys undertaken in May and October 2021 indicated that the natural physical characteristics, including water depth, underwater transparency and gross physical features of the seabed underneath the surveyed tuna cages at the NAS were similar to those at the reference sites. Furthermore, the physical characteristics of the seabed below the eight tuna pens surveyed and at the four reference sites were similar to those reported in previous video monitoring surveys and studies carried out at the NAS, including the baseline studies undertaken prior to initiation of tuna penning activities in the area. However, both 2021 sessions indicated the presence of anthropogenic items on the seabed below several of the cages, some of which (namely the short lengths of rope and small concrete weights with ropes attached) appeared to originate from the tuna farming activities. Therefore, the occurrence of anthropogenic items, including ones that appear to originate from the tuna penning activities, has persisted.

23. During the May 2021 survey three tuna carcasses, and skeletal remains and bones that appeared to originate from tuna, were recorded under some of the cages. Feed fish were only recorded in small amounts underneath AJD Tuna Ltd's Cage 16. No feed fish or remains of dead tuna were recorded at any of the four reference sites.

24. During the October 2021 survey, several tuna carcasses in different stages of decomposition and skeletal remains and bones that appeared to originate from tuna were recorded on the seabed below some of the tuna cages. Inquiries with the site manager as to the possible origin of the tuna carcasses elicited the same response as in the past; the carcasses did not originate from the tuna farm activities but from fishing of wild tuna by professional and / or amateur fishermen in the vicinity of the tuna penning sites. Fishermen carrying out such fishing activities often have difficulty retrieving the tuna as the line used to catch them gets entangled against the cage mooring ropes and the fishermen end up cutting the line, which eventually leads to death of the tuna and deposition of the latter on the seabed. At other times, on seeing government authorities approach them, the fishermen cut the line on which a tuna would have been caught and since the fish would have suffered intense exertion, or possible may have already died in the process, it eventually ends up dead on the seabed. As has already been stated in reports from previous monitoring sessions at the NAS, the activities of fishermen in the vicinity of local tuna farms leading to dead tuna ending up on the seabed below tuna cages and areas in their vicinity is documented in the scientific literature (for example, Arechavala-Lopez et al., 2015). Such practice may therefore possibly be the reason for the presence of dead tuna on the seabed below the cages located within the SAZ, especially given the presence of numerous wild tuna in the vicinity of the tuna pens, which will certainly attract professional and amateur fishermen. Other aspects, such as entanglement of wild tunas that try to get to the feed fish in cages and end up getting entangled in nets, and which eventually fall off without being detected and are deposited on the seabed, may also be the reason for dead tunas ending up on the seabed. The origins of the tuna carcass recorded at the northeast reference site could not be deduced, but a probable reason is that it originated from fishing activities by professional and / or amateur fishermen who for some reason abandoned the tuna following capture. The recorded skeletal remains and bones on the seabed in the vicinity of the cages most probably originate from tuna carcasses that would have decomposed.

25. During the October 2021 survey, the uneaten feed fish recorded under several of the fish cages at both tuna penning sites varied in their state of decomposition but in most cases the feed fish appeared to have been deposited recently. The amount of feed fish present on the seabed also varied amongst different tuna pens, such that one patch had the highest recorded value of '3' for the uneaten feed index. The presence of uneaten feed fish that would have decomposed completely leading to nutrient enrichment of the sediments, was indicated by the presence of patches with *Beggiatoa*. Inquiries with the farm sites manager on the cause for feed fish deposited on the seabed indicated that this was a combination of accidental spillage and reduced appetite of the Blue Fin Tuna during feeding time; the reason / s for the latter is not understood.

26. The presence of high numbers of scavenging benthic macrofauna (namely urchins) and demersal fish fauna (namely rays) indicated that the organic material originating from the tuna carcasses and feed fish that had been deposited on the seabed were being consumed through scavenging activities. Nevertheless, numerous tuna carcasses and skeletal remains of dead tuna, as well as large amounts of uneaten feed fish, lead to addition of large amounts of organic material to the seabed, which add to the already-loaded seabed due to organic enrichment by waste from the cages, potentially leading to undesirable effects, including anoxic conditions, that would impact benthic habitats adversely. This is especially true if the scavengers present do not cope with consuming large amounts of decomposing remains of the tuna. However, unless the decomposing tuna and uneaten feed fish are present in huge amounts, such effects are deemed temporary, since decomposition and the action of scavenging fauna will, over a few weeks to a few months, result in complete breakdown of tuna carcasses and uneaten feed fish deposited on the seabed, such that in the long term there will be no residual impact. The tuna penning fallow period between January and March / April helps ensures such process and prevents cumulative effects which would result if deposition of tuna carcasses on the seabed is continuous over a long period of many months / several years. The same can be said for uneaten feed fish that may end up on the seabed.

27. The near-absence of feed fish on the seabed recorded during the May 2021 session indicates no concern with regard to occurrence of such material on the bottom in the vicinity of the cages and the general NAS area. However, the appreciable presence of feed fish recorded in October 2021 in the vicinity of the cages is concerning. Even more concerning is the presence of tuna carcasses in the vicinity of the fish cages, while one carcass as also recorded from one of the reference sites. Nonetheless, overall, excluding the presence of anthropogenic items, uneaten feed fish and tuna carcasses, the natural physical characteristics of the seabed at Malta Mariculture Ltd's and AJD Tuna Ltd's tuna penning site are the same as those recorded during previous video surveys and are also typical of the bottom present off the northeastern coast of Malta at a depth of around 50 m.

28. With regard to anthropogenic items present on the seabed, some of which appear to have originated from the tuna farming activities, this has persisted. The presence of: (i) anthropogenic items originating from the tuna penning activities; (ii) tuna carcasses and skeletal remains, and (iii) patches with uneaten feed fish, may arguably be seen as resulting in some alteration of the physical characteristics of the seabed in the vicinity of the cages at the tuna penning site. However, some alteration to the seabed physical features can be said to have occurred as a result of the anthropogenic items present. However, the findings from direct observations made as part of the video survey sessions and qualitative comparison of the amount of such items recorded during consecutive video survey sessions, indicate no appreciable accumulation of anthropogenic items

such that no cumulative effects with respect to physical characteristics of the seabed are evident in this regard. Accordingly, the mitigation measures emphasised below should be noted.

29. In terms of biological characteristics, the findings from both the May and October 2021 surveys indicated similar features of the seabed below the tuna pens when compared to the reference sites that had the same bottom type. The predominant habitat type is Sublittoral Sediment (EUNIS code A5), of which the predominant assemblage type was an association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515). In places, the coarse sediment characterising this assemblage type had accumulations of rhodoliths; in places these, together with coarse mobile sediments, supported stands of macroalgae (mainly *Dictyota* spp. and *Flabellia petiolata*). The benthic megafauna associated with this habitat type were typical of the habitat type and included the Red Lance Urchin *Stylocidaris affinis,* the Long-Spined Urchin *Centrostephanus longispinus*, and the crinoid *Antedon mediterranea.* The seabed at the Sikka l'Bajda reference site supported a mosaic with patches of the biocenosis of *Posidonia oceanica* meadows (EUNIS code A5.535) and the biocoenosis of infralittoral algae (EUNIS code A3.131). The seagrass (*Posidonia oceanica*) appeared to be in a good state and unimpacted by the tuna penning activities. However, during the October 2021 survey, some of the recorded megafaunal species (mostly the aforementioned urchins) were present in an unusually high density, which can be attributed to organic enrichment of the seabed underneath the tuna cages as a result of input of waste from the tuna penning activities. The organic matter serves as food for macro- and megafaunal species, supporting a high density of the organisms. Uneaten feed fish were serving to attract benthic and demersal scavengers, such as Stingrays, which could be seen feeding on the baitfish. Furthermore, the uneaten feed fish that passed through the cage net would attract individuals of Atlantic Blue Fin Tuna (ABT) *Thunnus thynnus* from the surrounding sea area.

30. The high cover and healthy state of fleshy macroalgae and of the coralline algae making up the rhodoliths, and the presence of typical megafaunal species, all of which were recorded in association with the main benthic habitat present below the tuna cages and at the four reference sites, as well as the typical demersal fauna recorded from the surveys, indicate that no appreciable adverse impacts of the tuna penning activities on the biological characteristics of the seabed had occurred at the NAS. It is noteworthy that the abundance of megafauna and of demersal fishes was elevated in the vicinity of the tuna cages compared to what is expected of this habitat type in pristine coastal waters having similar environmental characteristics, but this is to be expected given nutrient loading in the area as a result of the tuna farming activities and presence of tuna carcasses on the seabed within the NAS. Therefore, in terms of impacts, it appears that no appreciable adverse cumulative effects with respect to the biological characteristics have occurred within the NAS, at least insofar as could be deduced from the results of direct observation of the seabed using ROV, although some alteration is evident given the increased abundance of megafaunal and demersal fish species recorded in the area. As already indicated above, the fallow period practiced by the tuna operators during January to March / April of each year (when there are hardly any tuna penning activities) serves to allow natural recovery of the benthic environment to a state which is similar to that at pristine sites having the same environmental characteristics. Nevertheless, the mitigation measures emphasised below should be noted.

31. In conclusion, the findings from the May and October 2021 water quality and video surveys indicate that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning activities may be seen as resulting in some alterations to the physical and biological characteristics of the seabed at the sites used by the two companies; these specifically apply to the autumn session and mainly

consisted of unusually high densities of scavenger invertebrates and fishes that are attracted to the sites by the presence of waste, including uneaten feed fish, originating from the tuna farming activities. The anthropogenic items that originated from the tuna farming activities, and which were detected on the seabed under the surveyed tuna pens, contribute most to the alteration (even if small) of the physical characteristics of the seabed at the tuna penning sites. Given that the alterations are not large and are reversible, the reported changes to benthic environment at the tuna penning sites are not deemed concerning. Furthermore, in terms of cumulative impacts on the physical and biological characteristics of the seabed, the results of the video surveys undertaken during 2021 indicate no appreciable cumulative effects. This is especially so since observations from video survey held in spring in 2019 and 2020 showed that the fallow period practiced by the tuna operators during January to March / April of each year (when there are no tuna penning activities or these are at a minimum) serves to allow natural recovery of the benthic environment to a state which is similar to that at pristine sites having the same environmental characteristics.

32. To mitigate potential alterations to the physical and biological characteristics of the seabed within the SAZ, the following recommendations are reiterated: (i) feeding of the tuna should be carefully monitored and feeding should be stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten food ending up on the bottom; (ii) measures should be taken to avoid anthropogenic litter ending up on the seabed; in the eventuality that anthropogenic items end up on the seabed by accident, every attempt should be made to retrieve and dispose of them in an appropriate manner; (iii) measures should be taken to avoid having tuna carcasses or the remains of dead tuna ending up on the seabed below the cages and in their vicinity, even if this is not the direct result of action by the tuna farm operators; in this respect retrieval of tuna carcasses and / or remains of dead tuna is possible at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites given that the water depth is around 50 m and accessible to SCUBA divers who can undertake such retrieval.

4. REFERENCES

Arechavala-Lopez P., Borg J. A., Segvic-Bubic T., Paolo Tomassetti P., Özgül A. & Sanchez-Jerez P., 2015. Aggregations of wild Atlantic Bluefin Tuna (*Thunnus thynnus* L.) at Mediterranean offshore fish farm sites: Environmental and management considerations. Fisheries Research 164: 178-184.

Borg J. A. (2017). Report on a video survey of benthic habitats in an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, made in May 2017. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. (2018). Report on an ecological assessment of an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, undertaken as part of the Environment Impact Assessment in connection with PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. & Agius A. (2020a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 34pp.

Borg J. A. & Agius A. (2020b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in October 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 36pp.

Borg J. A. & Agius A. (2020c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in April 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 22pp.

Borg J. A. & Agius A. (2020d). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in September 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 23pp.

Borg J. A. & Agius A. (2021a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 12pp.

Borg J. A. & Agius A. (2022a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in September 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 11pp.

Borg J. A. & Agius A. (2021b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in May 2021 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 19pp.

Borg J. A. & Agius A. (2022b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in October 2021 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 21pp.

Holmer M., Hansen P. K., Karakassis I., Borg J. A. & Schembri P. J., 2008. Monitoring of Environmental Impacts of Marine Aquaculture. In: Holmer M., Black K., Duarte C., Marba N., & Karakassis I. (editors) Aquaculture in the Ecosystem; pp. 47-85. Heidelberg, Germany: Springer; 326pp.

ANNEX 1

Environmental monitoring of tuna farming activities

Proposal for regular environmental monitoring of tuna farming activities at offshore sites

Prepared by

Joseph A Borg BSc MSc PhD (Plymouth) CBiol MRSB MMBA FIBMS

12, Sir Arthur Borton Street
Mosta, MST14
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

Ref: P-tuna-farming-monitoring_revised_082018

August 2018

Preamble

1.1 **Ecoserv Ltd (henceforth Ecoserv) has received requests from tuna farmers having operations in the Maltese Isalands, for environmental monitoring of the tuna penning activities. The terms of reference (ToR) for the environmental monitoring have been provided by the Department of Fisheries and Aquaculture (DFA) and the Environment and Resources Authority (ERA).**

1.2 **The ToR for environmental monitoring of tuna farming activities in Malta, as issued by the ERA, are comprehensive and follow the guidelines which one would expect for the monitoring of sea-based fish farm activities. However, given that tuna farming installations have recently (in 2017) been moved offshore (> 1 km offshore), the present consultant, together with Adi Associates Environmental Consultants Ltd, jointly acting on behalf of all the tuna farming operations in Malta, held discussions with the ERA with a view to revise the ToR of environmental monitoring The aim of this revision is to focus the monitoring on the components that are more readily indicative of potential adverse impacts, for there to be prompt issue of results, and to ensure cost-effectiveness of the monitoring programme. Justification for the proposed revision is partly based on the avilability of extensive data from environmental monitoring of local fish farming activities carried out over a period of more than 15 years.**

1.2 **The present document constitutes Ecoserv's revised proposal for environmental monitoring of offshore tuna farming activities in Malta following discussions held with the ERA in early August 2018.**

Brief overview of findings from environmental monitoring of tuna farming activities in Malta

2.2 Environmental monitoring of tuna farming activities has been ongoing at the offshore sites (located 1 km offshore) used by Azzopardi Fisheries Ltd (AF), FishandFish Ltd (F&F) and Malta Fishfarming Ltd (MFF) since 2000. The monitoring can be broadly divided into two main categories: (i) Water quality and (ii) monitoring of seabed physical and biological attributes. A brief description of the monitoring components, as well as a summary of the findings for each of these follows.

(i) <u>Water quality surveys</u>

Most of the water quality surveys carried out at the 3 tuna penning sites have been made at a bimonthly frequency, although some of the farms did not undertake any monitoring during some periods that extended several months. During the surveys, standard water quality attributes, namely dissolved oxygen, temperature, salinity, turbidity, nitrates, phosphates, Chlorophyll *a*, ammonia, and counts of intestinal bacteria, as well as sea current direction and speed, were measured at a number of sampling stations located in the immediate vicinity of the tuna farms and at up-current and down-current reference stations.

The results of the water quality surveys carried out to date indicated that, very rarely, lowered levels of oxygen, reduced water transparency and elevated nutrient (nitrates and/or

phosphates and/or ammonia) levels were sometimes recorded from the tuna penning sites during the farming season (July – December). However, the observed changes in the monitored attributes were often sporadic and not statistically significant, and have not resulted in appreciable alteration of water quality. Elevated counts of intestinal bacteria were also occasionally recorded but since such organisms do not originate from the tuna but from sewage, these results were not attributed to the tuna penning activities *per se*, although there is the possibility that large ships (e.g. processing ships) present in the vicinity of the farms may be the source of such contamination through discharge of sewage from their holding tanks.

Overall, therefore, the reports of surveys made within this monitoring category concluded that the tuna penning activities had not led to appreciable alteration of water quality in the vicinity of the tuna farms. However, it should be pointed out that some substances that appear to originate from the tuna farms and which were not monitored during the water quality surveys have been recorded to occur in waters in the vicinity of all three tuna penning sites and at a considerable distance away. Essentially, such substances are oils and fats that are released from the feed-fish when these are fed to the tuna. Release of such substances occurs when the feed fish are introduced in the tuna pens and when uneaten feed-fish end up outside the fish cages, and decomposition leads to release of fatty substances that accumulate on the surface and are transported offshore or inshore, depending on sea current strength and direction. Such substances are deemed to have no toxic effects on marine species and habitats, but are a nuisance to bathers, divers and coastal recreational activities, because of their sheer presence in the water and since they deposit on the shore and artificial surfaces (e.g. boat hulls etc.). It is pertinent to point out that although deposition of such substances is not envisaged to have any large adverse effects on marine species and habitats, especially those associated with the shore, this has not been assessed given the complete lack of studies that deal specifically with this aspect. Episodes that were characterised by the occurrence of such floating substances were particularly notable during the summer of 2016, when complaints and awareness of the issue by the general public reached an all-time high. The floating substances were commonly referred to as 'slime', and common sightings of the floating substance and the inconvenience it created to sea users even led to launching of a Facebook page titled 'Stop The Slime' (https://www.facebook.com/stoptheslimemalta). Concurrently, in October 2016 and during the winter and spring of 2017, episodes of occurrence of massive floating 'foam' were recorded from vast areas of Maltese coastal waters. While the occurrence of 'slime' could, directly or indirectly, be linked to fish farming activities, the occurrence of foam is in all probability related to substances secreted by algae, which when churned up by rough sea conditions lead to generation of the observed 'foam'.

(ii) Monitoring of seabed physical and biological attributes

This category has five main monitoring components, namely:

a. Video surveys of the seabed in the vicinity of the tuna pens

The main aim of this monitoring component is to gather qualitative and semi-quantitative data, using direct observation, on the physical and biological characteristics of the seabed underneath the tuna pens. Such surveys involve videography along transects below the tuna pens, and have been carried out twice per year (in October and February) in some years and more recently once per year, usually during the period October – December.

The results of this monitoring component can be summarised as follows:

- Towards the end of each penning season (in autumn) considerable amounts of uneaten feed-fish littered the seabed in the area lying directly below the tuna pens, but not in areas beyond the perimeter of the tuna pens. This resulted in alterations in the physical and biological characteristics of the seabed under the pens, namely:
    - Changes in biological characteristics which typically consist of high population densities of detritus-feeding and scavenging benthic (i.e. associated with seabed) fauna (e.g. the ophiuroid *Ophiura texturata*, the crab *Inachus* sp., the hermit crab *Pagurus* sp. and an unidentified goby).
    - Alterations in physical characteristics which typically consist of the presence of large quantities of fish bones and baitfish that are gradually consumed by scavengers or eventually decompose. There was also a considerable amount of anthropogenic items below the pens that originated from the farm operations, including concrete weights with ropes attached, sheets and sacks of fabric and other material, car tyres, lengths of rope and shot gun cartridges.
- The amount of uneaten baitfish present varied considerably between the different pens, and between different farms, with some only having a few feed-fish beneath them and others having multiple layers of decomposing feed-fish. Once the tuna farming season is over (late winter), a negligible amount of uneaten feed-fish remain on the seabed below the pens. However, thick layers of fish bones and of decomposing organic material persist under some of the pens. These observations indicate a consistent pattern, with the volume of uneaten feed-fish on the seabed decreasing only when the tuna have been harvested (and therefore there is no further addition of feed-fish). Any uneaten fish remaining on the seabed at this time will continue to decompose slowly and, if present in large numbers, form a continuous layer of decomposing organic material. Sometimes, following storms and possibly due to strong bottom currents, this layer is admixed with the underlying mobile sediment. In places where the decomposition process is complete, the only remains are fish bones that eventually disperse in the sediment leaving little or no trace of the original uneaten fish on the surface. Once the source of the impact (periodic addition of new uneaten food) is removed, slow recovery to the original state is characterised by the re-appearance of certain megafaunal species (e.g. the irregular sea urchin *Spatangus purpureus* and the crinoid *Antedon mediterranea*) that form part of the original fauna that characterise the bare muddy sand bottom of the areas where the tuna farms are located.
- The latest video surveys indicated the occasional presence of whole decomposing tuna on the seabed below a few of the tuna cages at the tuna penning sites. However, the tuna farm operators are adamant that the tunas have not originated from the farms. According to the tuna farm site managers, the tunas ended there following capture and subsequent release (accidental or deliberate) by amateur fishermen who would have caught the fish from the wild in the vicinity of the tuna pens. Apparently, local tuna farms are being frequented by amateur fishermen who deploy their fishing lines

with an aim to catch wild tuna that aggregate around the tuna farm; the latter phenomenon has been observed during the past few years at several tuna penning sites in the Mediterranean. Any tunas that are caught and: (i) either break free, or (ii) are cut free by the fishermen[2], die soon after release and end up on the seabed, where they decompose slowly. It appears that the local Fisheries and Aquaculture Department is aware of this problem.

b. Monitoring of physico-chemical attributes

The main aim of this monitoring component is to assess levels of organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics. Moreover, at least one survey involving assessment of levels of pollutants, including heavy metals and organic pollutants, was carried out at each of the three tuna penning sites. The monitoring design of the surveys to assess organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, is based on a Beyond **BACI**[3] layout, in which the results of quantitative analyses of sediment samples collected from the tuna farming site and from a number of control sites before the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. Such surveys were mostly carried out on a yearly basis; however, the AF tuna penning site was monitored twice per year during some years, while no monitoring was carried out at some of the tuna penning sites during some years.

Overall, the findings from surveys that were aimed at assessing organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, indicated 'pulse' (i.e. short duration) changes in the physico-chemical properties of the sediment following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens but no significant permanent alterations of the sediment characteristics at the operational sites have been recorded to date. Where significant changes were detected, these appeared to have resulted from accumulation of large amounts of uneaten feed-fish in the vicinity of the tuna pens, which decompose slowly causing alterations in the physico-chemical properties of the sediments.

The results of the surveys aimed at assessing levels of heavy metals and pollutant organics indicated that no harmful levels were present in the sediments in the vicinity of the tuna farms.

c. Monitoring of benthic diversity

The main aim of this monitoring component is to assess for potential changes in species populations and seabed habitat that may result from the tuna penning activities. The monitoring design is based on assessing total species richness and total abundance of selected benthic faunal species, as these are deemed good indicators of the overall state

[2] According to the site managers, the wild tuna caught by the amateur fishermen are sometimes cut free on being approached by fisheries officers who make regular site visits to the fish farms using a vessel owned by the local fisheries department.

[3] **B**efore **A**fter **C**ontrol **I**mpacted; see Underwood (1992): Underwood, A. J. (1992) Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161: 145 –178.

of species and habitats associated with the seabed. As in the case of the physico-chemical attributes monitoring component, the design for monitoring of benthic diversity is based on a Beyond **BACI** layout, in which the results of quantitative analyses of samples collected from the tuna farming site and from a number of control sites **before** the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. As in the case of the physico-chemical attributes monitoring component, monitoring of benthic diversity was mostly carried out on a yearly basis, however, the AF tuna penning site was monitored twice per year during some years, while no monitoring was carried out at some of the tuna penning sites during some years.

Overall, the findings from this component indicated that a significant 'press' (i.e. long-lasting) adverse impact (manifested as a significant decrease in total macroinvertebrate species richness and/or decrease in the abundance of one or more of the indicator species) had occurred following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens. Furthermore, enhanced productivity in the general area of the tuna farms and beyond, as a result of the tuna-penning activities, was evident from significant increases in the abundance of some of the indicator species recorded in some of the monitoring sessions.

These observations are a strong indication that, where present, adverse impacts on the benthic macroinvertebrate assemblages at the operational sites have resulted from processes that are mainly attributed to accumulation of large amounts of uneaten feed-fish and the slow decomposition of same, in the vicinity of the tuna pens. The uneaten feed-fish attract scavengers and other opportunistic fauna that cause changes to the original species composition of the benthic assemblages, while slow decomposition of the accumulated material causes alterations in the physico-chemical properties of the sediments, and presumably of the sediment-water interface, leading to adverse conditions for the biota originally present.

Over the past few years, data from 10 years of environmental monitoring of the tuna farms owned by AF, F&F and MFF, was subjected to detailed study and analyses as part of a PhD programme of research undertaken at the Department of Biology of the University of Malta, for which the present author is supervisor. To date, THREE papers have been published in leading peer-reviewed international journals, highlighting the study results; see Mangion *et al.*, 2014; 2017; 2018). Copies of these publications are appended to the present report for ease of reference. In summary, the results of these studies indicated that:

- For the largest tuna farm (located off the northeastern coast of Malta), the activity resulted in significant changes to sediment physico-chemical attributes and to the macroinvertebrate assemblages of soft bottom habitats located in the immediate vicinity of the fish cages up to a distance of some 200 m from the farm. However, it appears that the magnitude and spatial extent of the impact also depended on the feed management regime adopted at a tuna farm.
- High spatio-temporal variability in attributes of the macrobenthic invertebrates in the vicinity of three tuna farms (AF, F&F and MFF) was evident; this indicates that change in macroinvertebrate assemblages resulting from tuna farming activities differs between different farms. This observation corroborates the expectation that the level of influence of tuna farming activities on benthic habitats in the vicinity will vary with

the fish stocking density, the length of time a farm has been in operation, and the feed management strategy adopted at the farm during the production period.

- Significant correlation at the control plots between attributes of the macroinvertebrate assemblages and sediment physico-chemical attributes 1–2 km away from the tuna cages suggests that some influence of tuna farming may occur over a wider spatial extent than expected. However, given the high degree of overlap between different marine-based activities around the Maltese Islands, particularly in their southern coastal areas, it is also possible that other sources of organic enrichment apart from the tuna penning activities may be influencing the coastal waters where the tuna farms are located.

d. Monitoring of habitats of ecological importance

The aim of this monitoring component is to assess for potential adverse impacts of the tuna penning activities on marine habitats located near the tuna farms, namely seagrass *Posidonia oceanica* habitat. This monitoring component was undertaken annually between 2003 and 2006 at the AF and MFF tuna penning sites. The surveys were based on a beyond **BACI** design, in which quantitative morphometric data reflecting the state of the seagrass located closest to the farms is compared with that at a number of control sites.

The results of this monitoring component indicated no consistent trends of significant alterations in the state of *Posidonia oceanica* seagrass that may be attributed to the tuna farming activities. Consequently, the MEPA advised the tuna farm operators that this monitoring component need not be continued; hence no further sessions were undertaken after 2006.

e. Monitoring of popular dive sites

The aim of this monitoring component, which involved surveys of the state of the physical and biological characteristics of the seabed habitats, is to assess for potential adverse impacts of the tuna penning activities at popular dive sites located near some of the tuna farms. Such monitoring involved videography, assessment by direct observation and mapping surveys along transects within a defined area that includes the confines of the dive site. The sites monitored were: (i) 'Imperial Eagle' and 'Stubborn' dive sites, both of which are located not far from the AF tuna penning site; (ii) the 'Blenheim' dive site, located not far from the F&F tuna penning site; and (iii) Munxar Reef, located not far from the MFF tuna penning site. One survey per year was carried out at these sites between 2003 and 2006.

Monitoring of the physical and biological characteristics of the bottom at the dive sites showed no consistent trends of significant alterations of the seabed features as a result of the tuna farming operations. Consequently, the MEPA advised the tuna farm operators that this monitoring component need not be continued; hence no further session were undertaken after 2006.

2.3 The results of extensive environmental monitoring programmes held at the tuna penning sites used by AF, F&F and MFF during the past 15 years or so indicate that the main marine environmental impacts that may be attributed to the tuna penning operations are as follows:

(i) Alteration of physical and biological characteristics of the seabed below the tuna pens via deposition of large amounts of uneaten feed-fish, and anthropogenic items originating from the tuna farm operations. Although the uneaten feed-fish 'overwhelm' the seabed ecosystem since the typical fauna do not manage to consume all the uneaten feed, which therefore accumulates on the bottom and probably also spills over (albeit in smaller form, e.g. as particulate organic matter) to adjacent areas, it is ultimately biodegradable and does not persist in the environment for long. The uneaten feed-fish serve as a source of nutrient enrichment of the benthic ecosystem in the vicinity of the tuna farms and adjacent areas, resulting in increased productivity. However, this should not be considered a pretext for allowing addition of uneaten feed to the marine environment. As stated in the monitoring reports:

   a. Feeding of the tuna should be carefully monitored and stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten feed ending up on the bottom. The tuna operators may want to implement a procedure to ensure proper feed management by having random checks of the seabed below the tuna pens made by an independent environmental monitor.

   b. In the case of accident, should an inordinate amount of dead uneaten feed-fish end up on the bottom, every attempt should be made to remove as much of the material as possible using techniques that do not have an adverse effect on the seabed habitat.

   c. Uneaten feed-fish are most probably the source of oils and fats which eventually rise to the surface and are transported by sea currents to inshore areas where, rather than having a toxic effect on shallow water and shore marine species and habitats, they are a nuisance to coastal users including bathers and divers. On the other hand, the effects of such oils and fats on the ecology of shore habitat are not known. However, one would assume that they do not have appreciable adverse effects.

   d. If the situation concerning the presence of dead tuna is as described by the operator, i.e. it is resulting from uncontrolled fishing in the vicinity of the tuna farms, then there is a need for such an activity to be curbed. Furthermore, even if the dead tunas do not originate from the farms themselves, it would be beneficial if these are possibly removed from the seabed.

   e. Anthropogenic items deposited on the seabed as a result of the tuna penning operations, such as concrete weights, ropes etc should be removed and not allowed to accumulate on the bottom.

(ii) Alteration of water quality mainly via addition of oils and fats when feed-fish are fed to the tuna. As already stated above, any introduced oils and fats may be transported by sea currents to inshore areas where, rather than having a toxic effect on shallow water and shore marine species and habitats, they are a nuisance to coastal users including bathers and divers. On the other hand, the effects of such oils and fats on the ecology of shore habitat are not known; however, one would assume that they do not have appreciable adverse effects. As a mitigating measure, introduction of oils and fats with the feed to the marine environment should be avoided or reduced.

Proposal for environmental monitoring

3.1 The ERA ToR refer to monitoring of the following components, which are to be monitored at a frequency of 1 – 2 times per year at the south aquaculture zone (SAZ) where three tuna farms (F&F Ltd, MFF Ltd and Mare Blu Ltd) are located, and at the site off Mellieha Bay (north aquaculture site; NAS) where two tuna farms (AJD Tuna Ltd and MML Ltd) are located; both sites being located some 5-6 km offshore:

- Sediment quality, namely the parameters given in Table 1 below;
- Water quality, namely the parameters given in Table 2 below;
- Plankton, to establish the most abundant species of phytoplankton and zooplankton and to determine for the presence of toxic or harmful plankton;
- Video survey of the seabed to assess gross physical and biological features;
- Benthic assemblages to assess the condition of the benthic environment in the vicinity of the fish cages, compared to unperturbed conditions, which will be taken to be the situation at the reference stations.

Table 1: Parameters to be analysed in sediments.

Parameter	Method	Units (on D.M.)
Granulometry	Buchanan 1984	g
Total Organic Carbon (TOC)	UNI EN 13137:2002	%
Redox Potential	CNR IRSA 2 Q 64 Vol 3 1985	mV
Sulphide	CNR IRSA 12 Q 64 Vol 3 1986	µg
pH	CNR IRSA 1 Q 64 Vol 3 1985	pH units
Total Nitrogen	CNR IRSA 6 Q 64 Vol 3 1985	mg/g
Total Phosphorus	DM 13/09/1999 SO n°185 GU n°248 21/10/1999 Met XV.I	mg/g

Table 2: Parameters to be analysed in seawater.

Parameter	Method	Units
Temperature	In-situ / Portable Meter	°C
Salinity	In-situ / Portable Meter	psu
Dissolved Oxygen	In-situ / Portable Meter	%, mg/l
Turbidity	In-situ / Portable Meter	NTU,
Turbidity (Secchi Depth)	Secchi Disk	m
pH	pH meter	pH units
Chlorophyll *a*	APAT CNR IRSA 9020 Man 29 2003	µg/l
Total Nitrogen	APAT CNR IRSA 5030 Man 29 2003 + APAT CNR IRSA 4040 A1 Man 29 2003 + APAT CNR IRSA 4050 Man 29 2003	µg/l
Total Phosphorus	APAT CNR IRSA 4110 Man 29 2003	µg/l
Total Carbon	UNI EN 1484:1999	µg/l
Total suspended matter	APAT CNR IRSA 2090 B Man 29 2003	mg/l

While such monitoring components follow the guidelines that one would expect of monitoring programmes for sea-based fish farm activities, particularly ones located in coastal areas not far from the shore, given that all tuna farming installations have recently (in 2017) been moved offshore (> 1 km offshore), it would seem more appropriate to adopt a monitoring programme that enables prompt issue of results, while focussing on components that are more readily indicative of potential adverse impacts, while being cost-effective. Collection and analysis of samples of phytoplankton and sediment for species identification will necessitate months. A single grab sample collected by a 0.1 m^2 Van Veen Grab, which will fill a 10 litre bucket, may require 2-man weeks for sorting and several days to identify – this would be before any necessary statistical analyses is carried out. From experience by Ecoserv's personnel, sorting sediment and identifying marcoinvertebrates from a single monitoring session at one tuna farm site may require several months to nearly a full year to complete. In the case of the South Aquaculture Zone; monitoring of physico-chemical attributes and benthic diversity from two sessions held in 2008 and 2010 did not detect any significant changes following tuna penning activities at the site. Monitoring of plankton and routine water quality parameters such as Chlorophyll *a*, dissolved oxygen, turbidity, nutrients, etc will, in all probability, not serve to detect any change/impact resulting from the tuna farming activities as the offshore areas where the farms are currently located are characterised by very strong sea currents, exposed conditions, and a high energy regime that promote very high flushing of any wastes generated by the activity. Nevertheless, surveys of water quality will be carried out as detailed below, while a survey of sediment quality and benthic diversity will be carried out should the results of the video surveys indicate a potential adverse impact of the tuna penning activities on the seabed. The results from surveys of sediment quality and benthic diversity, should it be necessary to implement these, carried out at both the SAZ and NAS may be compared with the results of past baseline surveys (sediment quality and benthic diversity) of the seabed having the same physical and biological characteristics as those of the SAZ and NAZ.

The following environmental monitoring proposal is mainly aimed at focusing on components that are more readily indicative of potential adverse impacts, and on cost-effectiveness, while also serving as a 'check' for the farm operators themselves and still allowing for implementation of sediment quality and benthic diversity surveys should the ERA and present consultants deem that these are necessary if monitoring results indicate an adverse environmental impact resulting from the tuna penning activities:

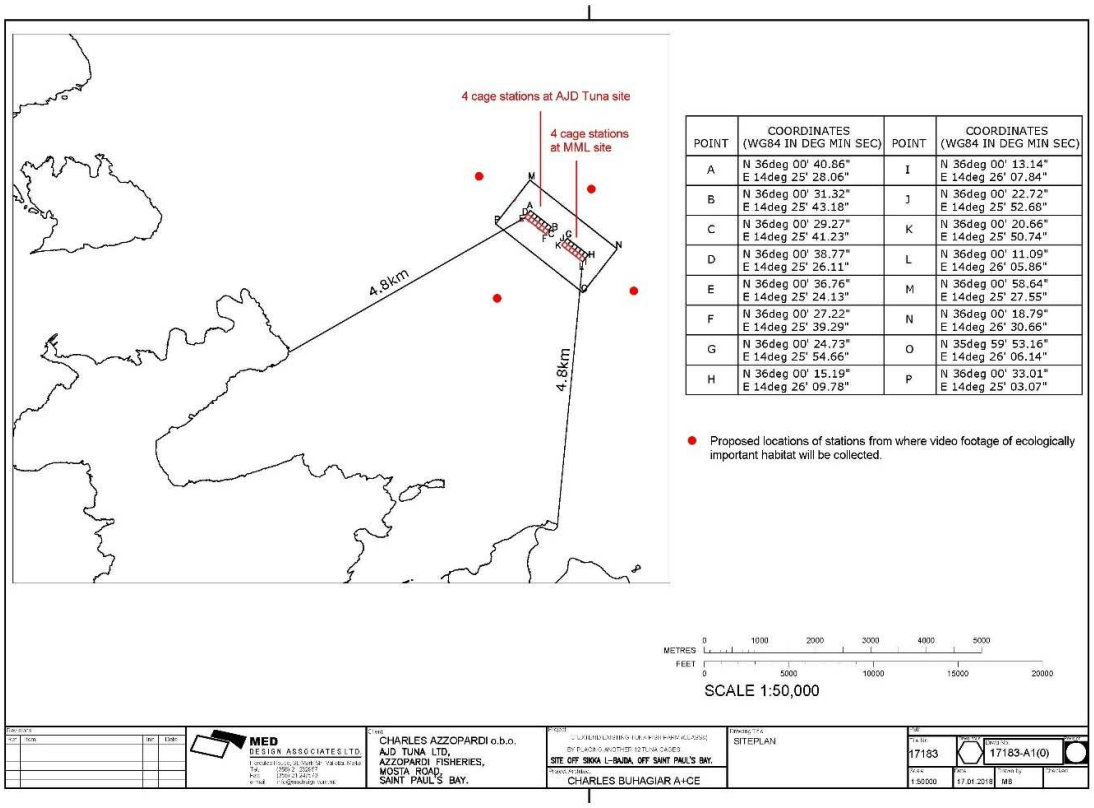
Video survey

A video survey using a remotely operated vehicle (ROV) will be undertaken below a select number of fish cages to assess for the following:

- Level of uneaten feed accumulating on the seabed;
- Species diversity and abundance of megafauna;
- Marine litter; and
- Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

The video survey will be undertaken using an ROV that will be navigated below, as much as possible, a select number of tuna cages at each of the SAZ and NAS; this will enable collection of the necessary video footage, which will be later analysed in the laboratory. It is proposed that video footage of the seabed will be collected in the vicinity of 8 cages (4 cages at each of the MML and AJD Tuna Ltd sites) at the NAS and 12 cages (4 cages at each of the F&F Ltd, MFF Ltd and Mare Blu Ltd sites) at the SAZ. The cages selected for monitoring using video footage will be selected at

random in the field by the scientists on the day of monitoring but the selected cages at any one site will be as distant from each other as possible to allow for representative assessment. The collected video footage will enable assessment of: (i) Levels of uneaten feed accumulating on the seabed; (ii) species diversity and abundance of megabenthic fauna; (iii) presence of marine litter; (iv) overall gross physical and biological characteristics of the seabed. Video footage of the seabed will also be collected at stations located at a distance from the SAZ and NAS but where the bottom may support a habitat of high ecological importance; in the case of the NAS, this would be maerl habitat located west, north and east of the site, as well as at 'Is-Sikka l-Bajda' located south of the site; in the case of the SAZ, this would be maerl habitat located west, north, east and south of the site. It is proposed that video footage will be collected from 4 stations in the vicinity of the NAS and 4 stations in the vicinity of the SAZ. The proposed locations of the monitoring stations are shown in Figures 1 and 2 below.



POINT	COORDINATES (WG84 IN DEG MIN SEC)	POINT	COORDINATES (WG84 IN DEG MIN SEC)
A	N 36deg 00' 40.86" E 14deg 25' 28.06"	I	N 36deg 00' 13.14" E 14deg 26' 07.84"
B	N 36deg 00' 31.32" E 14deg 25' 43.18"	J	N 36deg 00' 22.72" E 14deg 25' 52.68"
C	N 36deg 00' 29.27" E 14deg 25' 41.23"	K	N 36deg 00' 20.66" E 14deg 25' 50.74"
D	N 36deg 00' 38.77" E 14deg 25' 26.11"	L	N 36deg 00' 11.09" E 14deg 26' 05.86"
E	N 36deg 00' 36.76" E 14deg 25' 24.13"	M	N 36deg 00' 58.64" E 14deg 25' 27.55"
F	N 36deg 00' 27.22" E 14deg 25' 39.29"	N	N 36deg 00' 18.79" E 14deg 26' 30.66"
G	N 36deg 00' 24.73" E 14deg 25' 54.66"	O	N 35deg 59' 53.16" E 14deg 26' 06.14"
H	N 36deg 00' 15.19" E 14deg 26' 09.78"	P	N 36deg 00' 33.01" E 14deg 25' 03.07"

Figure 1. Map showing the locations of the temporary AJD Tuna Ltd and MML Ltd farm sites off Mellieha Bay, and the proposed locations of stations from where video footage of ecologically important benthic habitat will be collected (apart from video footage collected at 4 cage stations at each farm site).

The results of such assessment will be available within a few weeks and will clearly indicate the state of the seabed in the vicinity of the cages. Furthermore, the main output – the video footage – is in itself illustrative and will readily, clearly, and visually, show any change/adverse impact of the tuna farming activities on the seabed, including to the operator himself. The video footage may also be used readily by the ERA to effectively illustrate and inform planners, policy makers, politicians and the general public of the situation of the seabed below the cages.

Based on the outcome from the video surveys; in the eventuality that the findings indicate large changes in physical and biological characteristics of the seabed following the tuna penning activities, then the ERA would reserve the right to request a quantitative study to assess, in greater detail, any alterations to the benthic habitat. This would be done through quantitative assessment of sediment quality and benthic assemblages, as per the related component of the ERA's ToR. Such strategy will also serve as incentive for the operators to ensure proper management of the tuna farm activities and avoid potential adverse impacts on the seabed, as well as avoiding additional monitoring and associated high cost.

It is proposed to perform two monitoring sessions per year: in April/May, just before the start of the tuna penning season and in August/September at the peak of the farming season.

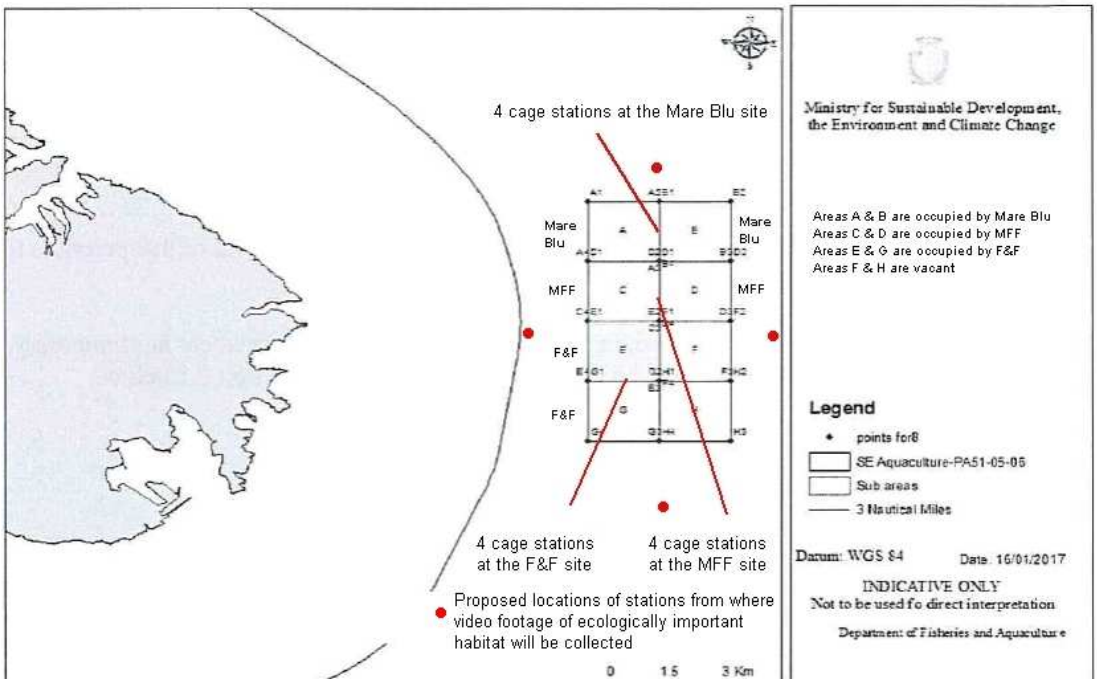


Figure 2. Map showing the locations of the Mare Blu Ltd, MFF Ltd and F&F Ltd farm sites within the south aquaculture zone, and the proposed locations of stations from where video footage of ecologically important benthic habitat will be collected (apart from video footage collected at 4 cage stations at each farm site).

Water quality

To monitor water quality, aerial photography sessions coupled with water quality surveys are proposed. The main aim of the aerial photographs is to detect any potential oil slicks and their extent, in the vicinity of the tuna farms, given that this is clearly a main issue. Such session will be held concurrently with *in-situ* measurement of water quality attributes and collection of marine water samples for later analysis in the laboratory. The different parameters that will be measured and analyzed are indicated in Table 2; these are the same as per the ERA's ToR. *In situ*

measurements (two replicates) and collection of seawater samples (two replicates) will be made at a water depth of 1 m (subsurface) at four stations located within each of the NAS and SAZ: an up-current station, two stations located at the centre of each site (NAS and SAZ), and a down-current station. Furthermore, two replicate samples of seawater will be taken at the surface from the same four stations for potential analysis of oils. The latter analysis will, however, only be undertaken if the aerial photographs show evidence of the presence of an oil slick. Observations on the following will also be made at each station:

- presence of floating material;
- surface oil slicks;
- tarry residues;
- surface foam/bubbles
- any odours present.
-

Water samples for laboratory analyses will be transferred to pre-treated glass or plastic bottles, as appropriate and depending on the analysis concerned. Samples will be maintained at a temperature of 4 – 8^{o}C during transport to the lab. Analysis for the parameters will be undertaken using standard methods. The parameters that require laboratory analysis will be analysed at a laboratory that is accredited according to the ISO 17025:2005 standard.

It is proposed to carry out two monitoring sessions per year, which also coincide with the period when the video session will be held: in April/May, just before the start of the tuna penning season, and in August/September, at the peak of the farming season.

Reporting

One report for each of the two monitoring components; i.e. video survey and water quality, and which will include the methodology used, findings and appraisal, will be submitted.

Sediment quality and benthic diversity

Should the results of the video surveys indicate an adverse impact on the seabed as a result of the tuna penning activities at either of the NAS or SAZ, sediment quality and benthic diversity surveys will be undertaken, as described below.

Sediment quality

To assess the chemical quality of sediments in the areas of study, samples will be collected for analysis from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. As much as practically possible, the sampled stations will have the same water depth. Two replicate sediment samples will be collected from each station using a 0.1m^2 Van Veen Grab that will be pre-cleaned and pre-treated to avoid contamination. The samples will then be transferred to pre-cleaned and pre-treated glass

or plastic sample containers depending on the type of analysis to be carried out. Sediment sampling and preservation will take place in accordance with the ISO 5667 set of guidelines that are followed as part of the procedures at the laboratories where the analyses will be carried out. Samples will be maintained at appropriate storage conditions until delivery to the analysing laboratory. The samples will be analysed at an ISO 17025:2005 accredited laboratory for the parameters indicated in Table 1. Standard analytical methods will be employed which will involve a pre-analytical step of extraction, intended to release any bound chemicals from the sediment particles.

To assess the physical characteristics of the sediments at each of the six stations, sediment samples for granulometric analysis will also be collected from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. For this purpose, two replicate sediment samples will be collected using a $0.1m^2$ Van Veen Grab from the same six sampling stations used to collect samples for chemical analyses. In the laboratory, the samples will be analysed by sieving through nested Endecott test-sieves on a mechanical sieve-shaker, according to the method given in Buchanan (1984). Using this method, the sediment will be separated into the different grain size fractions and the percentage contribution of each fraction, mean sediment grain size and the sediment's overall classification will be determined. The results obtained will be used to provide a description of the granulometric characteristics of the sampled sediments, namely: mean sediment grain size (according to the Wentworth Scale) and other relevant properties such as sorting and kurtosis.

Benthic diversity

To collect data for benthic diversity studies, a grab sample will be collected from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. Samples will be collected using a 0.1 m^2 Van Veen grab deployed from a vessel equipped with hoisting jib and winch. After the grab is brought on board, surplus seawater will be drained from the sample by placing it on a 1mm-mesh sieve; the retained sediment and biota will be temporarily preserved in 10% formaldehyde in seawater. In the laboratory, each sample will first be washed to remove the fine sediment (<1 mm fraction) and the preservative, and it will then be sorted to separate out all macrofauna (animals larger than 1 mm). The motile macrofauna will then be identified as far as possible. Where identification to species level was not possible, the different species present will be labelled using an alphabetical code (e.g. Mysidacea sp. A, etc.).

Reporting

One report for each of the two monitoring components; i.e. sediment quality and benthic diversity, and which will include the methodology used, findings and appraisal, will be submitted.

Training

To satisfy the requirements of staff training, the following programme that will encompass lectures and a practical demonstration session is being proposed:

- 1 hour lecture on permit obligations;
- 1 hour lecture on basic aspects of the marine environment;
- 1 hour lecture on monitoring of aquaculture activities; and
- 1 hour practical demonstration session concerning monitoring.

The training session will have a duration of one half day (0900 – 1330) and will include half an hour coffee break (between 11:00 and 11:30). Participants will be presented with an attendance certificate.

Responsibilities, personnel, equipment and facilities

Ecoserv Ltd will undertake all studies, including fieldwork, laboratory analyses, data analyses and production of reports. All work will be carried out by a team of qualified environmental scientists from Ecoserv Ltd under the supervision of Prof Joseph A Borg BSc MSc PhD CBiol MRSB MMBA FIBMS and Dr Julian Evans BSc (Hons) MSc PhD MMBA.

Further information on Ecoserv Ltd, together with a list of past projects serviced by the company can be downloaded from www.ecoserv.com.mt. The company's web site also features ongoing projects and assignments commissioned recently.

References

Mangion M., Borg J. A., Thompson R. & Schembri P. J., 2014. Influence of tuna penning activities on soft bottom macrobenthic assemblages. Marine Pollution Bulletin 79; 164-174.

Mangion M., Borg J. A., Sanchez Jerez P & Schembri P. J., 2017. Assessment of benthic biological indicators for evaluating the environmental impact of tuna farming. Aquaculture Research: 1 – 15.

Mangion M., Borg J. A., Sanchez-Jerez P., 2017. Differences in magnitude and spatial extent of impact of tuna farming on benthic macroinvertebrate assemblages. Regional Studies in Marine Science 18: 197-207

ANNEX 2

Environmental monitoring of tuna farming activities

Revision of water quality sampling design in relation to P-tuna-farming-monitoring_revised_082018 (Proposal for regular environmental monitoring of tuna farming activities at offshore sites)

The present revision of the sampling design in relation to monitoring of water quality at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay, is being made following agreement with the Environment and Resources Authority (ERA). The recommendation, which was agreed on by the ERA and the present consultant, is to add a further two sampling stations to the four stations that have been used in water quality monitoring sessions held in 2019 and 2020.

It is proposed that the locations of the two water quality monitoring stations (E and F in Figure 1) will tentatively be as indicated in Figure 1. However, the actual locations will be determined on the day of holding on the water quality survey, depending on the sea current direction, such that one of the stations will be 'up-current' and the other 'down-current'; i.e. the locations of the two stations can be anywhere along a semi-circle drawn north to south for each station.

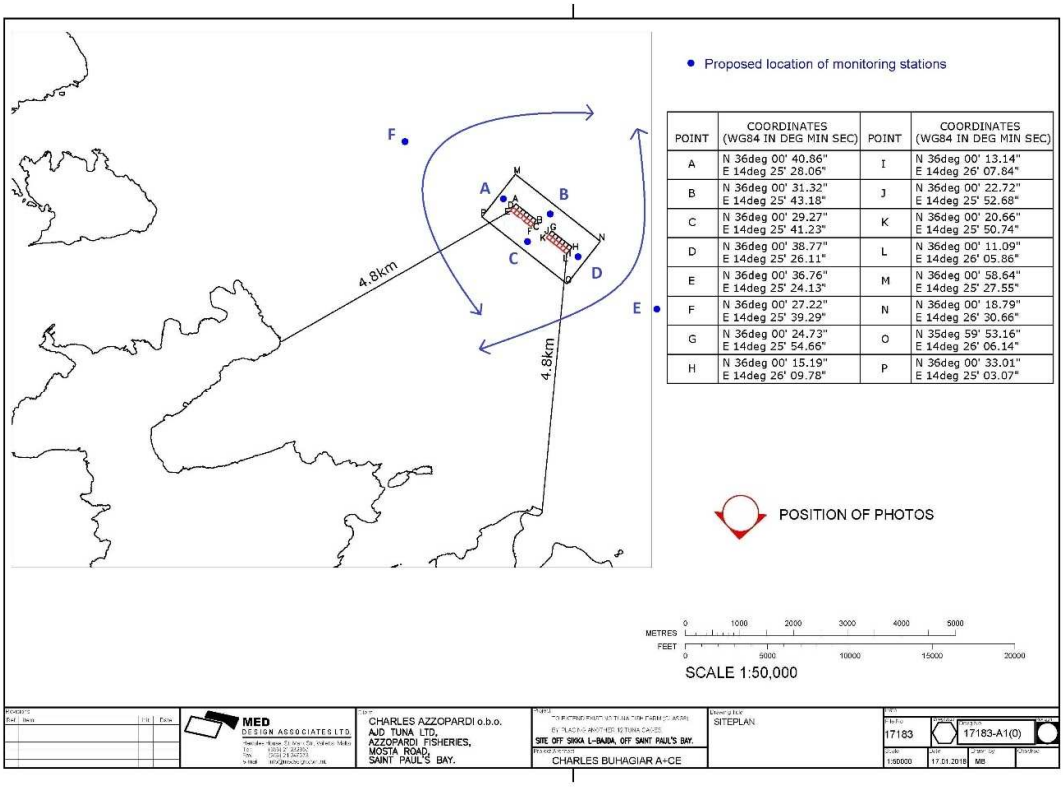


Figure 1. Map showing the location of AJD Tuna and MML's tuna penning sites off Mellieha Bay. The locations of the four stations A - D that have been used to monitor water quality during 2019 and 2020 are indicated. The new additional two sampling stations (E and F) are also indicated, however, it should be noted that their locations are not fixed but will be determined on the day of sampling, depending on the sea current direction (see main text in the present document). Base map source: ADI Associates Environmental Consultants.

In situ measurements and collection of seawater samples for later laboratory analyses, will be carried out at the same frequency and considering the same parameters as for the other four stations (A – D), and as detailed in the approved proposal for environmental monitoring.

Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site

Integrated assessment of monitoring of water quality and video surveys undertaken in 2022 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay

Prepared by

JOSEPH A. BORG
BSc MSc PhD (Plymouth) FIBMS FMBA FRSB CBiol

FOR

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

ECOSERV'S REPORT REFERENCE: 035-23

APRIL 2023

1. INTRODUCTION

1. An environmental monitoring program is required as part of the environmental permit (EP) for tuna penning operations carried out by AJD Tuna Ltd and Malta Mariculture Ltd at the 'North Aquaculture Site' (hereafter 'NAS') off Mellieha Bay. Ecoserv submitted a proposal for such environmental monitoring, which was subsequently approved by the Environmental Resources Authority (ERA). The proposal includes water quality monitoring, which is reported on in the present document.

2. The proposal by Ecoserv, bearing reference P-tuna-farming-monitoring_revised_082018 (See Annex 1), refers to collection of water samples from the four (4) monitoring stations from a depth of approximately 0.5 - 1 m. Additionally, the water quality survey includes *in situ* measurement of dissolved oxygen (DO), salinity, temperature and turbidity, at the same stations using a multi parameter meter. Measurement of current speed and direction also form part of the monitoring proposal. However, the sampling effort was subsequently (as of 2021) increased such that a total of six stations are monitored for water quality. Such modification of the monitoring design follows from advice received by the ERA based on the results from previous water quality monitoring sessions; such revision of the sampling plan is given in Annex 2. Two water quality sessions will be undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

3. With respect to monitoring of the seabed using underwater videography, Ecoserv's proposal refers to a video survey using a remotely operated vehicle (ROV) that will be undertaken below a select number of fish cages to assess the following:

   - Level of uneaten feed accumulating on the seabed;
   - Species diversity and abundance of megafauna;
   - Marine litter; and
   - Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

   The ROV will be navigated below a select number of tuna cages at the NAS; this will enable collection of the necessary video footage, which will be later analysed in the laboratory. It was proposed that video footage of the seabed will be collected in the vicinity of eight cages (4 cages at each of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites) at the SAZ. The tuna cages selected for monitoring using video footage collected by an ROV will be chosen at random by the scientists on the day of monitoring, but the selected cages will be as distant from each other as possible to allow for representative assessment. Video footage of the seabed will also be collected at stations located at a distance from the NAS but where the bottom may support a habitat of high ecological importance; e.g. seagrass *Posidonia oceanica* habitat present at Sikka l-Bajda located south of the NAS. Ecoserv's proposal (see Annex 1) gives further details of the advantages and uses of the outcomes from such video survey, and the reader is referred to the relative document.

4. Finally, the obligations set out in the permit also refer to an integrated assessment of the environmental monitoring undertaken during any one year. The present document comprises Ecoserv's report of integrated assessment of the findings from the water quality monitoring and video survey sessions undertaken in 2022 in the vicinity of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay (northeastern coast of Malta).

2. METHODOLOGY AND RESULTS

Water quality

5. Fieldwork in relation to the 2022 water quality sessions was undertaken in August and October. The August 2022 session was held later than originally planned but this resulted from logistical reasons. The day of holding of the survey was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. In situ measurements and collection of seawater samples were made at a total of six stations.

6. To view the methodological details and results of the *in situ* measurements and laboratory analyses, the reader is referred to Borg and Agius (2022a; 2023a). During both the August and October 2022 session, the two farms had tuna in most of their cages.

7. The results of the August 2022 water quality monitoring session indicated, overall, that levels of the monitored attributes at the NAS were within a range that is expected for local coastal offshore waters in summer; no appreciable differences in levels of the monitored attributes were noted amongst the six stations including the 'down-current' station, and the 'up-current' station. However, some patches with a white oily slick and foam having a fishy odour were present in the vicinity of the tuna penning sites, although no large amounts of the floating substance were present.

8. The results of the October 2022 water quality monitoring session indicated that levels of the monitored attributes at the NAS were within a range that is expected for local coastal offshore waters in autumn; no overall appreciable differences in levels of the monitored attributes were noted amongst the six stations, including the 'down-current' station. Values for TOC were marginally higher in the vicinity of the cages when compared to the reference stations, and one station (Station C) had a significantly higher value for total nitrogen but this was considered to be anomalous. A fishy odour was detected in the vicinity of the cages.

9. The conclusions reached for both the August and October 2022 water quality monitoring sessions were that, excluding the patches with a white oily slick and foam having a fishy odour present in the vicinity of the tuna penning sites in August 2022; and the marginally higher values of TOC recorded in the vicinity of the cages, the anomalously high level of nitrogen recorded at Station C, and the fishy odour present in the vicinity of the cages noted in October 2022, values of the monitored attributes were generally within a range that would be expected of local offshore waters. Hence, no appreciable differences in water quality were noted amongst the six monitored stations, including the 'down-current' and 'up-current' stations. Accordingly, the authors concluded that, overall, the tuna farming activities at the NAS did not result in appreciable alteration of water quality in terms of the monitored attributes.

Video survey

10. Fieldwork in relation to the 2022 video surveys was undertaken in July and October. The July 2022 session was held later than originally planned but this resulted from logistical reasons. The day on which the survey was held was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Video footage of the

seabed was collected using an ROV deployed from a 10 m vessel. During fieldwork, the ROV was deployed adjacent a tuna pen at a given compass cardinal point and lowered to the seabed there. The ROV was then manoeuvred to the other side of the tuna pen, i.e. towards the opposite compass cardinal point, while collecting video footage of the seabed. Video imagery from the ROV was recorded by the unit's HDI camera and saved on a laptop's hard disc on board the vessel during deployment. In both the July and October 2022 surveys, video footage was collected from below a total of eight tuna pens – four cages at each of the two tuna penning sites (AJD Tuna Ltd and Malta Mariculture Ltd) located within the NAS, and at four reference sites Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference. Following each session, the video record was analysed in the laboratory. Characterisation of the benthic assemblages was made using the scheme of Borg *et al*. (2013), which is based on the EUNIS typology that has been adapted for local use.

11. The 'uneaten food index' designed by Borg & Schembri to enable comparison of the relative amounts of dead fish present under the pens (see Holmer et al, 2008) was used in the assessments to quantify the amount of uneaten feed fish present on the seabed below a tuna pen, if applicable. The index, which ranges between 0 and 4, is described in Table 1.

Table 1.

The 'uneaten food index' devised by Borg & Schembri (see Holmer et al., 2008) for the purpose of quantifying and comparing the amount of dead uneaten feed-fish under the different tuna-pens.

Index value	Description
0	No uneaten fish present
1	< 1 uneaten fish present per m^2 of seabed
2	> 1 uneaten fish present per m^2 of seabed, but the fish do not form a continuous layer covering the seabed
3	> 1 uneaten fish present per m^2 of seabed. Fish form a single, uninterrupted layer within at least a $1m^2$ area on the seabed.
4	> 1 uneaten fish present per m^2 of seabed. Fish form two or more uninterrupted layers on top of each other within at least a $1m^2$ area on the seabed.

12. The results of the two sessions held in 2022 have been presented as reports and annexed video footage showing the state of the seabed at the tuna pens and reference sites surveyed. To view further details of the methodology used during the ROV surveys and full details of the findings thereof, the reader is referred to Borg and Agius (2022b; 2023b).

13. During the July 2022 session, video footage was collected from the four reference sites (Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference) and from below the following cages:

<u>AJD Tuna Ltd</u>
AJDT Cage 4
AJDT Cage 5

AJDT Cage 16
AJDT Cage 17
Malta Mariculture Ltd
MML Cage 7
MML Cage 9
MML Cage 20
MML Cage 23

During the October 2022 session, video footage was collected from the four reference sites (Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference) and from below the following cages:

AJD Tuna Ltd
AJDT Cage 3
AJDT Cage 6
AJDT Cage 14
AJDT Cage 17

Malta Mariculture Ltd
MML Cage 9
MML Cage 12
MML Cage 19
MML Cage 23

14. During both the July and October 2022 video monitoring sessions, most of the cages belonging to the two farms held tuna.

15. The results of the July 2022 session indicated the following:

- The recorded natural physical characteristics of the seabed at Malta Mariculture Ltd's and AJD Tuna Ltd's tuna penning site were the same as those noted during previous video surveys and were also typical of the bottom present off the northeastern coast of Malta within the 50 m – 80 m depth range, and at is-Sikka l-Bajda. However, in terms of anthropogenic influence, the presence of: (i) anthropogenic items originating from the tuna penning activities; (ii) tuna carcasses and skeletal remains, and (iii) patches with uneaten feed fish; may arguably be seen as resulting in some alteration of the physical characteristics of the seabed at the tuna penning sites. Such interpretations are similar to those from previous monitoring sessions.

- The recorded biological characteristics of the seabed indicated the presence of the same benthic habitats that were noted during previous monitoring sessions; overall the state of the seabed appeared good and the recorded benthic biota included megafauna (e.g. the urchin *Spatangus purpureus*) that were typical of the habitat. However, the authors noted a high density of some megafauna, which almost certainly resulted from the presence of elevated levels of organic matter on the seabed originating from uneaten feed fish and other waste generated by the tuna farms, given that these species feed on such matter. A high abundance of rays was also recorded below several of the tuna cages; these fish would have been attracted by the presence of uneaten feed fish, which they consume. At the southwestern (Sikka l'Bajda) reference site, the seagrass (*P. oceanica*) meadows appeared to be in a very good state and seemed unaffected by the tuna penning activities. The demersal and pelagic

fish fauna present in the vicinity of the tuna cages comprised species that are typical of local coastal areas but were present in high densities as a result of being attracted to food and waste originating from the tuna farms. Overall, the recorded biological characteristics indicated that some of the recorded megafaunal species are the same ones that are naturally associated with the habitat type (association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents) present within the surveyed area, and that the rhodolith accumulations appeared to be in a good state. Some benthic megafauna and rays that were attracted to the uneaten feed fish released from the tuna pens occurred in higher densities than is usual for the seabed habitat in its natural state. Therefore, in this regard, one may contend some alteration to the biological characteristics of the seabed in some places below the tuna cages at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites.

16. The results of the October 2022 session indicated the following:

- The recorded natural physical characteristics of the seabed at Malta Mariculture Ltd's and AJD Tuna Ltd's tuna penning site were the same as those recorded during previous video surveys and are also typical of the bottom present off the northeastern coast of Malta within the 50 m – 80 m depth range, and at is-Sikka l-Bajda. In term of anthropogenic influence, the presence of: some items originating from the tuna penning activities, a few tuna carcasses and skeletal remains, a few patches with uneaten feed fish, and some patches with *Beggiatoa*; could arguably be seen as resulting in some alteration of the physical characteristics of the seabed at the tuna penning sites. Such interpretations were similar to those from previous monitoring sessions. On the other hand, the authors noted an appreciable decrease in the number of tuna carcasses recorded on the seabed underneath the cages, which is an improvement on previous years.

- The recorded biological characteristics indicate that the seabed below the eight tuna pens and at three of the reference sites supported the same benthic habitats that have been recorded from previous video surveys. Several megabenthic biota (e.g. the urchin *Spatangus purpureus* and the crinoid *Antedon mediterranea*) recorded during the survey were typical of the habitat types present but some species were present in very high densities. As for the previous July 2022 session, the authors noted that this probably resulted from the presence of elevated levels of organic matter originating from uneaten feed fish that attract the megafauna. Likewise, the high abundance of rays recorded below several of the tuna cages evidently results attraction to uneaten feed fish, which they consume. At the southwestern (Sikka l'Bajda) reference site, the seagrass (*P. oceanica*) meadows appeared to be in a very good state and seemed unaffected by the tuna penning activities. The demersal and pelagic fish fauna present in the vicinity of the tuna cages comprised species that are typical of local coastal areas but were present in high densities as a result of being attracted to food and waste originating from the tuna farms. Overall, the recorded biological characteristics indicated the presence of the same megafaunal species that are naturally associated with the habitat types present within the surveyed area, while the rhodolith accumulations appeared to be in a good state. However, some benthic megafauna (namely *Centrostephanus longispinus*) and rays have been attracted to the uneaten feed fish that are released from the tuna pens, and occurred in unusual high densities. Therefore, in this regard, one may contend that some alteration to the biological characteristics of the seabed in some places below the tuna cages has occurred at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites.

4. APPRAISAL

Water quality

17. The results of water quality monitoring undertaken at the NAS during August and October 2022 indicated that, overall, the tuna farming activities at the NAS did not result in appreciable alteration of water quality in terms of the monitored attributes. Patches with a white oily slick and foam having a fishy odour were present in the vicinity of the tuna penning sites in August 2022; and marginally higher values of TOC recorded in the vicinity of the cages, an anomalously high level of nitrogen at Station C, and a fishy odour present in the vicinity of the cages, were recorded in October 2022. However, these observations were not deemed concerning.

18. In terms of cumulative impacts; the results of water quality monitoring undertaken during 2022 at the NAS indicated the absence of cumulative effects in the area.

19. Notwithstanding the above conclusions, it is recommended that the tuna farm operators make every effort to reduce the introduction of polluting substances to the marine environment, such as feed fish oils. If feed fish oils are released to the marine environment, these should be retained within the confines of the cages and collected using skimmers and / or other appropriate equipment. Any feed fish oils released to the marine environment, should not be allowed to be transported by water movement beyond the confines of the NAS.

Video survey

20. The results of both video surveys undertaken in July and October 2022 indicated that the natural physical characteristics, including water depth, underwater transparency and gross physical features of the seabed underneath the surveyed tuna cages at the NAS were similar to those at the reference sites. Furthermore, the physical characteristics of the seabed below the eight tuna pens surveyed and at the four reference sites were similar to those reported in previous video monitoring surveys and studies carried out at the NAS, including the baseline studies undertaken prior to initiation of tuna penning activities in the area. However, both 2022 sessions indicated the presence of anthropogenic items on the seabed below several of the cages, some of which (namely the short lengths of rope and small concrete weights with ropes attached) appeared to originate from the tuna farming activities, which indicates that the occurrence of anthropogenic items, including ones that appear to originate from the tuna penning activities, has persisted.

21. During the July 2022 session, some tuna carcasses and skeletal remains, and a few patches with uneaten feed fish, were recorded underneath the cages. During the October 2022 session, some tuna carcasses and skeletal remains, a few patches with uneaten feed fish, and some patches with *Beggiatoa*, were recorded underneath the cages. However, an appreciable decrease in the number of tuna carcasses present on the seabed underneath the cages was recorded in October 2022 when compared to the findings from the previous July 2022 session and surveys made in precious years, which is viewed as an improvement on previous years. The recorded presence of patches with *Beggatoa* on the seabed below some of the cages results from nutrient enrichment of the bottom sediments, and is a common occurrence at fish farm cage sites worldwide, particularly in places that are characterised by a low energy regime. The particularly calm

conditions that prevailed during summer and the beginning of autumn 2022 would have promoted the presence of the bacterial mat at the NAS, given that the latter does not qualify as a coastal area that has a low energy regime. It is predicted that sea storms at the NAS during autumn and winter 2022 will lead to heavy disturbance of the seabed and disappearance of the *Beggatoa.*

22. The presence of tuna carcasses in different stages of decomposition, as well as of skeletal remains and bones of tuna, has been discussed in previous integrated assessment reports. The site manager at the NAS fish farms insists that the carcasses did not originate from the tuna farm activities but from fishing of wild tuna by professional and / or amateur fishermen that enter the NAS. As has already been reported, it appears that fishermen sometimes have difficulty retrieving tuna as the line used to catch them gets entangled against the cage mooring ropes and the fishermen end up cutting the line, which eventually leads to death of the tuna and deposition of the latter on the seabed. At other times, on seeing government authorities approach them, the fishermen cut the line on which a tuna would have been caught and since the fish would have suffered exertion, or possible have already died in the process, it eventually ends up dead on the seabed. Such incidents involving fishermen carrying out activities in the vicinity of local tuna farms, leading to dead tuna on the seabed below tuna cages and areas in their vicinity, is documented in the scientific literature (for example, Arechavala-Lopez et al., 2015). Other incidents, such as entanglement of wild tunas that try to get to the feed fish in cages and end up getting entangled in nets, eventually detaching from the cage and sinking to the seabed without being detected, may also be the reason for dead tuna ending up on the seabed. The recorded skeletal remains and bones on the seabed in the vicinity of the cages most probably originate from tuna carcasses that would have decomposed.

23. Patches with uneaten feed fish were recorded under some tuna cages during both the July and October 2022 sessions but on comparing the amount present during the 2021 tuna penning season with that recorded in 2022, a decrease is noted during the latter, which is deemed to be an improvement. As already indicated in previous reports, the cause for feed fish deposited on the seabed may result from accidental spillage and / or reduced appetite of the tuna during feeding.

24. As noted in previous integrated assessment reports, the presence of high numbers of scavenging benthic macrofauna (namely urchins) and demersal fish fauna (namely rays) indicate that the organic material originating from the tuna carcasses and feed fish deposited on the seabed were being consumed through scavenging activities. The tuna carcasses and skeletal remains of dead tuna are expected to lead to addition of organic material to the seabed; if the latter reaches high levels there may be undesirable effects, including anoxic conditions, that would impact benthic habitats adversely. This would especially hold true if the scavengers present do not cope with consuming large amounts of decomposing remains of the tuna. However, unless the decomposing tuna and uneaten feed fish are present in large amounts, which the 2022 monitoring sessions indicated was not the case, such effects will be temporary since decomposition and the action of scavenging fauna will, over a few weeks to a few months, result in removal of tuna carcasses and uneaten feed fish deposited on the seabed, such that in the long term there will be no residual impact. The tuna penning fallow period between January and March / April helps to ensure such process and prevents cumulative effects which would result if deposition of large amounts of uneaten feed fish and / or tuna carcasses on the seabed is continuous over a long period of many months / several years. Nevertheless, the mitigation measures emphasised below should be noted.

25. With regard to anthropogenic items present on the seabed, some of which appear to have originated from the tuna farming activities; although this has persisted, comparison of the amount recorded during the July and October 2022 sessions with that recorded during previous sessions indicates no increase, and no appreciable accumulation.

26. In terms of biological characteristics, the findings from both the July and October 2022 surveys indicate similar features of the seabed below the tuna pens when compared to the reference sites that had the same bottom type. As already indicated in previous integrated assessment reports, the predominant habitat type is Sublittoral Sediment (EUNIS code A5), of which the predominant assemblage type was an association with rhodoliths in coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515). In places, the coarse sediment characterising this assemblage type supports accumulations of rhodoliths which in places support stands of macroalgae. The benthic megafauna associated with this habitat type were noted to be typical of the habitat type and mostly comprised the Heart Urchin *Spatangus purpureus*, the Red Lance Urchin *Stylocidaris affinis,* the Long-Spined Urchin *Centrostephanus longispinus*, and the crinoid *Antedon mediterranea.* The seabed at the Sikka l'Bajda reference site supports a mosaic with patches of the biocenosis of *Posidonia oceanica* meadows (EUNIS code A5.535) and the biocoenosis of infralittoral algae (EUNIS code A3.131). The seagrass (*Posidonia oceanica*) present there appeared to be in a good state and unimpacted by the tuna penning activities. However, during both the July and October 2022 sessions, some of the recorded megafaunal species (mostly *S. affinis* and *C. longispinus*) were present in unusually high numbers, which can be attributed to organic enrichment of the seabed underneath the tuna cages. The organic matter serves as food for macro- and megafaunal species, supporting a high density of the organisms. Uneaten feed fish served to also attract demersal scavengers, namely rays, which fed on the baitfish. Otherwise, the high cover and healthy state of fleshy macroalgae and of the coralline algae making up the rhodoliths, and the presence of typical megafaunal species, all of which were recorded in association with the main benthic habitat present below the tuna cages and at the four reference sites, as well as the typical demersal fauna recorded from the surveys, indicate that no appreciable adverse impacts of the tuna penning activities on the biological characteristics of the seabed had occurred at the NAS. Therefore, in terms of adverse impacts, it appears that no appreciable adverse cumulative effects with respect to biological characteristics have occurred within the NAS, at least insofar as could be deduced from the results of direct observation of the seabed using ROV, although some alteration is evident given the increased abundance of megafaunal and demersal fish species recorded in the area. As already indicated above, the fallow period practiced by the tuna operators during January to March / April of each year (when there are hardly any tuna penning activities) serves to allow natural recovery of the benthic environment to a state which is similar to that at pristine sites having the same environmental characteristics. Nevertheless, the mitigation measures emphasised below should be noted.

27. In conclusion, the findings from the 2022 water quality and video surveys indicate that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning activities may be seen as resulting in some alterations to the physical and biological characteristics of the seabed at the NAS. However, given that the alterations are not large and are reversible, the reported changes to benthic environment at the tuna penning sites are not deemed concerning. Furthermore, in terms of cumulative impacts on the physical and biological characteristics of the seabed, the results of the two video surveys undertaken during 2022 indicate no appreciable cumulative effects.

5. RECOMMENDATIONS

28. To mitigate potential alterations to the physical and biological characteristics of the seabed within the SAZ, the following recommendations are reiterated:
    1. Feeding of the tuna should be carefully monitored and feeding should be stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten food ending up on the bottom.
    2. Measures should be taken to avoid anthropogenic litter ending up on the seabed. In the eventuality that anthropogenic items end up on the seabed by accident, every attempt should be made to retrieve (which given the water depth of around 50 m at the NAS should be possible), and dispose of them in an appropriate manner.
    3. Measures should be taken to avoid having tuna carcasses or the remains of dead tuna ending up on the seabed below the cages and in their vicinity, even if this is not the direct result of action by the tuna farm operators; in this respect retrieval of tuna carcasses and / or remains of dead tuna, as long as these have been freshly deposited, is possible at the NAS given that the water depth is around 50 m and accessible to divers who can undertake such retrieval.

29. Given that the various water quality and video monitoring sessions held at the NAS since 2019 have indicated a more or less consistent pattern of findings, the present author suggests that the reports of monitoring sessions will have reduced detail and have a more concise layout, such as the one proposed recently to the ERA following the meeting held on 17-3-23, a draft version (for video monitoring during 2022) of which was also submitted to the Authority via email.

4. REFERENCES

Arechavala-Lopez P., Borg J. A., Segvic-Bubic T., Paolo Tomassetti P., Özgül A. & Sanchez-Jerez P., 2015. Aggregations of wild Atlantic Bluefin Tuna (*Thunnus thynnus* L.) at Mediterranean offshore fish farm sites: Environmental and management considerations. Fisheries Research 164: 178-184.

Borg J. A. (2017). Report on a video survey of benthic habitats in an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, made in May 2017. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. (2018). Report on an ecological assessment of an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, undertaken as part of the Environment Impact Assessment in connection with PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. & Agius A. (2020a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 34pp.

Borg J. A. & Agius A. (2020b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in October 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 36pp.

Borg J. A. & Agius A. (2020c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in April 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 22pp.

Borg J. A. & Agius A. (2020d). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in September 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 23pp.

Borg J. A. & Agius A. (2021a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 12pp.

Borg J. A. & Agius A. (2022a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in September 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 11pp.

Borg J. A. & Agius A. (2021b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in May 2021 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 19pp.

Borg J. A. & Agius A. (2022b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in October 2021 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 21pp.

Borg J. A. & Agius A. (2022a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in August 2022 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 12pp.

Borg J. A. & Agius A. (2023a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in October 2022 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 11pp.

Borg J. A. & Agius A. (2022b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in July 2022 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 19pp.

Borg J. A. & Agius A. (2023b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in October 2022 in the vicinity of

AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 21pp.

Holmer M., Hansen P. K., Karakassis I., Borg J. A. & Schembri P. J., 2008. Monitoring of Environmental Impacts of Marine Aquaculture. In: Holmer M., Black K., Duarte C., Marba N., & Karakassis I. (editors) Aquaculture in the Ecosystem; pp. 47-85. Heidelberg, Germany: Springer; 326pp.

ANNEX 1

Environmental monitoring of tuna farming activities

Proposal for regular environmental monitoring of tuna farming activities at offshore sites

Prepared by

Joseph A Borg BSc MSc PhD (Plymouth) CBiol MRSB MMBA FIBMS

12, Sir Arthur Borton Street
Mosta, MST14
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

Ref: P-tuna-farming-monitoring_revised_082018

August 2018

Preamble

1.1 **Ecoserv Ltd (henceforth Ecoserv) has received requests from tuna farmers having operations in the Maltese Isalands, for environmental monitoring of the tuna penning activities. The terms of reference (ToR) for the environmental monitoring have been provided by the Department of Fisheries and Aquaculture (DFA) and the Environment and Resources Authority (ERA).**

1.2 **The ToR for environmental monitoring of tuna farming activities in Malta, as issued by the ERA, are comprehensive and follow the guidelines which one would expect for the monitoring of sea-based fish farm activities. However, given that tuna farming installations have recently (in 2017) been moved offshore (> 1 km offshore), the present consultant, together with Adi Associates Environmental Consultants Ltd, jointly acting on behalf of all the tuna farming operations in Malta, held discussions with the ERA with a view to revise the ToR of environmental monitoring The aim of this revision is to focus the monitoring on the components that are more readily indicative of potential adverse impacts, for there to be prompt issue of results, and to ensure cost-effectiveness of the monitoring programme. Justification for the proposed revision is partly based on the avilability of extensive data from environmental monitoring of local fish farming activities carried out over a period of more than 15 years.**

1.2 **The present document constitutes Ecoserv's revised proposal for environmental monitoring of offshore tuna farming activities in Malta following discussions held with the ERA in early August 2018.**

Brief overview of findings from environmental monitoring of tuna farming activities in Malta

2.2 Environmental monitoring of tuna farming activities has been ongoing at the offshore sites (located 1 km offshore) used by Azzopardi Fisheries Ltd (AF), FishandFish Ltd (F&F) and Malta Fishfarming Ltd (MFF) since 2000. The monitoring can be broadly divided into two main categories: (i) Water quality and (ii) monitoring of seabed physical and biological attributes. A brief description of the monitoring components, as well as a summary of the findings for each of these follows.

(i) <u>Water quality surveys</u>

Most of the water quality surveys carried out at the 3 tuna penning sites have been made at a bimonthly frequency, although some of the farms did not undertake any monitoring during some periods that extended several months. During the surveys, standard water quality attributes, namely dissolved oxygen, temperature, salinity, turbidity, nitrates, phosphates, Chlorophyll *a*, ammonia, and counts of intestinal bacteria, as well as sea current direction and speed, were measured at a number of sampling stations located in the immediate vicinity of the tuna farms and at up-current and down-current reference stations.

The results of the water quality surveys carried out to date indicated that, very rarely, lowered levels of oxygen, reduced water transparency and elevated nutrient (nitrates and/or

phosphates and/or ammonia) levels were sometimes recorded from the tuna penning sites during the farming season (July – December). However, the observed changes in the monitored attributes were often sporadic and not statistically significant, and have not resulted in appreciable alteration of water quality. Elevated counts of intestinal bacteria were also occasionally recorded but since such organisms do not originate from the tuna but from sewage, these results were not attributed to the tuna penning activities *per se*, although there is the possibility that large ships (e.g. processing ships) present in the vicinity of the farms may be the source of such contamination through discharge of sewage from their holding tanks.

Overall, therefore, the reports of surveys made within this monitoring category concluded that the tuna penning activities had not led to appreciable alteration of water quality in the vicinity of the tuna farms. However, it should be pointed out that some substances that appear to originate from the tuna farms and which were not monitored during the water quality surveys have been recorded to occur in waters in the vicinity of all three tuna penning sites and at a considerable distance away. Essentially, such substances are oils and fats that are released from the feed-fish when these are fed to the tuna. Release of such substances occurs when the feed fish are introduced in the tuna pens and when uneaten feed-fish end up outside the fish cages, and decomposition leads to release of fatty substances that accumulate on the surface and are transported offshore or inshore, depending on sea current strength and direction. Such substances are deemed to have no toxic effects on marine species and habitats, but are a nuisance to bathers, divers and coastal recreational activities, because of their sheer presence in the water and since they deposit on the shore and artificial surfaces (e.g. boat hulls etc.). It is pertinent to point out that although deposition of such substances is not envisaged to have any large adverse effects on marine species and habitats, especially those associated with the shore, this has not been assessed given the complete lack of studies that deal specifically with this aspect. Episodes that were characterised by the occurrence of such floating substances were particularly notable during the summer of 2016, when complaints and awareness of the issue by the general public reached an all-time high. The floating substances were commonly referred to as 'slime', and common sightings of the floating substance and the inconvenience it created to sea users even led to launching of a Facebook page titled 'Stop The Slime' (https://www.facebook.com/stoptheslimemalta). Concurrently, in October 2016 and during the winter and spring of 2017, episodes of occurrence of massive floating 'foam' were recorded from vast areas of Maltese coastal waters. While the occurrence of 'slime' could, directly or indirectly, be linked to fish farming activities, the occurrence of foam is in all probability related to substances secreted by algae, which when churned up by rough sea conditions lead to generation of the observed 'foam'.

(ii) Monitoring of seabed physical and biological attributes

This category has five main monitoring components, namely:

a. Video surveys of the seabed in the vicinity of the tuna pens

The main aim of this monitoring component is to gather qualitative and semi-quantitative data, using direct observation, on the physical and biological characteristics of the seabed underneath the tuna pens. Such surveys involve videography along transects below the tuna pens, and have been carried out twice per year (in October and February) in some years and more recently once per year, usually during the period October – December.

The results of this monitoring component can be summarised as follows:

- Towards the end of each penning season (in autumn) considerable amounts of uneaten feed-fish littered the seabed in the area lying directly below the tuna pens, but not in areas beyond the perimeter of the tuna pens. This resulted in alterations in the physical and biological characteristics of the seabed under the pens, namely:
    - Changes in biological characteristics which typically consist of high population densities of detritus-feeding and scavenging benthic (i.e. associated with seabed) fauna (e.g. the ophiuroid *Ophiura texturata*, the crab *Inachus* sp., the hermit crab *Pagurus* sp. and an unidentified goby).
    - Alterations in physical characteristics which typically consist of the presence of large quantities of fish bones and baitfish that are gradually consumed by scavengers or eventually decompose. There was also a considerable amount of anthropogenic items below the pens that originated from the farm operations, including concrete weights with ropes attached, sheets and sacks of fabric and other material, car tyres, lengths of rope and shot gun cartridges.
- The amount of uneaten baitfish present varied considerably between the different pens, and between different farms, with some only having a few feed-fish beneath them and others having multiple layers of decomposing feed-fish. Once the tuna farming season is over (late winter), a negligible amount of uneaten feed-fish remain on the seabed below the pens. However, thick layers of fish bones and of decomposing organic material persist under some of the pens. These observations indicate a consistent pattern, with the volume of uneaten feed-fish on the seabed decreasing only when the tuna have been harvested (and therefore there is no further addition of feed-fish). Any uneaten fish remaining on the seabed at this time will continue to decompose slowly and, if present in large numbers, form a continuous layer of decomposing organic material. Sometimes, following storms and possibly due to strong bottom currents, this layer is admixed with the underlying mobile sediment. In places where the decomposition process is complete, the only remains are fish bones that eventually disperse in the sediment leaving little or no trace of the original uneaten fish on the surface. Once the source of the impact (periodic addition of new uneaten food) is removed, slow recovery to the original state is characterised by the re-appearance of certain megafaunal species (e.g. the irregular sea urchin *Spatangus purpureus* and the crinoid *Antedon mediterranea*) that form part of the original fauna that characterise the bare muddy sand bottom of the areas where the tuna farms are located.
- The latest video surveys indicated the occasional presence of whole decomposing tuna on the seabed below a few of the tuna cages at the tuna penning sites. However, the tuna farm operators are adamant that the tunas have not originated from the farms. According to the tuna farm site managers, the tunas ended there following capture and subsequent release (accidental or deliberate) by amateur fishermen who would have caught the fish from the wild in the vicinity of the tuna pens. Apparently, local tuna farms are being frequented by amateur fishermen who deploy their fishing lines

with an aim to catch wild tuna that aggregate around the tuna farm; the latter phenomenon has been observed during the past few years at several tuna penning sites in the Mediterranean. Any tunas that are caught and: (i) either break free, or (ii) are cut free by the fishermen[1], die soon after release and end up on the seabed, where they decompose slowly. It appears that the local Fisheries and Aquaculture Department is aware of this problem.

b. Monitoring of physico-chemical attributes

The main aim of this monitoring component is to assess levels of organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics. Moreover, at least one survey involving assessment of levels of pollutants, including heavy metals and organic pollutants, was carried out at each of the three tuna penning sites. The monitoring design of the surveys to assess organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, is based on a Beyond **BACI**[2] layout, in which the results of quantitative analyses of sediment samples collected from the tuna farming site and from a number of control sites before the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. Such surveys were mostly carried out on a yearly basis; however, the AF tuna penning site was monitored twice per year during some years, while no monitoring was carried out at some of the tuna penning sites during some years.

Overall, the findings from surveys that were aimed at assessing organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, indicated 'pulse' (i.e. short duration) changes in the physico-chemical properties of the sediment following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens but no significant permanent alterations of the sediment characteristics at the operational sites have been recorded to date. Where significant changes were detected, these appeared to have resulted from accumulation of large amounts of uneaten feed-fish in the vicinity of the tuna pens, which decompose slowly causing alterations in the physico-chemical properties of the sediments.

The results of the surveys aimed at assessing levels of heavy metals and pollutant organics indicated that no harmful levels were present in the sediments in the vicinity of the tuna farms.

c. Monitoring of benthic diversity

The main aim of this monitoring component is to assess for potential changes in species populations and seabed habitat that may result from the tuna penning activities. The monitoring design is based on assessing total species richness and total abundance of selected benthic faunal species, as these are deemed good indicators of the overall state

[1] According to the site managers, the wild tuna caught by the amateur fishermen are sometimes cut free on being approached by fisheries officers who make regular site visits to the fish farms using a vessel owned by the local fisheries department.

[2] **B**efore **A**fter **C**ontrol **I**mpacted; see Underwood (1992): Underwood, A. J. (1992) Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161: 145 –178.

of species and habitats associated with the seabed. As in the case of the physico-chemical attributes monitoring component, the design for monitoring of benthic diversity is based on a Beyond **BACI** layout, in which the results of quantitative analyses of samples collected from the tuna farming site and from a number of control sites **before** the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. As in the case of the physico-chemical attributes monitoring component, monitoring of benthic diversity was mostly carried out on a yearly basis, however, the AF tuna penning site was monitored twice per year during some years, while no monitoring was carried out at some of the tuna penning sites during some years.

Overall, the findings from this component indicated that a significant 'press' (i.e. long-lasting) adverse impact (manifested as a significant decrease in total macroinvertebrate species richness and/or decrease in the abundance of one or more of the indicator species) had occurred following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens. Furthermore, enhanced productivity in the general area of the tuna farms and beyond, as a result of the tuna-penning activities, was evident from significant increases in the abundance of some of the indicator species recorded in some of the monitoring sessions.

These observations are a strong indication that, where present, adverse impacts on the benthic macroinvertebrate assemblages at the operational sites have resulted from processes that are mainly attributed to accumulation of large amounts of uneaten feed-fish and the slow decomposition of same, in the vicinity of the tuna pens. The uneaten feed-fish attract scavengers and other opportunistic fauna that cause changes to the original species composition of the benthic assemblages, while slow decomposition of the accumulated material causes alterations in the physico-chemical properties of the sediments, and presumably of the sediment-water interface, leading to adverse conditions for the biota originally present.

Over the past few years, data from 10 years of environmental monitoring of the tuna farms owned by AF, F&F and MFF, was subjected to detailed study and analyses as part of a PhD programme of research undertaken at the Department of Biology of the University of Malta, for which the present author is supervisor. To date, THREE papers have been published in leading peer-reviewed international journals, highlighting the study results; see Mangion *et al.*, 2014; 2017; 2018). Copies of these publications are appended to the present report for ease of reference. In summary, the results of these studies indicated that:

- For the largest tuna farm (located off the northeastern coast of Malta), the activity resulted in significant changes to sediment physico-chemical attributes and to the macroinvertebrate assemblages of soft bottom habitats located in the immediate vicinity of the fish cages up to a distance of some 200 m from the farm. However, it appears that the magnitude and spatial extent of the impact also depended on the feed management regime adopted at a tuna farm.
- High spatio-temporal variability in attributes of the macrobenthic invertebrates in the vicinity of three tuna farms (AF, F&F and MFF) was evident; this indicates that change in macroinvertebrate assemblages resulting from tuna farming activities differs between different farms. This observation corroborates the expectation that the level of influence of tuna farming activities on benthic habitats in the vicinity will vary with

the fish stocking density, the length of time a farm has been in operation, and the feed management strategy adopted at the farm during the production period.

- Significant correlation at the control plots between attributes of the macroinvertebrate assemblages and sediment physico-chemical attributes 1–2 km away from the tuna cages suggests that some influence of tuna farming may occur over a wider spatial extent than expected. However, given the high degree of overlap between different marine-based activities around the Maltese Islands, particularly in their southern coastal areas, it is also possible that other sources of organic enrichment apart from the tuna penning activities may be influencing the coastal waters where the tuna farms are located.

d. Monitoring of habitats of ecological importance

The aim of this monitoring component is to assess for potential adverse impacts of the tuna penning activities on marine habitats located near the tuna farms, namely seagrass *Posidonia oceanica* habitat. This monitoring component was undertaken annually between 2003 and 2006 at the AF and MFF tuna penning sites. The surveys were based on a beyond **BACI** design, in which quantitative morphometric data reflecting the state of the seagrass located closest to the farms is compared with that at a number of control sites.

The results of this monitoring component indicated no consistent trends of significant alterations in the state of *Posidonia oceanica* seagrass that may be attributed to the tuna farming activities. Consequently, the MEPA advised the tuna farm operators that this monitoring component need not be continued; hence no further sessions were undertaken after 2006.

e. Monitoring of popular dive sites

The aim of this monitoring component, which involved surveys of the state of the physical and biological characteristics of the seabed habitats, is to assess for potential adverse impacts of the tuna penning activities at popular dive sites located near some of the tuna farms. Such monitoring involved videography, assessment by direct observation and mapping surveys along transects within a defined area that includes the confines of the dive site. The sites monitored were: (i) 'Imperial Eagle' and 'Stubborn' dive sites, both of which are located not far from the AF tuna penning site; (ii) the 'Blenheim' dive site, located not far from the F&F tuna penning site; and (iii) Munxar Reef, located not far from the MFF tuna penning site. One survey per year was carried out at these sites between 2003 and 2006.

Monitoring of the physical and biological characteristics of the bottom at the dive sites showed no consistent trends of significant alterations of the seabed features as a result of the tuna farming operations. Consequently, the MEPA advised the tuna farm operators that this monitoring component need not be continued; hence no further session were undertaken after 2006.

2.3 The results of extensive environmental monitoring programmes held at the tuna penning sites used by AF, F&F and MFF during the past 15 years or so indicate that the main marine environmental impacts that may be attributed to the tuna penning operations are as follows:

(i) Alteration of physical and biological characteristics of the seabed below the tuna pens via deposition of large amounts of uneaten feed-fish, and anthropogenic items originating from the tuna farm operations. Although the uneaten feed-fish 'overwhelm' the seabed ecosystem since the typical fauna do not manage to consume all the uneaten feed, which therefore accumulates on the bottom and probably also spills over (albeit in smaller form, e.g. as particulate organic matter) to adjacent areas, it is ultimately biodegradable and does not persist in the environment for long. The uneaten feed-fish serve as a source of nutrient enrichment of the benthic ecosystem in the vicinity of the tuna farms and adjacent areas, resulting in increased productivity. However, this should not be considered a pretext for allowing addition of uneaten feed to the marine environment. As stated in the monitoring reports:

   a. Feeding of the tuna should be carefully monitored and stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten feed ending up on the bottom. The tuna operators may want to implement a procedure to ensure proper feed management by having random checks of the seabed below the tuna pens made by an independent environmental monitor.

   b. In the case of accident, should an inordinate amount of dead uneaten feed-fish end up on the bottom, every attempt should be made to remove as much of the material as possible using techniques that do not have an adverse effect on the seabed habitat.

   c. Uneaten feed-fish are most probably the source of oils and fats which eventually rise to the surface and are transported by sea currents to inshore areas where, rather than having a toxic effect on shallow water and shore marine species and habitats, they are a nuisance to coastal users including bathers and divers. On the other hand, the effects of such oils and fats on the ecology of shore habitat are not known. However, one would assume that they do not have appreciable adverse effects.

   d. If the situation concerning the presence of dead tuna is as described by the operator, i.e. it is resulting from uncontrolled fishing in the vicinity of the tuna farms, then there is a need for such an activity to be curbed. Furthermore, even if the dead tunas do not originate from the farms themselves, it would be beneficial if these are possibly removed from the seabed.

   e. Anthropogenic items deposited on the seabed as a result of the tuna penning operations, such as concrete weights, ropes etc should be removed and not allowed to accumulate on the bottom.

(ii) Alteration of water quality mainly via addition of oils and fats when feed-fish are fed to the tuna. As already stated above, any introduced oils and fats may be transported by sea currents to inshore areas where, rather than having a toxic effect on shallow water and shore marine species and habitats, they are a nuisance to coastal users including bathers and divers. On the other hand, the effects of such oils and fats on the ecology of shore habitat are not known; however, one would assume that they do not have appreciable adverse effects. As a mitigating measure, introduction of oils and fats with the feed to the marine environment should be avoided or reduced.

Proposal for environmental monitoring

3.1 The ERA ToR refer to monitoring of the following components, which are to be monitored at a frequency of 1 – 2 times per year at the south aquaculture zone (SAZ) where three tuna farms (F&F Ltd, MFF Ltd and Mare Blu Ltd) are located, and at the site off Mellieha Bay (north aquaculture site; NAS) where two tuna farms (AJD Tuna Ltd and MML Ltd) are located; both sites being located some 5-6 km offshore:

- Sediment quality, namely the parameters given in Table 1 below;
- Water quality, namely the parameters given in Table 2 below;
- Plankton, to establish the most abundant species of phytoplankton and zooplankton and to determine for the presence of toxic or harmful plankton;
- Video survey of the seabed to assess gross physical and biological features;
- Benthic assemblages to assess the condition of the benthic environment in the vicinity of the fish cages, compared to unperturbed conditions, which will be taken to be the situation at the reference stations.

Table 1: Parameters to be analysed in sediments.

Parameter	Method	Units (on D.M.)
Granulometry	Buchanan 1984	g
Total Organic Carbon (TOC)	UNI EN 13137:2002	%
Redox Potential	CNR IRSA 2 Q 64 Vol 3 1985	mV
Sulphide	CNR IRSA 12 Q 64 Vol 3 1986	µg
pH	CNR IRSA 1 Q 64 Vol 3 1985	pH units
Total Nitrogen	CNR IRSA 6 Q 64 Vol 3 1985	mg/g
Total Phosphorus	DM 13/09/1999 SO n°185 GU n°248 21/10/1999 Met XV.I	mg/g

Table 2: Parameters to be analysed in seawater.

Parameter	Method	Units
Temperature	In-situ / Portable Meter	°C
Salinity	In-situ / Portable Meter	psu
Dissolved Oxygen	In-situ / Portable Meter	%, mg/l
Turbidity	In-situ / Portable Meter	NTU,
Turbidity (Secchi Depth)	Secchi Disk	m
pH	pH meter	pH units
Chlorophyll *a*	APAT CNR IRSA 9020 Man 29 2003	µg/l
Total Nitrogen	APAT CNR IRSA 5030 Man 29 2003 + APAT CNR IRSA 4040 A1 Man 29 2003 + APAT CNR IRSA 4050 Man 29 2003	µg/l
Total Phosphorus	APAT CNR IRSA 4110 Man 29 2003	µg/l
Total Carbon	UNI EN 1484:1999	µg/l
Total suspended matter	APAT CNR IRSA 2090 B Man 29 2003	mg/l

While such monitoring components follow the guidelines that one would expect of monitoring programmes for sea-based fish farm activities, particularly ones located in coastal areas not far from the shore, given that all tuna farming installations have recently (in 2017) been moved offshore (> 1 km offshore), it would seem more appropriate to adopt a monitoring programme that enables prompt issue of results, while focussing on components that are more readily indicative of potential adverse impacts, while being cost-effective. Collection and analysis of samples of phytoplankton and sediment for species identification will necessitate months. A single grab sample collected by a 0.1 m^2 Van Veen Grab, which will fill a 10 litre bucket, may require 2-man weeks for sorting and several days to identify – this would be before any necessary statistical analyses is carried out. From experience by Ecoserv's personnel, sorting sediment and identifying marcoinvertebrates from a single monitoring session at one tuna farm site may require several months to nearly a full year to complete. In the case of the South Aquaculture Zone; monitoring of physico-chemical attributes and benthic diversity from two sessions held in 2008 and 2010 did not detect any significant changes following tuna penning activities at the site. Monitoring of plankton and routine water quality parameters such as Chlorophyll *a*, dissolved oxygen, turbidity, nutrients, etc will, in all probability, not serve to detect any change/impact resulting from the tuna farming activities as the offshore areas where the farms are currently located are characterised by very strong sea currents, exposed conditions, and a high energy regime that promote very high flushing of any wastes generated by the activity. Nevertheless, surveys of water quality will be carried out as detailed below, while a survey of sediment quality and benthic diversity will be carried out should the results of the video surveys indicate a potential adverse impact of the tuna penning activities on the seabed. The results from surveys of sediment quality and benthic diversity, should it be necessary to implement these, carried out at both the SAZ and NAS may be compared with the results of past baseline surveys (sediment quality and benthic diversity) of the seabed having the same physical and biological characteristics as those of the SAZ and NAZ.

The following environmental monitoring proposal is mainly aimed at focusing on components that are more readily indicative of potential adverse impacts, and on cost-effectiveness, while also serving as a 'check' for the farm operators themselves and still allowing for implementation of sediment quality and benthic diversity surveys should the ERA and present consultants deem that these are necessary if monitoring results indicate an adverse environmental impact resulting from the tuna penning activities:

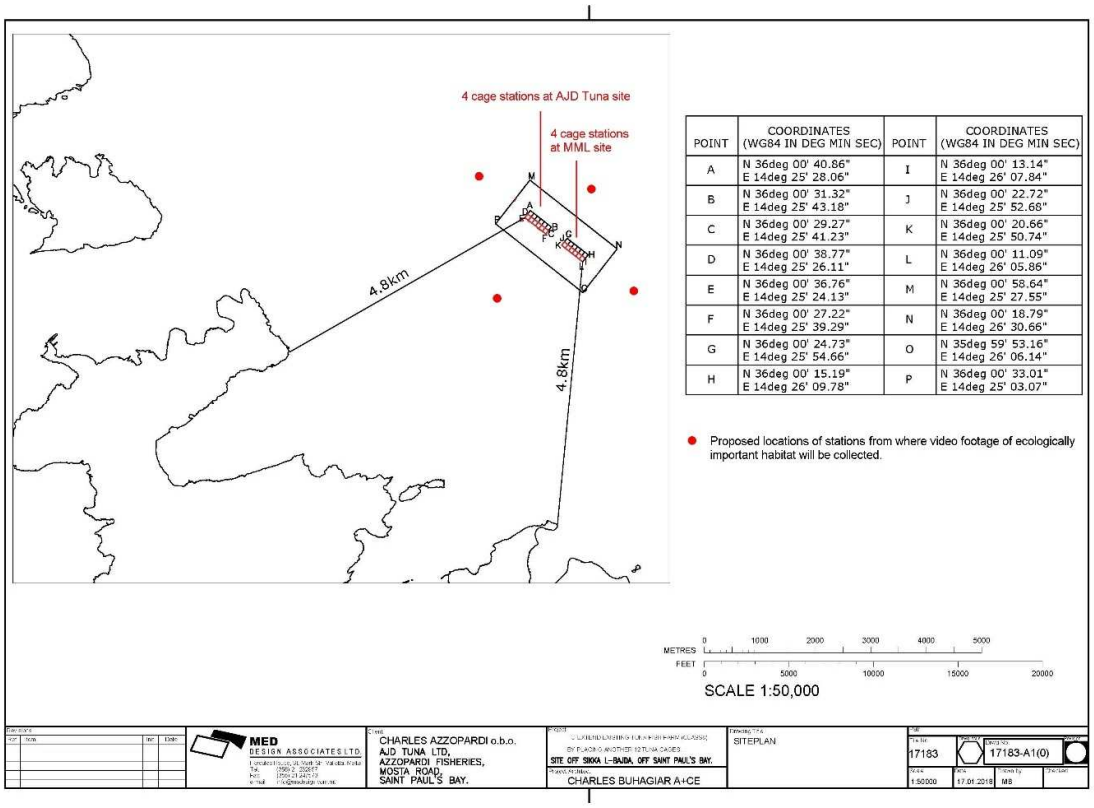
Video survey

A video survey using a remotely operated vehicle (ROV) will be undertaken below a select number of fish cages to assess for the following:

- Level of uneaten feed accumulating on the seabed;
- Species diversity and abundance of megafauna;
- Marine litter; and
- Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

The video survey will be undertaken using an ROV that will be navigated below, as much as possible, a select number of tuna cages at each of the SAZ and NAS; this will enable collection of the necessary video footage, which will be later analysed in the laboratory. It is proposed that video footage of the seabed will be collected in the vicinity of 8 cages (4 cages at each of the MML and AJD Tuna Ltd sites) at the NAS and 12 cages (4 cages at each of the F&F Ltd, MFF Ltd and Mare Blu Ltd sites) at the SAZ. The cages selected for monitoring using video footage will be selected at

random in the field by the scientists on the day of monitoring but the selected cages at any one site will be as distant from each other as possible to allow for representative assessment. The collected video footage will enable assessment of: (i) Levels of uneaten feed accumulating on the seabed; (ii) species diversity and abundance of megabenthic fauna; (iii) presence of marine litter; (iv) overall gross physical and biological characteristics of the seabed. Video footage of the seabed will also be collected at stations located at a distance from the SAZ and NAS but where the bottom may support a habitat of high ecological importance; in the case of the NAS, this would be maerl habitat located west, north and east of the site, as well as at 'Is-Sikka l-Bajda' located south of the site; in the case of the SAZ, this would be maerl habitat located west, north, east and south of the site. It is proposed that video footage will be collected from 4 stations in the vicinity of the NAS and 4 stations in the vicinity of the SAZ. The proposed locations of the monitoring stations are shown in Figures 1 and 2 below.



POINT	COORDINATES (WG84 IN DEG MIN SEC)	POINT	COORDINATES (WG84 IN DEG MIN SEC)
A	N 36deg 00' 40.86" E 14deg 25' 28.06"	I	N 36deg 00' 13.14" E 14deg 26' 07.84"
B	N 36deg 00' 31.32" E 14deg 25' 43.18"	J	N 36deg 00' 22.72" E 14deg 25' 52.68"
C	N 36deg 00' 29.27" E 14deg 25' 41.23"	K	N 36deg 00' 20.66" E 14deg 25' 50.74"
D	N 36deg 00' 38.77" E 14deg 25' 26.11"	L	N 36deg 00' 11.09" E 14deg 26' 05.86"
E	N 36deg 00' 36.76" E 14deg 25' 24.13"	M	N 36deg 00' 58.64" E 14deg 25' 27.55"
F	N 36deg 00' 27.22" E 14deg 25' 39.29"	N	N 36deg 00' 18.79" E 14deg 26' 30.66"
G	N 36deg 00' 24.73" E 14deg 25' 54.66"	O	N 35deg 59' 53.16" E 14deg 26' 06.14"
H	N 36deg 00' 15.19" E 14deg 26' 09.78"	P	N 36deg 00' 33.01" E 14deg 25' 03.07"

Figure 1. Map showing the locations of the temporary AJD Tuna Ltd and MML Ltd farm sites off Mellieha Bay, and the proposed locations of stations from where video footage of ecologically important benthic habitat will be collected (apart from video footage collected at 4 cage stations at each farm site).

The results of such assessment will be available within a few weeks and will clearly indicate the state of the seabed in the vicinity of the cages. Furthermore, the main output – the video footage – is in itself illustrative and will readily, clearly, and visually, show any change/adverse impact of the tuna farming activities on the seabed, including to the operator himself. The video footage may also be used readily by the ERA to effectively illustrate and inform planners, policy makers, politicians and the general public of the situation of the seabed below the cages.

Based on the outcome from the video surveys; in the eventuality that the findings indicate large changes in physical and biological characteristics of the seabed following the tuna penning activities, then the ERA would reserve the right to request a quantitative study to assess, in greater detail, any alterations to the benthic habitat. This would be done through quantitative assessment of sediment quality and benthic assemblages, as per the related component of the ERA's ToR. Such strategy will also serve as incentive for the operators to ensure proper management of the tuna farm activities and avoid potential adverse impacts on the seabed, as well as avoiding additional monitoring and associated high cost.

It is proposed to perform two monitoring sessions per year: in April/May, just before the start of the tuna penning season and in August/September at the peak of the farming season.

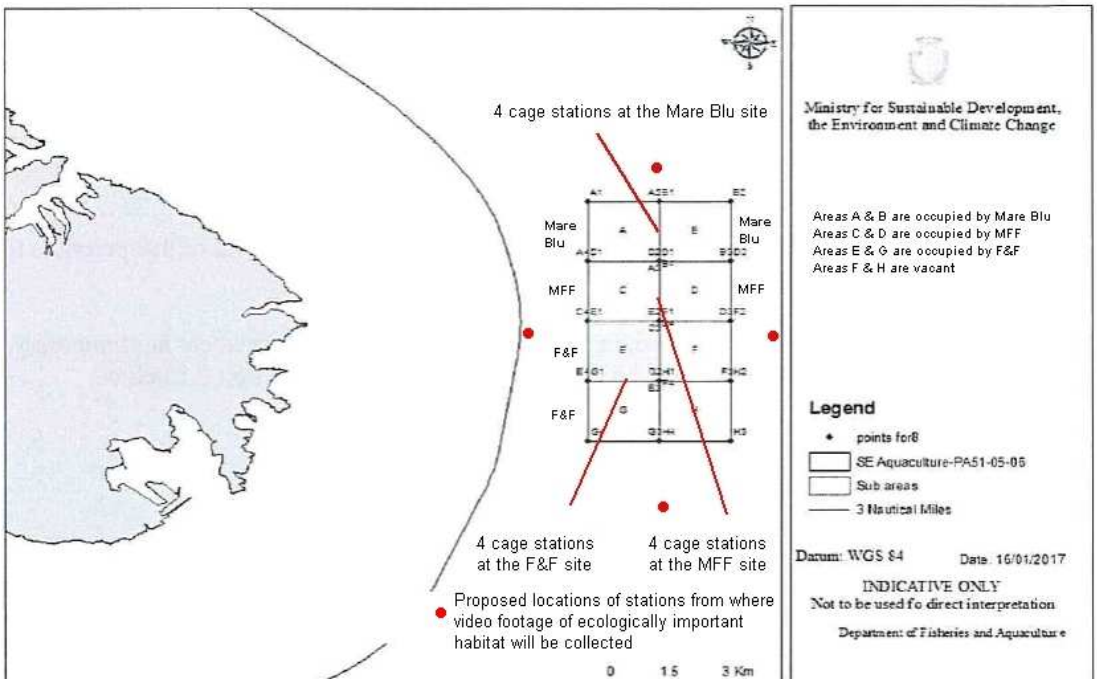


Figure 2. Map showing the locations of the Mare Blu Ltd, MFF Ltd and F&F Ltd farm sites within the south aquaculture zone, and the proposed locations of stations from where video footage of ecologically important benthic habitat will be collected (apart from video footage collected at 4 cage stations at each farm site).

Water quality

To monitor water quality, aerial photography sessions coupled with water quality surveys are proposed. The main aim of the aerial photographs is to detect any potential oil slicks and their extent, in the vicinity of the tuna farms, given that this is clearly a main issue. Such session will be held concurrently with *in-situ* measurement of water quality attributes and collection of marine water samples for later analysis in the laboratory. The different parameters that will be measured and analyzed are indicated in Table 2; these are the same as per the ERA's ToR. *In situ*

measurements (two replicates) and collection of seawater samples (two replicates) will be made at a water depth of 1 m (subsurface) at four stations located within each of the NAS and SAZ: an up-current station, two stations located at the centre of each site (NAS and SAZ), and a down-current station. Furthermore, two replicate samples of seawater will be taken at the surface from the same four stations for potential analysis of oils. The latter analysis will, however, only be undertaken if the aerial photographs show evidence of the presence of an oil slick. Observations on the following will also be made at each station:

- presence of floating material;
- surface oil slicks;
- tarry residues;
- surface foam/bubbles
- any odours present.
-

Water samples for laboratory analyses will be transferred to pre-treated glass or plastic bottles, as appropriate and depending on the analysis concerned. Samples will be maintained at a temperature of 4 – 8°C during transport to the lab. Analysis for the parameters will be undertaken using standard methods. The parameters that require laboratory analysis will be analysed at a laboratory that is accredited according to the ISO 17025:2005 standard.

It is proposed to carry out two monitoring sessions per year, which also coincide with the period when the video session will be held: in April/May, just before the start of the tuna penning season, and in August/September, at the peak of the farming season.

Reporting

One report for each of the two monitoring components; i.e. video survey and water quality, and which will include the methodology used, findings and appraisal, will be submitted.

Sediment quality and benthic diversity

Should the results of the video surveys indicate an adverse impact on the seabed as a result of the tuna penning activities at either of the NAS or SAZ, sediment quality and benthic diversity surveys will be undertaken, as described below.

Sediment quality

To assess the chemical quality of sediments in the areas of study, samples will be collected for analysis from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. As much as practically possible, the sampled stations will have the same water depth. Two replicate sediment samples will be collected from each station using a 0.1m^2 Van Veen Grab that will be pre-cleaned and pre-treated to avoid contamination. The samples will then be transferred to pre-cleaned and pre-treated glass

or plastic sample containers depending on the type of analysis to be carried out. Sediment sampling and preservation will take place in accordance with the ISO 5667 set of guidelines that are followed as part of the procedures at the laboratories where the analyses will be carried out. Samples will be maintained at appropriate storage conditions until delivery to the analysing laboratory. The samples will be analysed at an ISO 17025:2005 accredited laboratory for the parameters indicated in Table 1. Standard analytical methods will be employed which will involve a pre-analytical step of extraction, intended to release any bound chemicals from the sediment particles.

To assess the physical characteristics of the sediments at each of the six stations, sediment samples for granulometric analysis will also be collected from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. For this purpose, two replicate sediment samples will be collected using a $0.1m^2$ Van Veen Grab from the same six sampling stations used to collect samples for chemical analyses. In the laboratory, the samples will be analysed by sieving through nested Endecott test-sieves on a mechanical sieve-shaker, according to the method given in Buchanan (1984). Using this method, the sediment will be separated into the different grain size fractions and the percentage contribution of each fraction, mean sediment grain size and the sediment's overall classification will be determined. The results obtained will be used to provide a description of the granulometric characteristics of the sampled sediments, namely: mean sediment grain size (according to the Wentworth Scale) and other relevant properties such as sorting and kurtosis.

Benthic diversity

To collect data for benthic diversity studies, a grab sample will be collected from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. Samples will be collected using a 0.1 m^2 Van Veen grab deployed from a vessel equipped with hoisting jib and winch. After the grab is brought on board, surplus seawater will be drained from the sample by placing it on a 1mm-mesh sieve; the retained sediment and biota will be temporarily preserved in 10% formaldehyde in seawater. In the laboratory, each sample will first be washed to remove the fine sediment (<1 mm fraction) and the preservative, and it will then be sorted to separate out all macrofauna (animals larger than 1 mm). The motile macrofauna will then be identified as far as possible. Where identification to species level was not possible, the different species present will be labelled using an alphabetical code (e.g. Mysidacea sp. A, etc.).

Reporting

One report for each of the two monitoring components; i.e. sediment quality and benthic diversity, and which will include the methodology used, findings and appraisal, will be submitted.

Training

To satisfy the requirements of staff training, the following programme that will encompass lectures and a practical demonstration session is being proposed:

- 1 hour lecture on permit obligations;
- 1 hour lecture on basic aspects of the marine environment;
- 1 hour lecture on monitoring of aquaculture activities; and
- 1 hour practical demonstration session concerning monitoring.

The training session will have a duration of one half day (0900 – 1330) and will include half an hour coffee break (between 11:00 and 11:30). Participants will be presented with an attendance certificate.

Responsibilities, personnel, equipment and facilities

Ecoserv Ltd will undertake all studies, including fieldwork, laboratory analyses, data analyses and production of reports. All work will be carried out by a team of qualified environmental scientists from Ecoserv Ltd under the supervision of Prof Joseph A Borg BSc MSc PhD CBiol MRSB MMBA FIBMS and Dr Julian Evans BSc (Hons) MSc PhD MMBA.

Further information on Ecoserv Ltd, together with a list of past projects serviced by the company can be downloaded from www.ecoserv.com.mt. The company's web site also features ongoing projects and assignments commissioned recently.

References

Mangion M., Borg J. A., Thompson R. & Schembri P. J., 2014. Influence of tuna penning activities on soft bottom macrobenthic assemblages. Marine Pollution Bulletin 79; 164-174.

Mangion M., Borg J. A., Sanchez Jerez P & Schembri P. J., 2017. Assessment of benthic biological indicators for evaluating the environmental impact of tuna farming. Aquaculture Research: 1 – 15.

Mangion M., Borg J. A., Sanchez-Jerez P., 2017. Differences in magnitude and spatial extent of impact of tuna farming on benthic macroinvertebrate assemblages. Regional Studies in Marine Science 18: 197-207

ANNEX 2

Environmental monitoring of tuna farming activities

Revision of water quality sampling design in relation to P-tuna-farming-monitoring_revised_082018 (Proposal for regular environmental monitoring of tuna farming activities at offshore sites)

The present revision of the sampling design in relation to monitoring of water quality at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay, is being made following agreement with the Environment and Resources Authority (ERA). The recommendation, which was agreed on by the ERA and the present consultant, is to add a further two sampling stations to the four stations that have been used in water quality monitoring sessions held in 2019 and 2020.

It is proposed that the locations of the two water quality monitoring stations (E and F in Figure 1) will tentatively be as indicated in Figure 1. However, the actual locations will be determined on the day of holding on the water quality survey, depending on the sea current direction, such that one of the stations will be 'up-current' and the other 'down-current'; i.e. the locations of the two stations can be anywhere along a semi-circle drawn north to south for each station.

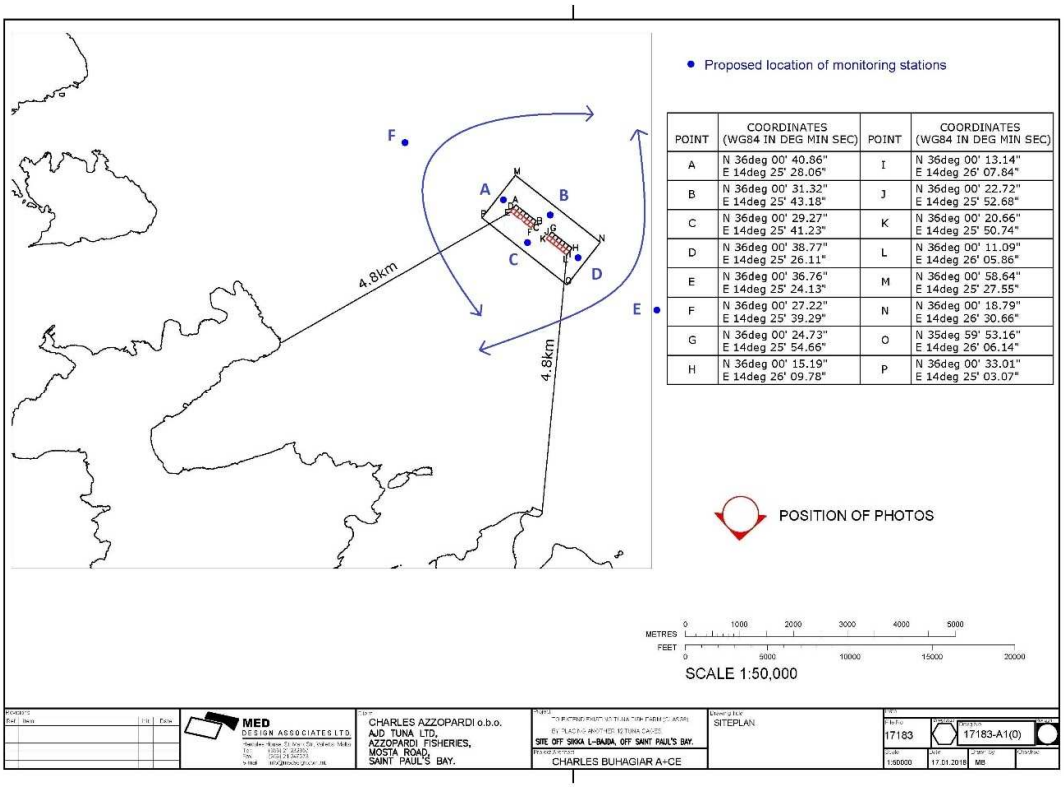


Figure 1. Map showing the location of AJD Tuna and MML's tuna penning sites off Mellieha Bay. The locations of the four stations A - D that have been used to monitor water quality during 2019 and 2020 are indicated. The new additional two sampling stations (E and F) are also indicated, however, it should be noted that their locations are not fixed but will be determined on the day of sampling, depending on the sea current direction (see main text in the present document). Base map source: ADI Associates Environmental Consultants.

In situ measurements and collection of seawater samples for later laboratory analyses, will be carried out at the same frequency and considering the same parameters as for the other four stations (A – D), and as detailed in the approved proposal for environmental monitoring.

Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site

Integrated assessment of monitoring of water quality, sediment quality and video surveys undertaken in 2023 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site off Mellieha Bay

Prepared by

JOSEPH A. BORG
BSc MSc PhD (Plymouth) FIBMS FMBA FRSB CBiol

FOR

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

ECOSERV'S REPORT REFERENCE: 057-24

MAY 2024

1. INTRODUCTION

1. An environmental monitoring program is required as part of the environmental permit (EP) for tuna penning operations carried out by AJD Tuna Ltd and Malta Mariculture Ltd at the 'North Aquaculture Site' (hereafter 'NAS') off Mellieha Bay. Ecoserv submitted a proposal for such environmental monitoring, which was subsequently approved by the Environmental Resources Authority (ERA).

2. The proposal by Ecoserv, bearing reference P-tuna-farming-monitoring_revised_082018 (See Annex 1), refers to collection of water samples from the four (4) monitoring stations from a depth of approximately 0.5 - 1 m. Additionally, the water quality survey includes *in situ* measurement of dissolved oxygen (DO), salinity, temperature and turbidity, at the same stations using a multi parameter meter. Measurement of current speed and direction also form part of the monitoring proposal. In 2021, sampling effort in relation to water quality was increased such that a total of six stations are monitored for water quality. Such modification of the monitoring design follows from advice received by the ERA, and was based on the results from past water quality monitoring sessions; a copy of the revised sampling plan is given in Annex 2. The proposal refers to two water quality sessions undertaken per year; one in spring during the fallow period, and the other in autumn towards the end of the tuna farming season.

3. As of 2023, the ERA also requested sediment quality monitoring, which necessitated collection of sediment samples for laboratory chemical analysis and granulometric analysis. Ecoserv submitted a proposal for such monitoring (see Annex 3), which was subsequently approved. The proposal refers to sediment samples collected from a total of eight stations; two stations located below two randomly selected cages from each of AJD Tuna Ltd. and Malta Mariculture Ltd., and four reference stations located northwest and southeast of the North Aquaculture Site (see Annex 3).

4. With respect to monitoring of the seabed using underwater videography, Ecoserv's proposal refers to a video survey using a remotely operated vehicle (ROV) that will be undertaken below a select number of fish cages to assess the following:

   - Level of uneaten feed accumulating on the seabed;
   - Species diversity and abundance of megafauna;
   - Marine litter; and
   - Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

   The ROV will be navigated below a select number of tuna cages at the NAS; this will enable collection of the necessary video footage, which will be later analysed in the laboratory. It was proposed that video footage of the seabed will be collected in the vicinity of eight cages (4 cages at each of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites) at the SAZ. The tuna cages selected for monitoring using video footage collected by an ROV will be chosen at random by the scientists on the day of monitoring, but the selected cages will be as distant from each other as possible to allow for representative assessment. Video footage of the seabed will also be collected at stations located at a distance from the NAS but where the bottom may support a habitat of high ecological importance; e.g. seagrass *Posidonia oceanica* habitat present at Sikka l-Bajda located south of the NAS. Ecoserv's proposal (see Annex 1) gives further details of the advantages and uses of the outcomes from such video survey, and the reader is referred to the relative document.

5. Finally, the obligations set out in the permit also refer to an integrated assessment of the environmental monitoring undertaken during any one year. The present document comprises Ecoserv's report of integrated assessment of the findings from the water and sediment quality monitoring surveys, as well as the video survey sessions undertaken in 2023 in the vicinity of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay (northeastern coast of Malta).

2. METHODOLOGY AND RESULTS

Water quality

6. Fieldwork in relation to the 2023 water quality sessions was undertaken in June and November. The day of holding of the respective survey was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. In situ measurements and collection of seawater samples were made at a total of six stations.

7. To view the methodological details and results of the *in situ* measurements and laboratory analyses, the reader is referred to Borg and Agius (2023c; 2023d). During the June 2023 session, most of the cages were empty, whilst during the November 2023 session, most of the cages were either full, or the tuna had been recently harvested.

8. The results of the June 2023 water quality monitoring session indicated that levels of the monitored attributes at the NAS were mostly within a range that is expected for local coastal offshore waters in summer, although TOC, TSS and total phosphorous were slightly elevated. However, no appreciable differences in levels of the monitored attributes were noted amongst the six stations including the 'down-current' station, and the 'up-current' station, indicating that the elevated readings were unlikely to have originated from the tuna farming activities.

9. The results of the November 2023 water quality monitoring session indicated that levels of the monitored attributes at the NAS were within a range that is expected for local coastal offshore waters in winter; no overall appreciable differences in levels of the monitored attributes were noted amongst the six stations, including the 'down-current' station. Values for TSS were somewhat high, especially in the vicinity of the cages, but this was also the case at the reference stations. However, turbidity and Secchi depth readings indicated a high level of water transparency, while these did not vary appreciably amongst stations.

10. The conclusions reached for both the June and November 2023 water quality monitoring sessions were that values of the monitored attributes were generally within a range that would be expected of local offshore waters, with some exceptions during the two sessions. However, the latter were not attributed to the tuna penning activities given that no appreciable differences in water quality were noted amongst the six monitored stations, including the 'down-current' and 'up-current' stations. Therefore, the overall conclusions were that the tuna farming activities at the NAS did not result in appreciable alteration of water quality in terms of the monitored attributes.

Sediment quality

11. Fieldwork in relation to the 2023 sediment quality sessions was undertaken in June and November. The day on which the survey was held was chosen at random but selection of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Collection of sediment samples were made at a total of eight stations; four cage stations (two cages from each of AJD Tuna Ltd., and Malta Mariculture Ltd.), and four reference stations.

12. To view the methodological details and results of laboratory analyses, the reader is referred to Borg and Agius (2023e; 2023f). During the June 2023 session, most of the cages were empty, whilst during the November 2023 session, most of the cages were either full, or the tuna had been recently harvested.

13. With respect to sediment quality, the results of the June 2023 session indicated that the sediment within and around the NAS is mostly coarse sand. Results of chemical analysis indicated that levels of monitored parameters were as expected of background conditions, while statistical analysis showed no significant difference between levels of most the parameters in sediment below the fish cages, and at the reference sites. The only exception was phosphorous, which was found to be higher at the cage sites compared to the reference sites noting, however, that the elevated levels were recorded from within the 'zone of allowable effect' (AZE), and therefore were expected to be higher than background values. The November 2023 session indicated that grain size was coarser than in June, and was mostly classified as very coarse sand. Levels of most parameters recorded during the November session were very similar to those recorded from the June session, and only phosphorous was found to be present at significantly higher levels at the cage sites in comparison to the reference sites. Nitrogen on the other hand, was lower at the cage sites, when compared to the reference sites.

14. Overall, it was concluded that the results of the two sediment quality monitoring sessions made at the NAS in 2023 were in line with what one would expect for sediments below fish farms. Furthermore, it was encouraging to note that with respect to considered parameters, there were no appreciable differences in levels between sediments below the cages and those at reference sites located approximately two Km away from the NAS, nor were there appreciable differences between the results of chemical analyses of sediments when comparing the start of tuna penning operations, to those recorded in 2023.

Video surveys

15. Fieldwork in relation to the 2023 video surveys was undertaken in June and September. The day on which the survey was held was chosen at random but choice of the date was subject to good sea conditions to ensure successful undertaking of fieldwork and data collection. Video footage of the seabed was collected using an ROV deployed from a 10 m vessel. During fieldwork, the ROV was deployed adjacent a tuna pen at a given compass cardinal point and lowered to the seabed there. The ROV was then manoeuvred to the other side of the tuna pen, i.e. towards the opposite compass cardinal point, while collecting video footage of the seabed. Video imagery from the ROV was recorded by the unit's HDI camera and saved on a laptop's hard disc on board the vessel during deployment. In both the June and September 2023 surveys, video footage was collected from below a total of eight tuna pens – four cages at each of the two tuna penning sites (AJD Tuna

Ltd and Malta Mariculture Ltd) located within the NAS, and at four reference sites Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference. Following each session, the video record was analysed in the laboratory. Characterisation of the benthic assemblages was made using the scheme of Borg *et al*. (2013), which is based on the EUNIS typology that has been adapted for local use.

16. The 'uneaten food index' designed by Borg & Schembri to enable comparison of the relative amounts of dead fish present under the pens (see Holmer et al, 2008) was used in the assessments to quantify the amount of uneaten feed fish present on the seabed below a tuna pen, if applicable. The index, which ranges between 0 and 4, is described in Table 1.

Table 1.

The 'uneaten food index' devised by Borg & Schembri (see Holmer et al., 2008) for the purpose of quantifying and comparing the amount of dead uneaten feed-fish under the different tuna-pens.

Index value	Description
0	No uneaten fish present
1	< 1 uneaten fish present per m^2 of seabed
2	> 1 uneaten fish present per m^2 of seabed, but the fish do not form a continuous layer covering the seabed
3	> 1 uneaten fish present per m^2 of seabed. Fish form a single, uninterrupted layer within at least a $1m^2$ area on the seabed.
4	> 1 uneaten fish present per m^2 of seabed. Fish form two or more uninterrupted layers on top of each other within at least a $1m^2$ area on the seabed.

17. The results of the two sessions held in 2023 have been presented in reports and annexed video footage showing the state of the seabed at the tuna pens and reference sites surveyed. To view further details of the methodology used during the ROV surveys and full details of the findings thereof, the reader is referred to Borg and Agius (2023g; 2024).

18. During the June 2023 session, video footage was collected from the four reference sites (Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference) and from below the following cages:

- AJD Tuna Ltd (AJDTL) Cage 2
- AJD Tuna Ltd (AJDTL) Cage 4
- AJD Tuna Ltd (AJDTL) Cage 14
- AJD Tuna Ltd (AJDTL) Cage 17
- Malta Mariculture Ltd (MML) Cage 7
- Malta Mariculture Ltd (MML) Cage 10
- Malta Mariculture Ltd (MML) Cage 19
- Malta Mariculture Ltd (MML) Cage 20

During the September 2023 session, video footage was collected from the four reference sites (Northwest Reference, Northeast Reference, Southeast Reference and Southwest Reference) and from below the following cages:

- AJD Tuna Ltd (AJDTL) Cage 2
- AJD Tuna Ltd (AJDTL) Cage 5
- AJD Tuna Ltd (AJDTL) Cage 13
- AJD Tuna Ltd (AJDTL) Cage 16
- Malta Mariculture Ltd (MML) Cage 8
- Malta Mariculture Ltd (MML) Cage 11
- Malta Mariculture Ltd (MML) Cage 21
- Malta Mariculture Ltd (MML) Cage 24

19. During the June 2023 video monitoring session all, or most, of the cages were empty. Whereas during the September 2023 session, most of the cages belonging to the two farms held tuna.

20. Following an agreement reached with the ERA, instead of a highly 'textual' report indicating findings from the video survey, Ecoserv was to produce a report with tables indicating the following below the surveyed cages and at the four reference sites:

    (i) Benthic habitat type present; and Geographical coordinates where the video transect starts;

    (ii) Semi-quantitative estimate of uneaten feedfish (if present); tuna carcasses (if present); and skeletal remains of tuna (if present);

    (iii) Anthropogenic items on the seabed (if present) including: ones probably originating from the tuna farms and ones of unknown origin.

    The scope of such information is to compare findings from consecutive video surveys to help establish any variation in the amount of items (see above) present on the seabed.

21. The results of both the June and September 2023 sessions indicated the following:

    - The seabed habitat type below the eight tuna pens and at three of the reference sites (Northwest reference, Northeast reference and Southwest reference) were similar to those recorded during previous surveys and mainly supported Sublittoral Sediment (EUNIS code A5), of which the predominant assemblage type was an association with rhodoliths on coarse sands and fine gravels under the influence of bottom currents (EUNIS code A5.515). The accumulations of rhodoliths were mostly present in the troughs of seabed current ripples. Apart from the red algae comprising the rhodoliths, patches with macroalgae were present where the sediments were consolidated through the presence of very coarse material such as rhodoliths and stones. The most abundant megafaunal species recorded during the surveys were ones that are typical of the habitat type recorded under the cages and at the three aforementioned reference sites. The seabed at the southwest (Sikka l'Bajda) reference site mainly supported a biocenosis of *Posidonia oceanica* meadows (EUNIS code A5.535), a biocoenosis of infralittoral algae (EUNIS code A3.131), and patches with sublittoral sediment (EUNIS code A5), which together formed a mosaic. The seagrass *Posidonia oceanica* appeared to be in a very good state. The demersal fish fauna were also typical of the respective habitat types from where they were recorded during the surveys.

    - In terms of the perceived influence of the tuna farms on the environment at the NAS, the findings from the June 2023 survey indicated similar findings to those from baseline studies undertaken prior to initiation of tuna penning activities and from previous video monitoring

surveys made at the NAS in spring; apart from anthropogenic items (some of which appear to have originated from the tuna farms), two tuna carcasses (one each under MML Cage 19 and MML Cage 20), skeletal remains of tuna, and a high density of hermit crabs *Pagurus* sp. (the latter recorded under MML Cage 7); the seabed below the eight tuna pens surveyed appears to have retained similar physical and biological characteristics. As recorded in previous sessions, a number of anthropogenic items, some of which appear to have originated from the tuna farming activities, were present below the cages. However, excluding MML Cage 7, where fish bones originating from uneaten feed fish were present, no uneaten feed fish were recorded under the cages. The presence of fish bones originating from uneaten feed fish, as well as bones originating from one or more tuna individuals that were recorded under MML Cage 7, led to the higher density of hermit crab *Pagurus* sp. present on the seabed there. As far as could be seen from the video imagery, no anoxic conditions or other indications of an adverse state of the seabed habitats and species were detected; for example, all close-up imagery indicated a healthy state for the rhodoliths and associated macroalgae. Moreover, the presence of species that are typical of a pristine seabed characteristic of the surveyed sites indicated a good state of the seabed, overall, at the NAS, while the seagrass *Posidonia oceanica* present within the 'Sikka l-Bajda' area located soutwest of the NAS appeared to be in a very good state and not influenced by AJD Tuna Ltd's and MML's tuna farming activities.

- In terms of the perceived influence of the tuna farms on the environment at the NAS, the findings from the September 2023 survey indicated that the seabed area under the cages and at the reference sites supports benthic habitat types that are similar to those identified in the baseline studies undertaken prior to initiation of tuna penning activities. However, input of organic waste from the tuna farm and the anthropogenic items (several of which originate from the tuna penning activities) present on the bottom under some of the tuna cages have led to some alteration of the physical and biological characteristics of the benthic environment; this is mainly manifested by an increase in the abundance of benthic and demersal megafaunal scavengers that have been attracted to the area by the presence of organic matter (such as that originating from uneaten feed fish), while the particulate matter and anthropogenic items contribute to some modification of the physical environment. With regard to anthropogenic items that appear to have originated from the tuna farming activities; while the number of ropes is similar when comparing observations from the previous (June 2023) session with the present one, the number of weights appears to have increased, and the two very long tubes that may have served as supporting ring for the cage at the surface were not recorded in June 2023. As far as could be seen from the video imagery, no anoxic conditions or other indications of an adverse state of the seabed habitats and species were detected; for example, all close-up imagery indicated a healthy state for the rhodoliths and associated macroalgae. However, the abundance of some indicator species such as of the Heart Urchin *Spatangus purpureus* appeared to be lower under the cages compared to the reference sites. On the other hand, other species that are typical of a pristine seabed, such as the Red Lance Urchin *Stylocidaris affinis* and the crinoid *Antedon mediterranea,* were present on the bottom under the cages, indicating an overall good state of the seabed. The seagrass *Posidonia oceanica* present within the 'Sikka l-Bajda' area located soutwest of the NAS appeared to be in a very good state and not influenced by AJD Tuna Ltd's and MML's tuna farming activities.

4. APPRAISAL

Water quality

22. The results of water quality monitoring undertaken at the NAZ during June and November 2023 indicated that, overall, the tuna farming activities at the NAZ did not result in appreciable alteration of water quality in terms of the monitored attributes. Where some parameters were noted to be elevated, when comparing the recorded levels from all six monitoring stations, including the up-current and down-current stations (located some 2Km away from the farm site), it was concluded that such elevated levels were unlikely to be due to tuna farming activities at the NAS.

23. In terms of cumulative impacts; the results of water quality monitoring undertaken during 2023 at the NAS indicated the absence of cumulative effects in the area.

24. Notwithstanding the above conclusions, it is recommended that the tuna farm operators make every effort to reduce the introduction of polluting substances to the marine environment, such as feed fish oils. If feed fish oils are released to the marine environment, these should be retained within the confines of the cages and collected using skimmers and / or other appropriate equipment. Any feed fish oils released to the marine environment, should not be allowed to be transported by water movement beyond the confines of the NAS.

Sediment quality

25. The June and the November 2023 sediment quality surveys indicated that the seabed area within the NAS is mostly characterised by coarse to very coarse sediment. Grain size tended to be somewhat larger, overall, during the November session in comparison to the June session. Results of chemical analysis from both the June and November sessions indicated that phosphorous tends to be higher below the cages when compared to reference sites, although the recorded levels were not alarmingly high. Furthermore, the area below the cages is considered to be under an 'allowable zone of effect'. Levels of all other parameters considered, were not found to differ significantly between the cage sites and the reference sites, except for levels of total nitrogen recorded during the November 2023 session, which were actually lower at the farm site when compared to the reference sites.

26. Overall, the recorded results indicated that the effects of tuna farming on the sediments below the farms, and the immediate surroundings are limited, and where present, appear to be mostly confined to the general footprint of the NAS. Furthermore, where elevated levels were recorded, these were deemed normal of what one would expect from an area located directly below the farm cages and hence under an 'allowable zone of effect'; sediments below farm cages are subject to organic enrichment, which will alter the sediment characteristics to some degree.

Video survey

27. The results of the June and September 2023 video surveys both indicated that the perceived impact of the tuna farming activities on the seabed could be deemed to be insignificant to low, although such evaluation does not take into account the presence of anthropogenic litter.

Conclusions

28. In conclusion, the findings from the 2023 water and sediment quality and video surveys, indicated that AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning activities may be seen as resulting in some alterations to the physical and biological characteristics of the seabed at the NAS. The perceived impact of the tuna farming activities on the seabed could be deemed to be insignificant to low, although such evaluation does not take into account the presence of anthropogenic litter. However, given that any alterations present are not large and reversible, the reported changes to benthic environment at the tuna penning sites are not deemed concerning. Furthermore, in terms of cumulative impacts on the physical and biological characteristics of the seabed, the results of the two video surveys undertaken during 2023 indicate no appreciable cumulative effects.

5. RECOMMENDATIONS

29. The same recommendations that have been proposed in previous reports of environmental monitoring surveys at the NAS apply: (i) feeding of the tuna should be carefully monitored and feeding should be stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten food ending up on the bottom; (ii) measures should be taken to avoid anthropogenic litter ending up on the seabed; in the eventuality that anthropogenic items end up on the seabed by accident, every attempt should be made to retrieve and dispose of them in an appropriate manner; and (iii) measures should be taken to avoid having tuna carcasses or the remains of dead tuna ending up on the seabed below the cages and in their vicinity, even if this is not the direct result of action by the tuna farm operators – in this respect, the present consultants informed the Site Manager of the presence of the tuna carcass present under one of the cages; unfortunately the carcass was in a state of advanced decomposition such that proper retrieval was not feasible.

6. REFERENCES

Arechavala-Lopez P., Borg J. A., Segvic-Bubic T., Paolo Tomassetti P., Özgül A. & Sanchez-Jerez P., 2015. Aggregations of wild Atlantic Bluefin Tuna (*Thunnus thynnus* L.) at Mediterranean offshore fish farm sites: Environmental and management considerations. Fisheries Research 164: 178-184.

Borg J. A. (2017). Report on a video survey of benthic habitats in an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, made in May 2017. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. (2018). Report on an ecological assessment of an area off the northeastern coast of Malta, proposed for designation as an offshore tuna penning site, undertaken as part of the Environment Impact Assessment in connection with PA 02175/18: Extension to an existing tuna farm operation off the North East coast of Malta. Malta: unpublished report, Ecoserv Ltd.

Borg J. A. & Agius A. (2020a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 34pp.

Borg J. A. & Agius A. (2020b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in October 2020 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 36pp.

Borg J. A. & Agius A. (2020c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in April 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 22pp.

Borg J. A. & Agius A. (2020d). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in September 2020 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 23pp.

Borg J. A. & Agius A. (2021a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in May 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 12pp.

Borg J. A. & Agius A. (2022a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in September 2021 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 11pp.

Borg J. A. & Agius A. (2021b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in May 2021 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 19pp.

Borg J. A. & Agius A. (2022b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in October 2021 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 21pp.

Borg J. A. & Agius A. (2022a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in August 2022 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 12pp.

Borg J. A. & Agius A. (2023a). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in October 2022 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 11pp.

Borg J. A. & Agius A. (2022b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in July 2022 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 19pp.

Borg J. A. & Agius A. (2023b). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in October 2022 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 21pp.

Borg J. A. & Agius A. (2023c). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in June 2023 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 16pp.

Borg J. A. & Agius A. (2023d). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a water quality survey made in November 2023 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 16pp.

Borg J. A. & Agius A. (2023e). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a sediment quality survey made in June 2023 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 15pp.

Borg J. A. & Agius A. (2023f). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site. Report of a sediment quality survey made in November 2023 at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay. Malta; Ecoserv Ltd., unpublished report, 31pp.

Borg J. A. & Agius A. (2023g). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in June 2023 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 10pp.

Borg J. A. & Agius A. (2024). Environmental Monitoring of AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning site; Report on video footage of the seabed collected in September 2023 in the vicinity of AJD Tuna's and Malta Mariculture Ltd's tuna penning sites, and reference sites, off Mellieha Bay. Malta: unpublished report, Ecoserv Ltd; 11pp.

Holmer M., Hansen P. K., Karakassis I., Borg J. A. & Schembri P. J., 2008. Monitoring of Environmental Impacts of Marine Aquaculture. In: Holmer M., Black K., Duarte C., Marba N., & Karakassis I. (editors) Aquaculture in the Ecosystem; pp. 47-85. Heidelberg, Germany: Springer; 326pp.

ANNEX 1

Environmental monitoring of tuna farming activities

Proposal for regular environmental monitoring of tuna farming activities at offshore sites

Prepared by

Joseph A Borg BSc MSc PhD (Plymouth) CBiol MRSB MMBA FIBMS

12, Sir Arthur Borton Street
Mosta, MST14
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

Ref: P-tuna-farming-monitoring_revised_082018

August 2018

Preamble

1.1 **Ecoserv Ltd (henceforth Ecoserv) has received requests from tuna farmers having operations in the Maltese Isalands, for environmental monitoring of the tuna penning activities. The terms of reference (ToR) for the environmental monitoring have been provided by the Department of Fisheries and Aquaculture (DFA) and the Environment and Resources Authority (ERA).**

1.2 **The ToR for environmental monitoring of tuna farming activities in Malta, as issued by the ERA, are comprehensive and follow the guidelines which one would expect for the monitoring of sea-based fish farm activities. However, given that tuna farming installations have recently (in 2017) been moved offshore (> 1 km offshore), the present consultant, together with Adi Associates Environmental Consultants Ltd, jointly acting on behalf of all the tuna farming operations in Malta, held discussions with the ERA with a view to revise the ToR of environmental monitoring The aim of this revision is to focus the monitoring on the components that are more readily indicative of potential adverse impacts, for there to be prompt issue of results, and to ensure cost-effectiveness of the monitoring programme. Justification for the proposed revision is partly based on the avilability of extensive data from environmental monitoring of local fish farming activities carried out over a period of more than 15 years.**

1.2 **The present document constitutes Ecoserv's revised proposal for environmental monitoring of offshore tuna farming activities in Malta following discussions held with the ERA in early August 2018.**

Brief overview of findings from environmental monitoring of tuna farming activities in Malta

2.2 Environmental monitoring of tuna farming activities has been ongoing at the offshore sites (located 1 km offshore) used by Azzopardi Fisheries Ltd (AF), FishandFish Ltd (F&F) and Malta Fishfarming Ltd (MFF) since 2000. The monitoring can be broadly divided into two main categories: (i) Water quality and (ii) monitoring of seabed physical and biological attributes. A brief description of the monitoring components, as well as a summary of the findings for each of these follows.

(i) <u>Water quality surveys</u>

Most of the water quality surveys carried out at the 3 tuna penning sites have been made at a bimonthly frequency, although some of the farms did not undertake any monitoring during some periods that extended several months. During the surveys, standard water quality attributes, namely dissolved oxygen, temperature, salinity, turbidity, nitrates, phosphates, Chlorophyll *a*, ammonia, and counts of intestinal bacteria, as well as sea current direction and speed, were measured at a number of sampling stations located in the immediate vicinity of the tuna farms and at up-current and down-current reference stations.

The results of the water quality surveys carried out to date indicated that, very rarely, lowered levels of oxygen, reduced water transparency and elevated nutrient (nitrates and/or

phosphates and/or ammonia) levels were sometimes recorded from the tuna penning sites during the farming season (July – December). However, the observed changes in the monitored attributes were often sporadic and not statistically significant, and have not resulted in appreciable alteration of water quality. Elevated counts of intestinal bacteria were also occasionally recorded but since such organisms do not originate from the tuna but from sewage, these results were not attributed to the tuna penning activities *per se*, although there is the possibility that large ships (e.g. processing ships) present in the vicinity of the farms may be the source of such contamination through discharge of sewage from their holding tanks.

Overall, therefore, the reports of surveys made within this monitoring category concluded that the tuna penning activities had not led to appreciable alteration of water quality in the vicinity of the tuna farms. However, it should be pointed out that some substances that appear to originate from the tuna farms and which were not monitored during the water quality surveys have been recorded to occur in waters in the vicinity of all three tuna penning sites and at a considerable distance away. Essentially, such substances are oils and fats that are released from the feed-fish when these are fed to the tuna. Release of such substances occurs when the feed fish are introduced in the tuna pens and when uneaten feed-fish end up outside the fish cages, and decomposition leads to release of fatty substances that accumulate on the surface and are transported offshore or inshore, depending on sea current strength and direction. Such substances are deemed to have no toxic effects on marine species and habitats, but are a nuisance to bathers, divers and coastal recreational activities, because of their sheer presence in the water and since they deposit on the shore and artificial surfaces (e.g. boat hulls etc.). It is pertinent to point out that although deposition of such substances is not envisaged to have any large adverse effects on marine species and habitats, especially those associated with the shore, this has not been assessed given the complete lack of studies that deal specifically with this aspect. Episodes that were characterised by the occurrence of such floating substances were particularly notable during the summer of 2016, when complaints and awareness of the issue by the general public reached an all-time high. The floating substances were commonly referred to as 'slime', and common sightings of the floating substance and the inconvenience it created to sea users even led to launching of a Facebook page titled 'Stop The Slime' (https://www.facebook.com/stoptheslimemalta). Concurrently, in October 2016 and during the winter and spring of 2017, episodes of occurrence of massive floating 'foam' were recorded from vast areas of Maltese coastal waters. While the occurrence of 'slime' could, directly or indirectly, be linked to fish farming activities, the occurrence of foam is in all probability related to substances secreted by algae, which when churned up by rough sea conditions lead to generation of the observed 'foam'.

(ii) Monitoring of seabed physical and biological attributes

This category has five main monitoring components, namely:

a. Video surveys of the seabed in the vicinity of the tuna pens

The main aim of this monitoring component is to gather qualitative and semi-quantitative data, using direct observation, on the physical and biological characteristics of the seabed underneath the tuna pens. Such surveys involve videography along transects below the tuna pens, and have been carried out twice per year (in October and February) in some years and more recently once per year, usually during the period October – December.

The results of this monitoring component can be summarised as follows:

- Towards the end of each penning season (in autumn) considerable amounts of uneaten feed-fish littered the seabed in the area lying directly below the tuna pens, but not in areas beyond the perimeter of the tuna pens. This resulted in alterations in the physical and biological characteristics of the seabed under the pens, namely:
    - Changes in biological characteristics which typically consist of high population densities of detritus-feeding and scavenging benthic (i.e. associated with seabed) fauna (e.g. the ophiuroid *Ophiura texturata*, the crab *Inachus* sp., the hermit crab *Pagurus* sp. and an unidentified goby).
    - Alterations in physical characteristics which typically consist of the presence of large quantities of fish bones and baitfish that are gradually consumed by scavengers or eventually decompose. There was also a considerable amount of anthropogenic items below the pens that originated from the farm operations, including concrete weights with ropes attached, sheets and sacks of fabric and other material, car tyres, lengths of rope and shot gun cartridges.
- The amount of uneaten baitfish present varied considerably between the different pens, and between different farms, with some only having a few feed-fish beneath them and others having multiple layers of decomposing feed-fish. Once the tuna farming season is over (late winter), a negligible amount of uneaten feed-fish remain on the seabed below the pens. However, thick layers of fish bones and of decomposing organic material persist under some of the pens. These observations indicate a consistent pattern, with the volume of uneaten feed-fish on the seabed decreasing only when the tuna have been harvested (and therefore there is no further addition of feed-fish). Any uneaten fish remaining on the seabed at this time will continue to decompose slowly and, if present in large numbers, form a continuous layer of decomposing organic material. Sometimes, following storms and possibly due to strong bottom currents, this layer is admixed with the underlying mobile sediment. In places where the decomposition process is complete, the only remains are fish bones that eventually disperse in the sediment leaving little or no trace of the original uneaten fish on the surface. Once the source of the impact (periodic addition of new uneaten food) is removed, slow recovery to the original state is characterised by the re-appearance of certain megafaunal species (e.g. the irregular sea urchin *Spatangus purpureus* and the crinoid *Antedon mediterranea*) that form part of the original fauna that characterise the bare muddy sand bottom of the areas where the tuna farms are located.
- The latest video surveys indicated the occasional presence of whole decomposing tuna on the seabed below a few of the tuna cages at the tuna penning sites. However, the tuna farm operators are adamant that the tunas have not originated from the farms. According to the tuna farm site managers, the tunas ended there following capture and subsequent release (accidental or deliberate) by amateur fishermen who would have caught the fish from the wild in the vicinity of the tuna pens. Apparently, local tuna farms are being frequented by amateur fishermen who deploy their fishing lines

with an aim to catch wild tuna that aggregate around the tuna farm; the latter phenomenon has been observed during the past few years at several tuna penning sites in the Mediterranean. Any tunas that are caught and: (i) either break free, or (ii) are cut free by the fishermen[1], die soon after release and end up on the seabed, where they decompose slowly. It appears that the local Fisheries and Aquaculture Department is aware of this problem.

b. Monitoring of physico-chemical attributes

The main aim of this monitoring component is to assess levels of organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics. Moreover, at least one survey involving assessment of levels of pollutants, including heavy metals and organic pollutants, was carried out at each of the three tuna penning sites. The monitoring design of the surveys to assess organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, is based on a Beyond **BACI**[2] layout, in which the results of quantitative analyses of sediment samples collected from the tuna farming site and from a number of control sites before the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. Such surveys were mostly carried out on a yearly basis; however, the AF tuna penning site was monitored twice per year during some years, while no monitoring was carried out at some of the tuna penning sites during some years.

Overall, the findings from surveys that were aimed at assessing organic carbon content and organic nitrogen content of the sediments, and sediment granulometric characteristics, indicated 'pulse' (i.e. short duration) changes in the physico-chemical properties of the sediment following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens but no significant permanent alterations of the sediment characteristics at the operational sites have been recorded to date. Where significant changes were detected, these appeared to have resulted from accumulation of large amounts of uneaten feed-fish in the vicinity of the tuna pens, which decompose slowly causing alterations in the physico-chemical properties of the sediments.

The results of the surveys aimed at assessing levels of heavy metals and pollutant organics indicated that no harmful levels were present in the sediments in the vicinity of the tuna farms.

c. Monitoring of benthic diversity

The main aim of this monitoring component is to assess for potential changes in species populations and seabed habitat that may result from the tuna penning activities. The monitoring design is based on assessing total species richness and total abundance of selected benthic faunal species, as these are deemed good indicators of the overall state

[1] According to the site managers, the wild tuna caught by the amateur fishermen are sometimes cut free on being approached by fisheries officers who make regular site visits to the fish farms using a vessel owned by the local fisheries department.

[2] **B**efore **A**fter **C**ontrol **I**mpacted; see Underwood (1992): Underwood, A. J. (1992) Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161: 145 –178.

of species and habitats associated with the seabed. As in the case of the physico-chemical attributes monitoring component, the design for monitoring of benthic diversity is based on a Beyond **BACI** layout, in which the results of quantitative analyses of samples collected from the tuna farming site and from a number of control sites **before** the start of the farming operations are compared with those obtained after a farming season using advanced statistical analyses. As in the case of the physico-chemical attributes monitoring component, monitoring of benthic diversity was mostly carried out on a yearly basis, however, the AF tuna penning site was monitored twice per year during some years, while no monitoring was carried out at some of the tuna penning sites during some years.

Overall, the findings from this component indicated that a significant 'press' (i.e. long-lasting) adverse impact (manifested as a significant decrease in total macroinvertebrate species richness and/or decrease in the abundance of one or more of the indicator species) had occurred following some but not all of the tuna penning seasons; when these changes were recorded they were restricted to the seabed area located in the immediate vicinity of the tuna pens and/or in the general area occupied by the pens. Furthermore, enhanced productivity in the general area of the tuna farms and beyond, as a result of the tuna-penning activities, was evident from significant increases in the abundance of some of the indicator species recorded in some of the monitoring sessions.

These observations are a strong indication that, where present, adverse impacts on the benthic macroinvertebrate assemblages at the operational sites have resulted from processes that are mainly attributed to accumulation of large amounts of uneaten feed-fish and the slow decomposition of same, in the vicinity of the tuna pens. The uneaten feed-fish attract scavengers and other opportunistic fauna that cause changes to the original species composition of the benthic assemblages, while slow decomposition of the accumulated material causes alterations in the physico-chemical properties of the sediments, and presumably of the sediment-water interface, leading to adverse conditions for the biota originally present.

Over the past few years, data from 10 years of environmental monitoring of the tuna farms owned by AF, F&F and MFF, was subjected to detailed study and analyses as part of a PhD programme of research undertaken at the Department of Biology of the University of Malta, for which the present author is supervisor. To date, THREE papers have been published in leading peer-reviewed international journals, highlighting the study results; see Mangion *et al.*, 2014; 2017; 2018). Copies of these publications are appended to the present report for ease of reference. In summary, the results of these studies indicated that:

- For the largest tuna farm (located off the northeastern coast of Malta), the activity resulted in significant changes to sediment physico-chemical attributes and to the macroinvertebrate assemblages of soft bottom habitats located in the immediate vicinity of the fish cages up to a distance of some 200 m from the farm. However, it appears that the magnitude and spatial extent of the impact also depended on the feed management regime adopted at a tuna farm.
- High spatio-temporal variability in attributes of the macrobenthic invertebrates in the vicinity of three tuna farms (AF, F&F and MFF) was evident; this indicates that change in macroinvertebrate assemblages resulting from tuna farming activities differs between different farms. This observation corroborates the expectation that the level of influence of tuna farming activities on benthic habitats in the vicinity will vary with

the fish stocking density, the length of time a farm has been in operation, and the feed management strategy adopted at the farm during the production period.

- Significant correlation at the control plots between attributes of the macroinvertebrate assemblages and sediment physico-chemical attributes 1–2 km away from the tuna cages suggests that some influence of tuna farming may occur over a wider spatial extent than expected. However, given the high degree of overlap between different marine-based activities around the Maltese Islands, particularly in their southern coastal areas, it is also possible that other sources of organic enrichment apart from the tuna penning activities may be influencing the coastal waters where the tuna farms are located.

d. Monitoring of habitats of ecological importance

The aim of this monitoring component is to assess for potential adverse impacts of the tuna penning activities on marine habitats located near the tuna farms, namely seagrass *Posidonia oceanica* habitat. This monitoring component was undertaken annually between 2003 and 2006 at the AF and MFF tuna penning sites. The surveys were based on a beyond **BACI** design, in which quantitative morphometric data reflecting the state of the seagrass located closest to the farms is compared with that at a number of control sites.

The results of this monitoring component indicated no consistent trends of significant alterations in the state of *Posidonia oceanica* seagrass that may be attributed to the tuna farming activities. Consequently, the MEPA advised the tuna farm operators that this monitoring component need not be continued; hence no further sessions were undertaken after 2006.

e. Monitoring of popular dive sites

The aim of this monitoring component, which involved surveys of the state of the physical and biological characteristics of the seabed habitats, is to assess for potential adverse impacts of the tuna penning activities at popular dive sites located near some of the tuna farms. Such monitoring involved videography, assessment by direct observation and mapping surveys along transects within a defined area that includes the confines of the dive site. The sites monitored were: (i) 'Imperial Eagle' and 'Stubborn' dive sites, both of which are located not far from the AF tuna penning site; (ii) the 'Blenheim' dive site, located not far from the F&F tuna penning site; and (iii) Munxar Reef, located not far from the MFF tuna penning site. One survey per year was carried out at these sites between 2003 and 2006.

Monitoring of the physical and biological characteristics of the bottom at the dive sites showed no consistent trends of significant alterations of the seabed features as a result of the tuna farming operations. Consequently, the MEPA advised the tuna farm operators that this monitoring component need not be continued; hence no further session were undertaken after 2006.

2.3 The results of extensive environmental monitoring programmes held at the tuna penning sites used by AF, F&F and MFF during the past 15 years or so indicate that the main marine environmental impacts that may be attributed to the tuna penning operations are as follows:

(i) Alteration of physical and biological characteristics of the seabed below the tuna pens via deposition of large amounts of uneaten feed-fish, and anthropogenic items originating from the tuna farm operations. Although the uneaten feed-fish 'overwhelm' the seabed ecosystem since the typical fauna do not manage to consume all the uneaten feed, which therefore accumulates on the bottom and probably also spills over (albeit in smaller form, e.g. as particulate organic matter) to adjacent areas, it is ultimately biodegradable and does not persist in the environment for long. The uneaten feed-fish serve as a source of nutrient enrichment of the benthic ecosystem in the vicinity of the tuna farms and adjacent areas, resulting in increased productivity. However, this should not be considered a pretext for allowing addition of uneaten feed to the marine environment. As stated in the monitoring reports:

   a. Feeding of the tuna should be carefully monitored and stopped as soon as the fish are satiated, in order to avoid as much as possible uneaten feed ending up on the bottom. The tuna operators may want to implement a procedure to ensure proper feed management by having random checks of the seabed below the tuna pens made by an independent environmental monitor.

   b. In the case of accident, should an inordinate amount of dead uneaten feed-fish end up on the bottom, every attempt should be made to remove as much of the material as possible using techniques that do not have an adverse effect on the seabed habitat.

   c. Uneaten feed-fish are most probably the source of oils and fats which eventually rise to the surface and are transported by sea currents to inshore areas where, rather than having a toxic effect on shallow water and shore marine species and habitats, they are a nuisance to coastal users including bathers and divers. On the other hand, the effects of such oils and fats on the ecology of shore habitat are not known. However, one would assume that they do not have appreciable adverse effects.

   d. If the situation concerning the presence of dead tuna is as described by the operator, i.e. it is resulting from uncontrolled fishing in the vicinity of the tuna farms, then there is a need for such an activity to be curbed. Furthermore, even if the dead tunas do not originate from the farms themselves, it would be beneficial if these are possibly removed from the seabed.

   e. Anthropogenic items deposited on the seabed as a result of the tuna penning operations, such as concrete weights, ropes etc should be removed and not allowed to accumulate on the bottom.

(ii) Alteration of water quality mainly via addition of oils and fats when feed-fish are fed to the tuna. As already stated above, any introduced oils and fats may be transported by sea currents to inshore areas where, rather than having a toxic effect on shallow water and shore marine species and habitats, they are a nuisance to coastal users including bathers and divers. On the other hand, the effects of such oils and fats on the ecology of shore habitat are not known; however, one would assume that they do not have appreciable adverse effects. As a mitigating measure, introduction of oils and fats with the feed to the marine environment should be avoided or reduced.

Proposal for environmental monitoring

3.1 The ERA ToR refer to monitoring of the following components, which are to be monitored at a frequency of 1 – 2 times per year at the south aquaculture zone (SAZ) where three tuna farms (F&F Ltd, MFF Ltd and Mare Blu Ltd) are located, and at the site off Mellieha Bay (north aquaculture site; NAS) where two tuna farms (AJD Tuna Ltd and MML Ltd) are located; both sites being located some 5-6 km offshore:

- Sediment quality, namely the parameters given in Table 1 below;
- Water quality, namely the parameters given in Table 2 below;
- Plankton, to establish the most abundant species of phytoplankton and zooplankton and to determine for the presence of toxic or harmful plankton;
- Video survey of the seabed to assess gross physical and biological features;
- Benthic assemblages to assess the condition of the benthic environment in the vicinity of the fish cages, compared to unperturbed conditions, which will be taken to be the situation at the reference stations.

Table 1: Parameters to be analysed in sediments.

Parameter	Method	Units (on D.M.)
Granulometry	Buchanan 1984	g
Total Organic Carbon (TOC)	UNI EN 13137:2002	%
Redox Potential	CNR IRSA 2 Q 64 Vol 3 1985	mV
Sulphide	CNR IRSA 12 Q 64 Vol 3 1986	µg
pH	CNR IRSA 1 Q 64 Vol 3 1985	pH units
Total Nitrogen	CNR IRSA 6 Q 64 Vol 3 1985	mg/g
Total Phosphorus	DM 13/09/1999 SO n°185 GU n°248 21/10/1999 Met XV.I	mg/g

Table 2: Parameters to be analysed in seawater.

Parameter	Method	Units
Temperature	In-situ / Portable Meter	°C
Salinity	In-situ / Portable Meter	psu
Dissolved Oxygen	In-situ / Portable Meter	%, mg/l
Turbidity	In-situ / Portable Meter	NTU,
Turbidity (Secchi Depth)	Secchi Disk	m
pH	pH meter	pH units
Chlorophyll *a*	APAT CNR IRSA 9020 Man 29 2003	µg/l
Total Nitrogen	APAT CNR IRSA 5030 Man 29 2003 + APAT CNR IRSA 4040 A1 Man 29 2003 + APAT CNR IRSA 4050 Man 29 2003	µg/l
Total Phosphorus	APAT CNR IRSA 4110 Man 29 2003	µg/l
Total Carbon	UNI EN 1484:1999	µg/l
Total suspended matter	APAT CNR IRSA 2090 B Man 29 2003	mg/l

While such monitoring components follow the guidelines that one would expect of monitoring programmes for sea-based fish farm activities, particularly ones located in coastal areas not far from the shore, given that all tuna farming installations have recently (in 2017) been moved offshore (> 1 km offshore), it would seem more appropriate to adopt a monitoring programme that enables prompt issue of results, while focussing on components that are more readily indicative of potential adverse impacts, while being cost-effective. Collection and analysis of samples of phytoplankton and sediment for species identification will necessitate months. A single grab sample collected by a 0.1 m^2 Van Veen Grab, which will fill a 10 litre bucket, may require 2-man weeks for sorting and several days to identify – this would be before any necessary statistical analyses is carried out. From experience by Ecoserv's personnel, sorting sediment and identifying marcoinvertebrates from a single monitoring session at one tuna farm site may require several months to nearly a full year to complete. In the case of the South Aquaculture Zone; monitoring of physico-chemical attributes and benthic diversity from two sessions held in 2008 and 2010 did not detect any significant changes following tuna penning activities at the site. Monitoring of plankton and routine water quality parameters such as Chlorophyll *a*, dissolved oxygen, turbidity, nutrients, etc will, in all probability, not serve to detect any change/impact resulting from the tuna farming activities as the offshore areas where the farms are currently located are characterised by very strong sea currents, exposed conditions, and a high energy regime that promote very high flushing of any wastes generated by the activity. Nevertheless, surveys of water quality will be carried out as detailed below, while a survey of sediment quality and benthic diversity will be carried out should the results of the video surveys indicate a potential adverse impact of the tuna penning activities on the seabed. The results from surveys of sediment quality and benthic diversity, should it be necessary to implement these, carried out at both the SAZ and NAS may be compared with the results of past baseline surveys (sediment quality and benthic diversity) of the seabed having the same physical and biological characteristics as those of the SAZ and NAZ.

The following environmental monitoring proposal is mainly aimed at focusing on components that are more readily indicative of potential adverse impacts, and on cost-effectiveness, while also serving as a 'check' for the farm operators themselves and still allowing for implementation of sediment quality and benthic diversity surveys should the ERA and present consultants deem that these are necessary if monitoring results indicate an adverse environmental impact resulting from the tuna penning activities:

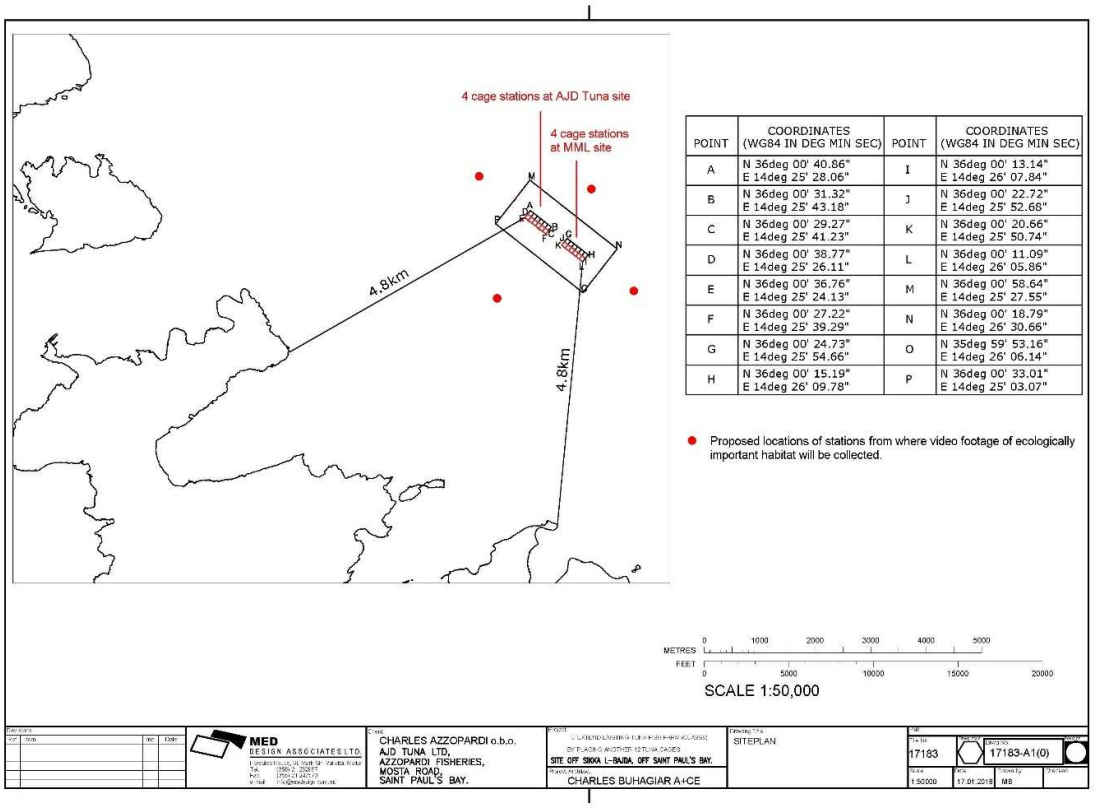
Video survey

A video survey using a remotely operated vehicle (ROV) will be undertaken below a select number of fish cages to assess for the following:

- Level of uneaten feed accumulating on the seabed;
- Species diversity and abundance of megafauna;
- Marine litter; and
- Overall impacts from the farm activities on the physical and biological characteristics of the seabed.

The video survey will be undertaken using an ROV that will be navigated below, as much as possible, a select number of tuna cages at each of the SAZ and NAS; this will enable collection of the necessary video footage, which will be later analysed in the laboratory. It is proposed that video footage of the seabed will be collected in the vicinity of 8 cages (4 cages at each of the MML and AJD Tuna Ltd sites) at the NAS and 12 cages (4 cages at each of the F&F Ltd, MFF Ltd and Mare Blu Ltd sites) at the SAZ. The cages selected for monitoring using video footage will be selected at

random in the field by the scientists on the day of monitoring but the selected cages at any one site will be as distant from each other as possible to allow for representative assessment. The collected video footage will enable assessment of: (i) Levels of uneaten feed accumulating on the seabed; (ii) species diversity and abundance of megabenthic fauna; (iii) presence of marine litter; (iv) overall gross physical and biological characteristics of the seabed. Video footage of the seabed will also be collected at stations located at a distance from the SAZ and NAS but where the bottom may support a habitat of high ecological importance; in the case of the NAS, this would be maerl habitat located west, north and east of the site, as well as at 'Is-Sikka l-Bajda' located south of the site; in the case of the SAZ, this would be maerl habitat located west, north, east and south of the site. It is proposed that video footage will be collected from 4 stations in the vicinity of the NAS and 4 stations in the vicinity of the SAZ. The proposed locations of the monitoring stations are shown in Figures 1 and 2 below.



POINT	COORDINATES (WG84 IN DEG MIN SEC)	POINT	COORDINATES (WG84 IN DEG MIN SEC)
A	N 36deg 00' 40.86" E 14deg 25' 28.06"	I	N 36deg 00' 13.14" E 14deg 26' 07.84"
B	N 36deg 00' 31.32" E 14deg 25' 43.18"	J	N 36deg 00' 22.72" E 14deg 25' 52.68"
C	N 36deg 00' 29.27" E 14deg 25' 41.23"	K	N 36deg 00' 20.66" E 14deg 25' 50.74"
D	N 36deg 00' 38.77" E 14deg 25' 26.11"	L	N 36deg 00' 11.09" E 14deg 26' 05.86"
E	N 36deg 00' 36.76" E 14deg 25' 24.13"	M	N 36deg 00' 58.64" E 14deg 25' 27.55"
F	N 36deg 00' 27.22" E 14deg 25' 39.29"	N	N 36deg 00' 18.79" E 14deg 26' 30.66"
G	N 36deg 00' 24.73" E 14deg 25' 54.66"	O	N 35deg 59' 53.16" E 14deg 26' 06.14"
H	N 36deg 00' 15.19" E 14deg 26' 09.78"	P	N 36deg 00' 33.01" E 14deg 25' 03.07"

Figure 1. Map showing the locations of the temporary AJD Tuna Ltd and MML Ltd farm sites off Mellieha Bay, and the proposed locations of stations from where video footage of ecologically important benthic habitat will be collected (apart from video footage collected at 4 cage stations at each farm site).

The results of such assessment will be available within a few weeks and will clearly indicate the state of the seabed in the vicinity of the cages. Furthermore, the main output – the video footage – is in itself illustrative and will readily, clearly, and visually, show any change/adverse impact of the tuna farming activities on the seabed, including to the operator himself. The video footage may also be used readily by the ERA to effectively illustrate and inform planners, policy makers, politicians and the general public of the situation of the seabed below the cages.

Based on the outcome from the video surveys; in the eventuality that the findings indicate large changes in physical and biological characteristics of the seabed following the tuna penning activities, then the ERA would reserve the right to request a quantitative study to assess, in greater detail, any alterations to the benthic habitat. This would be done through quantitative assessment of sediment quality and benthic assemblages, as per the related component of the ERA's ToR. Such strategy will also serve as incentive for the operators to ensure proper management of the tuna farm activities and avoid potential adverse impacts on the seabed, as well as avoiding additional monitoring and associated high cost.

It is proposed to perform two monitoring sessions per year: in April/May, just before the start of the tuna penning season and in August/September at the peak of the farming season.

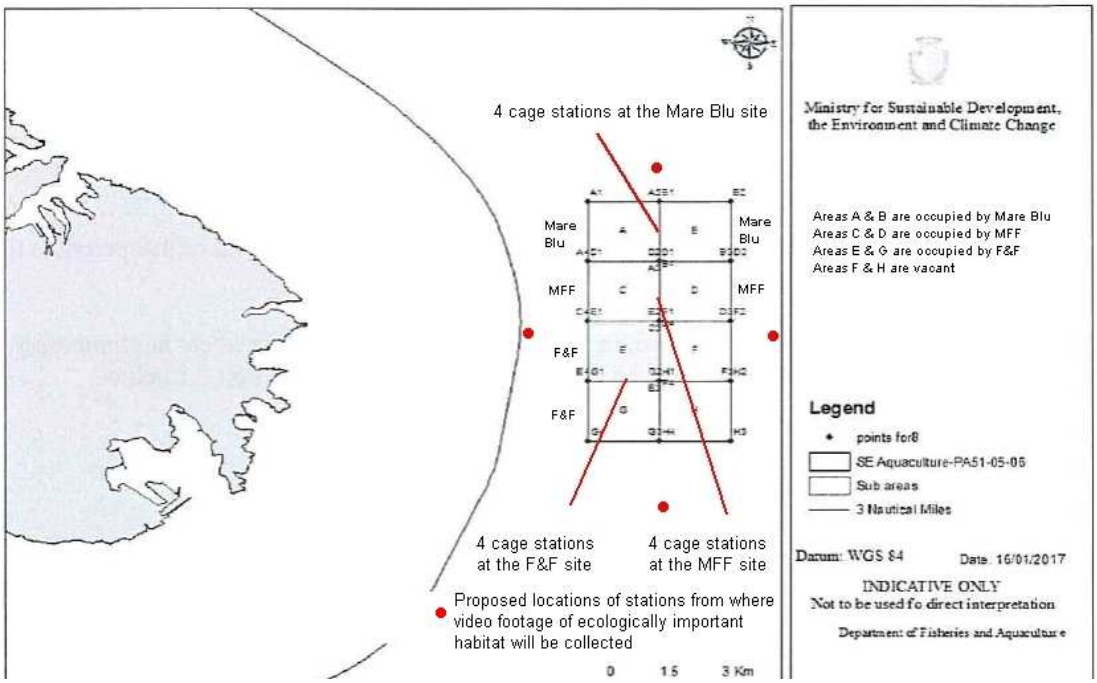


Figure 2. Map showing the locations of the Mare Blu Ltd, MFF Ltd and F&F Ltd farm sites within the south aquaculture zone, and the proposed locations of stations from where video footage of ecologically important benthic habitat will be collected (apart from video footage collected at 4 cage stations at each farm site).

Water quality

To monitor water quality, aerial photography sessions coupled with water quality surveys are proposed. The main aim of the aerial photographs is to detect any potential oil slicks and their extent, in the vicinity of the tuna farms, given that this is clearly a main issue. Such session will be held concurrently with *in-situ* measurement of water quality attributes and collection of marine water samples for later analysis in the laboratory. The different parameters that will be measured and analyzed are indicated in Table 2; these are the same as per the ERA's ToR. *In situ*

measurements (two replicates) and collection of seawater samples (two replicates) will be made at a water depth of 1 m (subsurface) at four stations located within each of the NAS and SAZ: an up-current station, two stations located at the centre of each site (NAS and SAZ), and a down-current station. Furthermore, two replicate samples of seawater will be taken at the surface from the same four stations for potential analysis of oils. The latter analysis will, however, only be undertaken if the aerial photographs show evidence of the presence of an oil slick. Observations on the following will also be made at each station:

- presence of floating material;
- surface oil slicks;
- tarry residues;
- surface foam/bubbles
- any odours present.
-

Water samples for laboratory analyses will be transferred to pre-treated glass or plastic bottles, as appropriate and depending on the analysis concerned. Samples will be maintained at a temperature of 4 – 8^{o}C during transport to the lab. Analysis for the parameters will be undertaken using standard methods. The parameters that require laboratory analysis will be analysed at a laboratory that is accredited according to the ISO 17025:2005 standard.

It is proposed to carry out two monitoring sessions per year, which also coincide with the period when the video session will be held: in April/May, just before the start of the tuna penning season, and in August/September, at the peak of the farming season.

Reporting

One report for each of the two monitoring components; i.e. video survey and water quality, and which will include the methodology used, findings and appraisal, will be submitted.

Sediment quality and benthic diversity

Should the results of the video surveys indicate an adverse impact on the seabed as a result of the tuna penning activities at either of the NAS or SAZ, sediment quality and benthic diversity surveys will be undertaken, as described below.

Sediment quality

To assess the chemical quality of sediments in the areas of study, samples will be collected for analysis from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. As much as practically possible, the sampled stations will have the same water depth. Two replicate sediment samples will be collected from each station using a 0.1m^2 Van Veen Grab that will be pre-cleaned and pre-treated to avoid contamination. The samples will then be transferred to pre-cleaned and pre-treated glass

or plastic sample containers depending on the type of analysis to be carried out. Sediment sampling and preservation will take place in accordance with the ISO 5667 set of guidelines that are followed as part of the procedures at the laboratories where the analyses will be carried out. Samples will be maintained at appropriate storage conditions until delivery to the analysing laboratory. The samples will be analysed at an ISO 17025:2005 accredited laboratory for the parameters indicated in Table 1. Standard analytical methods will be employed which will involve a pre-analytical step of extraction, intended to release any bound chemicals from the sediment particles.

To assess the physical characteristics of the sediments at each of the six stations, sediment samples for granulometric analysis will also be collected from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. For this purpose, two replicate sediment samples will be collected using a $0.1m^2$ Van Veen Grab from the same six sampling stations used to collect samples for chemical analyses. In the laboratory, the samples will be analysed by sieving through nested Endecott test-sieves on a mechanical sieve-shaker, according to the method given in Buchanan (1984). Using this method, the sediment will be separated into the different grain size fractions and the percentage contribution of each fraction, mean sediment grain size and the sediment's overall classification will be determined. The results obtained will be used to provide a description of the granulometric characteristics of the sampled sediments, namely: mean sediment grain size (according to the Wentworth Scale) and other relevant properties such as sorting and kurtosis.

Benthic diversity

To collect data for benthic diversity studies, a grab sample will be collected from the same four stations located in the vicinity of the tuna cages and used for the video survey at each farm site and at both the NAS and SAZ (see Figures 1 and 2). Grab samples will only be collected from the farm site where the video survey indicates an adverse impact. No grab samples will be collected at the stations used to monitor ecologically important habitat unless the video survey indicates an adverse impact there as well. Samples will be collected using a 0.1 m^2 Van Veen grab deployed from a vessel equipped with hoisting jib and winch. After the grab is brought on board, surplus seawater will be drained from the sample by placing it on a 1mm-mesh sieve; the retained sediment and biota will be temporarily preserved in 10% formaldehyde in seawater. In the laboratory, each sample will first be washed to remove the fine sediment (<1 mm fraction) and the preservative, and it will then be sorted to separate out all macrofauna (animals larger than 1 mm). The motile macrofauna will then be identified as far as possible. Where identification to species level was not possible, the different species present will be labelled using an alphabetical code (e.g. Mysidacea sp. A, etc.).

Reporting

One report for each of the two monitoring components; i.e. sediment quality and benthic diversity, and which will include the methodology used, findings and appraisal, will be submitted.

Training

To satisfy the requirements of staff training, the following programme that will encompass lectures and a practical demonstration session is being proposed:

- 1 hour lecture on permit obligations;
- 1 hour lecture on basic aspects of the marine environment;
- 1 hour lecture on monitoring of aquaculture activities; and
- 1 hour practical demonstration session concerning monitoring.

The training session will have a duration of one half day (0900 – 1330) and will include half an hour coffee break (between 11:00 and 11:30). Participants will be presented with an attendance certificate.

Responsibilities, personnel, equipment and facilities

Ecoserv Ltd will undertake all studies, including fieldwork, laboratory analyses, data analyses and production of reports. All work will be carried out by a team of qualified environmental scientists from Ecoserv Ltd under the supervision of Prof Joseph A Borg BSc MSc PhD CBiol MRSB MMBA FIBMS and Dr Julian Evans BSc (Hons) MSc PhD MMBA.

Further information on Ecoserv Ltd, together with a list of past projects serviced by the company can be downloaded from www.ecoserv.com.mt. The company's web site also features ongoing projects and assignments commissioned recently.

References

Mangion M., Borg J. A., Thompson R. & Schembri P. J., 2014. Influence of tuna penning activities on soft bottom macrobenthic assemblages. Marine Pollution Bulletin 79; 164-174.

Mangion M., Borg J. A., Sanchez Jerez P & Schembri P. J., 2017. Assessment of benthic biological indicators for evaluating the environmental impact of tuna farming. Aquaculture Research: 1 – 15.

Mangion M., Borg J. A., Sanchez-Jerez P., 2017. Differences in magnitude and spatial extent of impact of tuna farming on benthic macroinvertebrate assemblages. Regional Studies in Marine Science 18: 197-207

ANNEX 2

Environmental monitoring of tuna farming activities

Revision of water quality sampling design in relation to P-tuna-farming-monitoring_revised_082018 (Proposal for regular environmental monitoring of tuna farming activities at offshore sites)

The present revision of the sampling design in relation to monitoring of water quality at AJD Tuna Ltd's and Malta Mariculture Ltd's tuna penning sites off Mellieha Bay, is being made following agreement with the Environment and Resources Authority (ERA). The recommendation, which was agreed on by the ERA and the present consultant, is to add a further two sampling stations to the four stations that have been used in water quality monitoring sessions held in 2019 and 2020.

It is proposed that the locations of the two water quality monitoring stations (E and F in Figure 1) will tentatively be as indicated in Figure 1. However, the actual locations will be determined on the day of holding on the water quality survey, depending on the sea current direction, such that one of the stations will be 'up-current' and the other 'down-current'; i.e. the locations of the two stations can be anywhere along a semi-circle drawn north to south for each station.

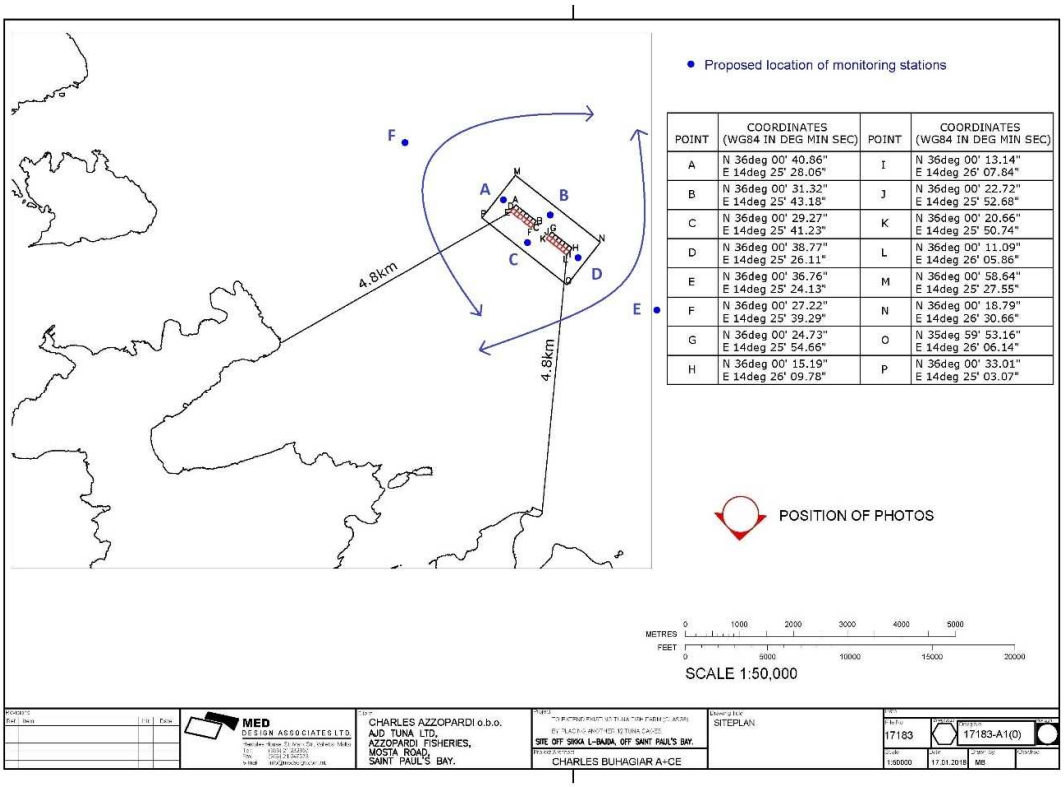


Figure 1. Map showing the location of AJD Tuna and MML's tuna penning sites off Mellieha Bay. The locations of the four stations A - D that have been used to monitor water quality during 2019 and 2020 are indicated. The new additional two sampling stations (E and F) are also indicated, however, it should be noted that their locations are not fixed but will be determined on the day of sampling, depending on the sea current direction (see main text in the present document). Base map source: ADI Associates Environmental Consultants.

In situ measurements and collection of seawater samples for later laboratory analyses, will be carried out at the same frequency and considering the same parameters as for the other four stations (A – D), and as detailed in the approved proposal for environmental monitoring.

ANNEX 3

Environmental monitoring of tuna farming activities

Proposal for assessment of sediment quality: incorporation of sampling design for sediments in relation to P-tuna-farming-monitoring_revised_082018 (Proposal for regular environmental monitoring of tuna farming activities at offshore sites)

Prepared by

JOSEPH A. BORG
BSc MSc PhD (Plymouth) FIBMS FMBA FRSB CBiol

FOR

12, Sir Arthur Borton Street
Mosta, MST1881
MALTA

Telephone: (+356) 2143 1900
Fax: (+356) 21424 137
e-mail: info@ecoserv.com.mt

www.ecoserv.com.mt

MAY 2023

The present proposal for incorporation of sampling and analyses of sediments, as well as an appraisal thereof, for inclusion in environmental monitoring at Malta Mariculture Ltd's and AJD Tuna Ltd's tuna penning sites at the Northwest Aquaculture Site (NAS), is being made in response to a request by the Environment and Resources Authority (ERA). The request by the ERA is to carry out assessment of sediment quality for the following attributes:

a. Granulometry
b. TOC
c. Redox Potential
d. Sulphide
e. pH
f. Total Nitrogen
g. Total Phosphorus

It is proposed to collect two replicate samples at each of a total eight stations as indicated in Figure 1, such that a total of 16 sediment samples will be collected. Sediment samples will be collected using a standard 20 L Van Veen grab deployed from a 10 m vessel equipped with high-up and navigational equipment. All precautions will be taken to avoid potential cross contamination of sediments between subsequent sample collection using the grab, as well as use of appropriate sample containers for storing the collected samples. The sediment samples will be analysed for the attributes given in Table 1. All analyses will be carried out at an accredited foreign laboratory. The results and an appraisal thereof will be included in a report submitted to the clients for forwarding to the ERA.

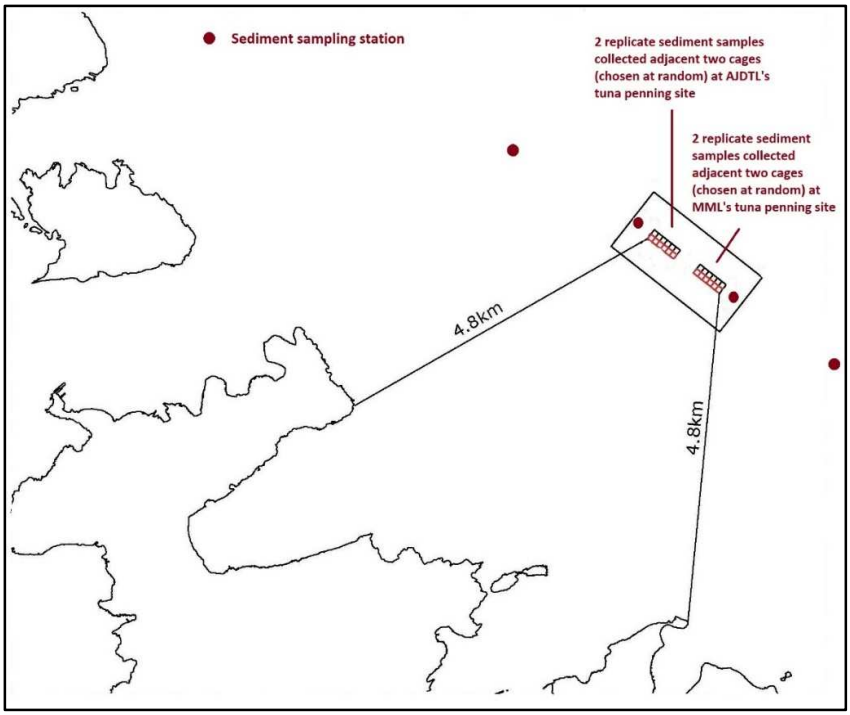


Figure 1. Map showing the locations of Malta Mariculture Ltd's and AJD Tuna Ltd's tuna penning sites at the Northeast Aquaculture Site, together with the proposed locations of the EIGHT sediment sampling stations; four of which are aligned along a northwest – southeast imaginary line and one station is located adjacent each of two cages belonging to each tuna farm.

Table 1. Sediment attributes to be assessed, related method of analysis and units.

Attribute	Method	Detection limit	Unit
Particle Size Distribution - dry sieving (<2mm/<20mm/<63mm/<125mm)	BS EN ISO 17892-4:2016	Not applicable	mm
Total Organic Carbon (TOC)	Titrimetry	0.1	%
Redox Potential	Probe	N/a	mV
Sulphide	ISE	1	mg/kg
pH	Potentiometric	+ / - 0.1	pH Units
Nitrogen - Kjeldahl (Total)	Digestion	5	mg/kg
Phosphorus (aqua regia extractable)	ICP-OES	20	mg/kg